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5-1.01 PLANS AND WORKING DRAWINGS

When the specifications require working drawings to be submitted to the Division of Structure Design, the drawings shall be submitted to: Division of Structure Design, Documents Unit, Mail Station 9, 1801 30th Street, Sacramento, CA 95816, Telephone 916 227-8252.

5-1.__ PAYMENTS

Attention is directed to Sections 9-1.06, "Partial Payments," and 9-1.07, "Payment After Acceptance," of the Standard Specifications and these special provisions.

For the purpose of making partial payments pursuant to Section 9-1.06, "Partial Payments," of the Standard Specifications, the amount set forth for the contract items of work hereinafter listed shall be deemed to be the maximum value of the contract item of work which will be recognized for progress payment purposes:

A. Clearing and Grubbing $_____
B. Develop Water Supply $_____
C. Roadside Clearing $_____
D. Prepare Water Pollution Control Program $_____
E. Prepare Storm Water Pollution Prevention Plan $_____
F. Progress Schedule (Critical Path Method) $_____

After acceptance of the contract pursuant to the provisions in Section 7-1.17, "Acceptance of Contract," of the Standard Specifications, the amount, if any, payable for a contract item of work in excess of the maximum value for progress payment purposes hereinabove listed for the item, will be included for payment in the first estimate made after acceptance of the contract.

In determining the partial payments to be made to the Contractor, only the following listed materials will be considered for inclusion in the payment as materials furnished but not incorporated in the work:

A. Soil Nail Assembly
B. Rock Bolt
C. Bar Reinforcing Steel
D. Underdrain Pipe
E. Miscellaneous Metal
F. Metal Panel

5-1.__ PROJECT INFORMATION

The information in this section has been compiled specifically for this project and is made available for bidders and Contractors. Other information referenced in the Standard Specifications and these special provisions do not appear in this section. The information is subject to the conditions and limitations set forth in Section 2-1.03, "Examination of Plans, Specifications, Contract, and Site of Work," and Section 6-2, "Local Materials," of the Standard Specifications. Bidders and Contractors shall be responsible for knowing the procedures for obtaining information.

Information attached to the project plans is as follows:

A. Log of test borings.

Information included in the Information Handout provided to bidders and Contractors is as follows:

A. Geohydrolic Report
B. Geotechnical Data Report
C. Structural Design Criteria for Devil's Slide Tunnel – Final Lining and Portals
D. Report for Portal and Foundation Design Recommendation

Information available for inspection at the District Office is as follows:

A. _____.

Cross sections are available in paper or electronic copy.
Cross sections are not available for this project.
The District Office in which the work is situated is located at _____.
Information available for inspection at the Transportation Laboratory is as follows:

A. _____.

Bidders and Contractors may contact the Transportation Laboratory to request viewing rock cores via electronic mail at the following address:

Coreroom@dot.ca.gov

Request shall be submitted at least 5 working days before the intended date for viewing, and shall include the District-County-Route, bridge number, contract number, viewing date, and contact information including telephone number.

Plans of the existing bridges may be requested by fax from the Office of Structure Maintenance and Investigations, 1801 30th Street, Sacramento, CA, Fax (916) 227-8357.

Plans of the existing bridges available to bidders and Contractors are reproductions of the original contract plans, with significant changes noted, and working drawings, and do not necessarily show normal construction tolerances and variances. Where dimensions of new construction required by this contract are dependent on the dimensions of the existing bridges, the Contractor shall verify the controlling field dimensions and shall be responsible for adjusting dimensions of the work to fit existing conditions.

SECTION 6. TUNNEL INITIAL LINING CONSTRUCTION

Tunnel work described herein and as shown on the plans shall conform to the requirements of these special provisions and Sections 1 through 9 of the Standard Specifications. Sections 10 through 95 of the Standard Specifications shall not apply to the work in this Section 6 except when specific reference is made thereto.

SECTION 6-1. GENERAL REQUIREMENTS

6-1.01 PART 1 – GENERAL

This work shall consist of tunnel initial lining construction in accordance with the details shown on the plans and these special provisions.

6-1.02 PART 2 – PRODUCT (BLANK)

6-1.03 PART 3 – EXECUTION (BLANK)

6-1.04 PART 4 – MEASUREMENT AND PAYMENT (BLANK)

SECTION 6-2. GEOTECHNICAL BASELINE REPORT

6-2.01 PART 1 – GENERAL

A Geotechnical Baseline Report (GBR) is provided to present a baseline of subsurface conditions anticipated to be encountered during mined tunnel, chamber, and cross passage constructions and to summarize the geotechnical basis for design of the Devil's Slide Tunnels. It includes: a summary of the project and descriptions of the portals and mined tunnels; interpretations of the geological and geotechnical information obtained for the project; a summary of anticipated ground behavior and groundwater conditions; a summary of how these anticipated conditions have been reflected in the project design; and discussions of other design and construction considerations that will impact the work.

The GBR shall be applicable only to mined tunnels.

The GBR is provided to assist bidders in evaluating the requirements for excavating and supporting the ground. The baseline conditions presented in the GBR will be used by the Engineer to evaluate disagreements, disputes, claims, and any differing site condition that may be submitted during the course of construction.

The GBR is the sole source for the interpretation of geological and geotechnical conditions on this project. Interpretations made in other reference reports shall be considered as part of the design development process and shall not be included as part of the contract.

In the event of conflicts, discrepancies, or inconsistencies with the reports and documents as listed in Section, “Project Information,” of these special provisions, or any other geotechnical data available in any way to the Contractor, the GBR shall take precedence.

The GBR is not intended to specify ground conditions or ground behavior to the extent that the Contractor is relieved of any and all responsibility for making its own interpretation of ground conditions or ground behavior with respect to its proposed means and methods of construction. Due to the direct relationship between the Contractor's means and methods associated with construction and the resulting rock and structure interactional behavior, actual behavior may vary from that presented in this GBR. The Contractor shall evaluate rock and groundwater conditions as they relate to and interact with the Contractor’s selected method of construction.

The GBR does not address issues relative to potentially contaminated spoils or potentially contaminated groundwater.

6-2.02 PART 2 – PRODUCT (BLANK)

6-2.03 PART 3 – EXECUTION (BLANK)

6-2.04 PART 4 – MEASUREMENT AND PAYMENT (BLANK)

SECTION 6-3. TUNNELING BY SEQUENTIAL EXCAVATION METHOD

6-3.01 PART 1 - GENERAL

SCOPE

This section specifies excavation and support of the mined tunnels, utilizing the Sequential Excavation Method (SEM) to excavate and support the tunnels of both standard and enlarged cross sections, cross passages, equipment chambers, access passages, and niches.

The SEM utilizes New Austrian Tunneling Method (NATM) principles for the construction of the mined tunnels, modified so as to predetermine the various support measures required, defined as Support Categories, along different parts of the tunnels.

The SEM utilizes a set of support measures for each Category, and local, variations in the support measures if needed by ground conditions as approved by the Engineer, including the following:

A. Lattice girders
B. Dewatering
C. Grouted steel pipes (arch canopy)
D. Rock dowels, of different types
E. Spiles
F. Face bolts
G. Reinforced shotcrete
H. Bore holes for probing ahead
I. Pipe Arch Canopies

Local support measures, if ordered by the Engineer, will be paid for as extra work as provided in Section 4-l.03D, "Extra Work," of the Standard Specifications.

This specification section describes the excavation and support of the mined tunnels in accordance with the construction sequences shown on the plans. The Contractor is responsible for safe excavation and construction process, adequacy, and overall performance of the tunnels during construction.

The excavation of the mined tunnels will progress through ground varying from competent rock, weathered rock, highly fractured rock, and earth. Mixed tunnels face conditions are expected for some locations in the mined tunnel construction.

Excavation and Support Category Ranges: All stations indicating limits of typical excavation and support classes and types of final lining referenced herein or as shown on the plans are for bid purposes only. During construction, excavation and support classes must be installed appropriately for the ground conditions as determined by the Contractor, subject to the approval of the Engineer.

REFERENCE STANDARDS

American Society for Testing & Materials (ASTM):

A. ASTM A36 Specification for Structural Steel
B. ASTM A 53 Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
C. ASTM A82 Standard Specification #or Steel Wire, Plain, for Concrete Reinforcement
D. ASTM A185 Standard Specification for Steel Welded Wire Reinforcement, Plain, for Concrete

E. ASTM A325 Specification for Structural Bolts, Steel, Heat Treated, 12011 05ksi Minimum Tensile Strength
F. ASTM A501 Specification for Hot-formed Welded and Seamless Carbon Steel Structural Tubing
G. ASTM A615 Specification for Deformed and Plain Billet-steel Bars for Concrete Reinforcement
H. ASTM C109 Standard Test Method for Compressive Strength of Hydraulic Cement Mortars Using 2-inch Cube Specimens
I. ASTM C144 Specification for Aggregate for Masonry Mortar
J. ASTM (3150 Specification for Portland Cement

American Institute of Steel Construction (AISC):

A. AISC Specifications for Structural Joints Using ASTM A325

American Concrete Institute (ACI)

A. ACI 506.2 Specification for Shotcrete
B. ACI 506R Guide to Shotcrete
C. ACI 318 Reinforced Concrete

DEFINITIONS

A. Excavation Design Line: Design line of excavation inside of which no earth or surrounding ground shall intrude. The shotcrete lining has been designed to take the load of the excavated ground, and an anticipated lining deformation has been provided for each Support Category. The Contractor must add the anticipated compensation for deformations to the radii of the Design Line after Deformation, both values of which are given in the Drawings, plus the lining thickness, to compute the required excavation radii for different Support Categories.
B. SEM Excavation: Mined excavation in ground, using various predetermined support measures, defined as Support Categories, along different parts of the tunnels. Excavation in ground may include the removal of: competent to weathered rock, grout, and shotcrete and bolts previously installed for face support.
C. Excavation and Support Sequence: Prescribed excavation and support procedure for sequential stages of tunnel excavation based on ground conditions expected during excavation. Locally encountered conditions may require local measures of support.
D. Partial Excavation Drift: Large tunnel excavation cross sections split into smaller sections to reduce excavation cross sectional area and ground disturbance. Partial Excavation Drifts are for top heading, bench, invert excavation, sidewall drift, and twin sidewall drift. Top Heading: Upper part of partial excavation of tunnel cross section for the purpose of reducing cross sectional area and ground disturbance, as shown in the contract drawings. Bench: Middle portion of partial excavation of tunnel cross section for the purpose of reducing cross sectional area and ground disturbance, as shown on the plans. The bench is a berm or block of ground within the outline of the tunnel which is left after a top heading has been excavated. Invert: Lower part of partial excavation of tunnel cross section for the purpose of reducing cross sectional area, following the top heading (in two stage excavations) or bench excavation as shown on the plans.

E. Sidewall Drift: Partial Excavation Drifts located at both tunnel halves with specified minimum distance between the partial drifts, supported by a temporary shotcrete middle wall and the shotcrete lining for the full mined tunnel cross section.
F. Twin Sidewall Drift: Two Sidewall Drifts, advanced simultaneously, located on either side of the tunnel cross section, supported by temporary reinforced shotcrete sidewalls. One Center Drift located between the sidewall drifts, excavated as last area to complete the full tunnel cross section.
G. Length of Round: Length of additionally exposed ground opened up during one excavation increment and immediately followed by the installation of support as shown on the plans. Maximum unsupported span and length of round shall be as shown in the plans.
H. Over-excavation: Intentional or unintentional excavation of ground beyond the excavation design line. The Contractor shall design over-excavation to accommodate any expected construction tolerances, in addition to tunnel lining deformations. Tunnel lining compensations for deformation expected for different Support Categories shall be as shown in the plans.
I. Geologic Overbreak: Volume of ground dislocated or excavated beyond the excavation design line due to ground conditions and behavior. The Contactor must assess ground conditions to determine how much, if any, overbreak may occur.
J. Pre-Support: Support elements installed prior to excavation of the ground, including spiling and face bolts.
K. Standard Support Measures: Support for SEM tunnels includes those measures required to maintain the inherent strength of the ground surrounding the tunnel openings, enhancing the stress redistribution process while preventing unnecessary loosening. Support measures include lattice girders, shotcrete lining, rock dowels, spiles, face bolts, and pipe arches canopies.
L. Local Support Measures: Ground support measures approved by the Engineer, added or deleted when necessary to the Standard Support Measures.
M. Initial Shotcrete Lining: Shotcrete of thickness and reinforcement as shown on the plans for the full support of mined tunnels and partial excavation drifts, including temporary middle and sidewalls and temporary inverts. The shotcrete lining is reinforced with fibers, lattice girders, welded wire fabric at intersections, and starter bars.
N. In-tunnel Water Control: Collection and removal of groundwater ahead of the tunnel face or penetrating into the tunnel. Included are temporary construction drainage and gravity dewatering from within the tunnel. Temporary construction drainage devices includes drainage mats, PVC-hoses, or similar materials used to collect and drain off groundwater from areas at the excavated ground surface before applying shotcrete lining to allow application of the shotcrete lining and/or for dewatering of seepage through the shotcrete lining, and pump sumps, pumps and installation, operation and maintenance of required equipment.
O. Rock Dowel - Cemented or Resin Grouted: This type of Rock Dowel is an untensioned rod inserted into a drilled hole and grouted along its entire length using cement grout or resin capsules. The Rock Dowel consists of a high yield steel deformed ribbed bar with cut or rolled threads at one end, a face plate, shim plates and nut.
P. Rock Dowel – Deformed Tube: Manufactured from a mechanically reshaped steel tube, inflated by hydraulic pressure into tight contact with the pre-drilled hole into which the tube is inserted.
Q. Rebar Spiling: Rebars without end drill bits driven into the ground, or with self drilling bits, or installed and grouted into pre-drilled holes at the tunnel heading ahead of the

tunnel excavation face to pre-support the ground at locations shown on the plans or as required by ground conditions.

R. Self Drilling and Grouted Dowel: This type of Rock Dowel is equipped with a sacrificial drill bit and is made from high tensile strength steel tubes. If the required bolt length in radial direction is longer than the diameter of the tunnels, couplings are used to adjust the length of the bolts. As spiling, the Dowels are installed at the tunnel heading ahead and above of the tunnel excavation face and grouted as a means to pre-support the ground.

S. Face Stabilization Wedge or Berm: Unexcavated portion of the heading temporarily left in place to enhance face stability.

T. Pocket Excavation: Excavation sequence used in ground with very limited standup time. The excavation face is split into smaller areas (pockets) of excavation. Pocket excavation is carried out in a series along the tunnel circumference facilitating the installation of shotcrete support.

U. Face Bolts: Fiberglass bolts installed horizontally in the tunnel face into pre-drilled holes using epoxy grouts for full bonding between bolt and ground over the full length of the bolt in order to stabilize the tunnel face in fractured competent soil or rock.

V. Lattice Girder: A lightweight, three-dimensional steel framework or truss made to act as a unit by connecting all components with lacing bars; used in conjunction with shotcrete for initial lining reinforcement and to provide cross section control.

W. Pipe Arch Canopy: Solid wall or perforated wall steel pipes, installed at the tunnel's heading ahead of the tunnel's face and grouted as a means to support the ground where unstable ground is encountered at crown, or where proposed by Contractor and approved by Engineer.

X. Probe Drilling or Exploratory Drilling: Geologic exploration of ground conditions ahead of the face by means of probe holes (without core extraction), or by core drilling to recover rock core samples.

Y. Contingency Procedures: Procedures to implement additional measures as required by ground conditions and approved or directed by the Engineer.

Z. Contingency Plan: A Plan based on a detailed assessment of ground and site conditions that document contingency procedures to be followed to deal with various potential conditions that could be anticipated.

SUBMITTALS

The Contractor shall submit the following for approval in accordance with the general requirements and with the additional requirements as specified for each, at least 60 days prior to start of SEM works or as specified herein:

A. Construction Work Plans:

1. The Contractor shall submit working drawings, detailed descriptions, data and calculations of proposed materials, facilities, equipment to be used and method of construction in conformance with Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications, including but not limited to the following:

a) Tunnel Construction Work Plans for all SEM tunnels, including:

1) Key excavation plan including proposed excavation and support sequence and direction of tunneling.

2) Sequence and timing of top heading, and bench or invert excavation and anticipated advance rates.
3) Methods of construction including shotcrete lining installation details, all pre-support and support elements including measures for tunnel stoppages, and measures to maintain safe work spaces.
4) Methods of construction for breakouts of cross passages from tunnels and chambers.
5) Excavation and support sequences at break-outs.
6) Details on excavation of ground for all materials identified in the GBR.
7) Removal of boulders and other obstructions.
8) Method of controlling line and grade of linings.
9) Details on excavation and removal of all temporary pre-support and temporary shotcrete.
10) Installation of In-tunnel water control measures, including temporary sumps, and construction drains.
11) Site traffic management plan and its relationship to tunnel excavation and material haulage.
12) Have drawings and computations signed and sealed by a Professional Engineer licensed in the State of California.

b) Equipment:

1) Surveying equipment for SEM tunnel work.
2) Drilling equipment for SEM tunnel operations.
3) Excavation equipment for all SEM tunnel excavations including make and model, manufacturer's literature describing equipment dimensions and capabilities.
4) Haulage equipment for SEM tunnel operations.
5) Shotcrete batching plants.
6) Shotcrete spraying equipment and pump.
7) Hoisting plants.
8) Illumination of tunnels.
9) Emergency power supply for In-tunnel operations.
10) In-tunnel water control, including drain pipes, drainage mats, temporary sumps, construction drains, pumps, procedures to be followed, and standby power supply.
11) Water treatment plants and settlement tanks for water removed from the tunnels.
12) Temporary tunnel ventilation system.
13) Grouting pumps for contact grouting, grouted pipe spiling, etc.
14) Rock dowel drills

c) Materials:

1) Shotcrete.
2) Material for contact grouting, grouted pipe spiling, rebar spiling grouting.
3) Lattice Girders.
4) Arch Canopy Pipe.
5) Bolts for Self-Drilled and Grouted Pipe Spiling.

6) Steel fibers, synthetic fibers
7) Self-drilled steel dowels.
8) Fiberglass face dowels and resin for bonding.
9) Rebars for rebar spiling.
10) Materials for temporary groundwater control and construction drainage.

B. Documentation and Periodic Reports:

1. Air Quality Reports:

a) Have available for inspection by the Engineer reports of test for toxic and hazardous gases and other atmospheric impurities in the working environment. Reports to be kept at Contractor's field office.

2. Geologic Report:

a) Submit daily reports describing all SEM related activities. Inspect, determine, and record the following information, as many as may be appropriate, at the tunnel face upon completion of excavation of each round, but before installation of support measures:

1) Location of round identified by station.
2) Type of soil or rock strata at face, and especially at crown.
3) General degree of weathering of rock mass.
4) Weathering of joint surfaces.
5) Joint type and joint set orientation.
6) Approximate number of joint sets.
7) Joint roughness.
8) Spacing of any discontinuities.
9) Joint infillings, if any.
10) Water inflows, if any, estimated by flow rate timed into containers of known volume.
11) Overbreak.
12) Any other geological structures or features that may be significant.
13) Photographs of the tunnels face to be taken, and identified by station.

b) Face and Tunnel Heading Mapping: Prepare geologic mapping of each tunnel heading, including photograph, once per shift and documentation of all pre-support and support measures for each heading. The mapping will be signed each shift by the Contractor's SEM shift superintendent and the Engineer's SEM Inspectors.
c) Submit photo documentation and boring logs for all probe and exploratory drillings within 24 hours of completion of drilling operation.
d) Submit weekly report on all geologic features encountered during the SEM tunnel construction operations in the relevant period. The geologic report shall include information such as ground type, ground conditions, groundwater conditions, obstructions, average tunneling progress, and other relevant observations. Include complete geologic mapping of all tunnel headings. The geologic report shall also include a summary of instrument readings and interpretation of results as

specified Section 6-5, "Instrumentation and Monitoring," related to the tunnels performance.

e) Prepare final reports on geologic conditions encountered, support and pre-support measures installed and problems encountered after completion of each tunnel, latest 30 days after completion of the shotcrete lining of the respective tunnel.

3. Groundwater Discharge Reports:

   a) Observe and record average flow rates and time of operation of each dewatering system used. Provide appropriate devices, such as flow meters, for observing flow rates. Submit data daily during operating period of each dewatering system on forms and in format as approved by the Engineer.

C. Survey Control:

1. Survey personnel qualifications. Provide qualified survey personnel in accordance with General Requirements of the Project.
2. Type and location of horizontal and vertical control monuments to be set. Establish a secondary survey control system consisting of horizontal and vertical reference points for constructing the tunnels and placing concrete lining. Install horizontal control points either as a brass disc or lead and tack. Install vertical control points either as a brass disc or 12 mm diameter by minimum 75 mm long anchor bolt with nut and washer
3. Survey procedures and equipment. Employ survey procedures and equipment that are in accordance with the FGCC "Standards and Specifications for Geodetic Control Networks" using Second Order, Class 2 specifications for horizontal control work and Second Order, Class 2 specifications for vertical control
4. Design and location of theodolite instrument platform mounting bracket, bracing support hardware, method of attachment to shotcrete lining, brass mounting screw, and standing platform underneath instrument mounting bracket.
5. Survey data collection equipment and processing software; and traverse reduction and adjustment software.

   a) Provide and maintain all equipment and software necessary to record all secondary survey control measurement observations. Assemble measurement observations in digital data collection files and proved data to the Engineer in a format that is compatible and in accordance with the AASHTO Survey Data Management System (SDMS) technical specification for survey data.
   b) All survey data collection files transmitted to the Engineer shall contain: a time and date stamp for each observation, original filed measurements and the correctly computed coordinates/elevations in addition to the survey data tags necessary to re-compute the file if required.
   c) Preserve original data collection files and provide on copy of each file to the Engineer.

6. Survey equipment certification of adjustment; and calibration results of electronic distance measuring instruments (EDMl's) and prisms.
7. Tribrach adjustment method and equipment.

D. Tunnel Scanning Survey:

1. Before installation of the shotcrete lining, waterproofing, and permanent concrete lining, the tunnels' surfaces shall be surveyed with an automated tunnels scanner. The scan shall be double checked in areas where physical re-profiling of the tunnels' cross section is indicated.
2. The data shall be plotted in graphical form allowing direct comparison between theoretical and actual geometry.
3. Required results:

   a) 24 hours after scanning of the excavated area the contractor shall present comparison of actual excavation versus designed excavation profile as area plot as well as cross section
   b) 48 hours after application of shotcrete contractor shall present comparison of actual shotcrete versus designed shotcrete lining as area plot as well as cross section
   c) 48 hours after application of shotcrete contractor shall present comparison of actual shotcrete thickness of applied shotcrete versus designed shotcrete thickness as area plot as well as cross section.
   d) 14 days prior to installation of the water membrane contractor shall provide area plots of final shotcrete lining documenting that no under profile exists in the sections to be sealed.
   e) 14 days prior to installation of the water membrane contractor shall provide area plots of final shotcrete lining documenting that shotcrete smoothness is according to specification

4. After completion of final lining contractor shall present comparison of final lining versus designed profile as area plot as well as cross section. Contractor shall present comparison of actual thickness of final lining versus designed thickness as area plot as well as cross section. Contractor shall provide picture documentation of final lining.

E. Qualifications and Experience

1. Qualifications and experience of the Contractor's Tunnel Engineers at least 60 days prior to start of SEM works.
2. Qualifications and experience of SEM Tunnel Superintendents at least 60 days prior to start of SEM works.

F. Contingency Procedures:

1. At least 30 days prior to start of SEM excavation, submit a Contingency Plan that is based on a detailed assessment of ground and site conditions that may require additional measures not described herein for the Engineer's approval. Conditions to be assessed include groundwater, soil and lining conditions as well as equipment, traffic restrictions, and water control. Risks associated with these conditions, their likelihood and countermeasures to either avoid or mitigate these situations shall be described in detail. As a minimum the contingency plan shall include:

a) Name and qualification of personnel responsible for implementing contingency procedures.
b) Description of conditions considered to require contingency measures.
c) Plans outlining contingency procedures to be employed in the event of:

    1) Tunnel deformations beyond specified limits
    2) Face instability.
    3) Unexpected inflow of groundwater.
    4) Overbreak - minor and significant.
    5) Detailed description of response procedure (chain of command) monitoring values exceed the Alarm Values specified Section 6-5. Instrumentation and Monitoring.

d) Plans detailing surveillance during stoppages such as weekends and holidays as well as directed stoppages.
e) Plans detailing measures to be applied for the resumption of tunneling operation after stoppages.
f) Methods of verification of the successful implementation of contingency measures.
g) Procedures detailing surveillance during longer stoppages.
h) Plans detailing measures to be applied for the resumption of tunneling operation after stoppages.
i) Contingency Plan to be prepared in consultation with Engineer, and is subject to Engineer approval.
j) Stability of initial shotcrete lining is defined as closure measurements of 0.5 millimeter per day or less for a period of 10 consecutive days.

QUALITY CONTROL

A. .The Contractor’s Tunnel Engineer: Contractor's field staff to include the Contractor’s Tunnel Engineer meeting the following requirements:

    1. Education: Graduate civil engineer from accredited college or university, domestic or foreign.
    2. Experience: Minimum 8 years construction experience on site, utilizing SEM techniques in tunnel with shotcrete support, including 5 years hard ground SEM experience.
    3. Minimum one tunnel project greater than 90 square meter excavated tunnel cross section using multiple drifts.
    4. Proficient in spoken and written English.

C. Do not commence fieldwork until designated the Contractor’s Tunnel Engineer has been approved in writing by the Engineer.
D. Approved Contractor’s Tunnel Engineer shall report for Work at the site at least six weeks prior to commencement of tunnel excavation and remain on site for minimum four weeks after completion of all final concrete and shotcrete lining work. The Contractor’s Tunnel Engineer shall be involved in all tunneling related planning phases.
E. Duties to include the following:

1. Supervising excavation to ensure the safety and quality of construction. The Tunnel Engineer should evaluate the need to conduct pre-construction testing and determine the overall scope of associated testing requirements. Some properties will need to be monitored on a shift-by-shift basis, others on a daily, weekly, or monthly basis. Where ground support installation becomes critical during the excavation cycle, shotcrete placement may become subject to inspection and testing on a shift-by-shift basis 2. Devising and implementing contingency procedures as required by ground conditions or directed by the Engineer, coordinating remedial measures when ground loss at tunnel heading or instability of tunnel occurs, or when they appear likely.
2. Preparing daily written interpretation of instrumentation measurement readings taken during excavation. Determination of the appropriate support class for each advance of the heading based on an evaluation of the freshly exposed face and top heading, the anticipated conditions immediately ahead of the face and in the bench/invert area for review by the Engineer.
3. Daily assessment of support adequacy at the tunnel face with respect to ground conditions and corresponding excavation and support requirements and other supports and keeping written record thereof for review by the Engineer. Hold daily discussions with the Engineer at the tunnel faces regarding ground conditions and corresponding excavation and utilization of SEM support items, and keeping written records thereof. Inspect, determine, and record the following information, as many as may be appropriate, at the tunnel face upon completion of excavation of each round, but before installation of support measures:

   a) Location of round identified by station.
   b) Type of soil or rock strata at face, and especially at crown.
   c) General degree of weathering of rock mass.
   d) Weathering of joint surfaces.
   e) Joint type and joint set orientation.
   f) Approximate number of joint sets.
   g) Joint roughness.
   i) Spacing of any discontinuities.
   j) Joint infillings, if any.
   k) Water inflows, if any, estimated by flow rate timed into containers of known volume.
   l) Overbreak.
   m) Any other geological structures or features that may be significant.
   n) Photographs of the tunnels face to be taken, and identified by station

4. Submitting weekly reports on geologic conditions as encountered during excavation for The Engineer's use including record of daily discussion. The geologic report shall include complete geologic mapping of the tunnel headings. The tunnel headings shall be mapped at least once per shift.
5. Evaluating instrumentation readings and submit monitoring reports as specified elsewhere.
6. Participating in all pertinent coordination meetings with the Engineer.
7. Prepare final reports on geologic conditions encountered, support and pre- support measures installed and problems encountered after completion of each tunnel, latest 30 days after completion of the shotcrete lining of the respective tunnel.
8. Be available on site at all times during all SEM related excavation.

F. SEM Tunnel Shift Superintendent: Contractor's field staff to include minimum one SEM Tunnel Shift Superintendent for each shift meeting the following requirements:

1. Experience: Minimum 10 years construction experience on site, utilizing SEM techniques in tunnel with shotcrete support, including 5 years hard ground SEM as superintendent.
2. Minimum one SEM station excavation or similar complex with multiple shafts, adits and tunnels using SEM techniques.
3. Minimum one tunnel project greater than 90 square meters excavated tunnel cross section using multiple drifts.
4. Proficient in spoken and written English.

G. Do not commence field work until SEM Tunnel Shift Superintendents have been approved in writing by the Engineer.

H. Approved SEM Tunnel Superintendents shall report for Work at the site prior to commencement of SEM excavation and shall be available full time during SEM excavation and installation of support. Quality control will emphasize inspection of materials, production processes, and setting of reinforcement. The most frequently encountered assignments include:

1. Identification, examination and acceptance of shotcrete materials. This will include verification of quality based on certifications and test results from producers and suppliers, as well as sampling and testing of materials delivered to the job site;
2. Control of proportioning and batching and mixture proportioning and adjustment, tests for consistency of the shotcrete;
3. Examination of the tunnel heading and all surfaces to receive shotcrete including structural steel, reinforcing steel and embedded items, surface preparation and other preparatory work;
4. Inspection of concrete batching, mixing, conveying, placing, finishing, curing and the protection of shotcrete;
5. Inspection of other support elements, such as lattice girders, rock dowels, etc. that are an integral part of or affect the installation of the shotcrete lining;
6. Preparation of any required test panels or acquiring in-place shotcrete specimens for laboratory tests and curing and protection of these specimens;

I. In the event that ground loss at the tunnel heading or instability of tunnel heading occurs or appears likely, and SEM Tunnel Project Engineer is not physically present at the tunnel heading, duties of the SEM Tunnel Shift Superintendent to include the following:

1. Supervising excavation to ensure the safety and quality of construction.
2. Implementing contingency procedures as required by ground conditions or directed by the Engineer, coordinating remedial measures when ground loss at tunnel heading or instability of tunnel occurs, or when they appear likely.
3. Notifying personnel responsible for performing Contingency Procedures as outlined in the Contingency Plan and report immediately at tunnel heading.
4. Directing modification in tunneling techniques.
5. Notifying the Engineer of any ground losses at tunnel heading.

6. Notifying personnel responsible for monitoring instruments to increase frequency of monitoring as specified.
7. Assist SEM Tunnel Project Engineer in his duties as required.

J. Have necessary equipment in working order present at site at all times for installation of support, face support, and additional support measures, and other approved measures.

6-3.02 PART 2 - PRODUCTS

PRODUCT DELIVERY, AVAILABILITY, STORAGE AND HANDLING

A. The Contractor shall have adequate supply of required materials for Standard Support Measures and SEM Local Measures available on site ready for application at all times as follows:

1. Shotcrete: Have sufficient amount of fiber reinforced shotcrete available to be applied at each excavation face during the entire excavation period for immediate application to complete excavation round. No excavation shall be permitted in the absence of sufficient amount of shotcrete available at the tunnel heading.
2. Reinforcement: Have lattice girders, rebars, welded wire fabric and other reinforcing materials readily available on site for next excavation round of each heading before commencing excavation.
3. Regular In-tunnel Water Control: Have sufficient drainage mats, pipes, hoses, well points, pumps and other materials for installation and operation of regular in- tunnel water control available on site before commencing excavation.
4. Rebar Spiling: Have 10 percent of the bid quantity for rebar spiles available on site at all times during SEM excavation (except for final stage).
5. Grouted Pipe Spiling: Have 10 percent of the bid quantity for grouted pipe spiles available on site at all times during SEM excavation.
6. Rock dowels: Have 10 percent of the bid quantity for metal sheets available on site at all times during SEM excavation (except for final stage).
7. Face Bolts: Have 20 face bolts available on site at all times during SEM excavation (except for final stage).
8. Grout: Have sufficient grout and all grouting equipment on site during SEM excavation to install SEM support measure items, including grouted pipe spiles, rock dowels, contact grouting.

B. Store all materials in accordance with the suppliers' specification. Maintain materials in a clean and undamaged condition. Damaged or destroyed materials shall be replaced by the Contractor at no cost to the Engineer.

SHOTCRETE

Shotcrete shall conform to Section 6-6, “Shotcrete,” of these special provisions.

INITIAL SHOTCRETE LINING

Shotcrete tunnel lining shall conform to Section 6-4, “Shotcrete Tunnel Lining,” of these special provisions.

TEMPORARY CONSTRUCTION TUNNEL VENTILATION

A. Supply temporary construction ventilation equipment in accordance with health and safety regulations, specifications and requirements. For requirements refer to OSHA CFR Title 29, Part 1926, Subpart S - Underground Construction, Caissons, Cofferdams and Compressed Air, or Caltrans Construction Safety Orders.

REBAR SPILING

A. Standard deformed steel reinforcing bars, minimum length as indicated in the plans, conforming to ASTM A615M, Grade 420, installed in drilled and grouted holes.
B. Self-drilled and grouted dowels may be used as approved by the Engineer.
C. Use cementitious grout as specified for grouted pipe spiling.

GROUTED PIPE SPILING

Grouted pipe spiling shall conform to Section, “Miscellaneous Metal,” of these special provisions and the following requirements:

A. Pipes:

1. .Diameters and lengths as shown in the drawings
2. Self-drilled and grouted anchors or bolts may be used as approved by the Engineer.

B. Grout Mix Design: Ingredients that are compatible, non-corrosive to steel and free from calcium chloride.

1. Cement: ASTM C150, Type I or 111. Cement shall be fresh and shall not contain any lumps or other indication of hydration or "pack set".
2. Sand: ASTM C144, except maximum particle size limited to Size 16 sieve.
3. Early setting grout required: minimum compressive strength of 700 kPa, 4 hours of installation.
4. Water: Portable.
5. Admixtures and additives: Microsilica or other pozzolanic materials, liquefiers, accelerating, retarding and water reducing agents may be used as approved by the Engineer.
6. Resin or chemical grout meeting or exceeding the above specified set time and strength requirements may be used as approved by the Engineer.

WELDED WIRE FABRIC

Welded wire fabric shall conform to the requirements specified in Section 6-6, “Shotcrete,” of these special provisions.

DRAINAGE MATS, DRAIN HOSESAND WELL POINTS

A. Drainage Mat: system ENKADRAIN, AKWADRAIN, Mira DRAIN, CONTECH C-Drain or Sarnafil Drainage Panel or approved equal for application on exposed ground surface.

B. Drain Pipes: Pointed steel drainage pipes of minimum 40 mm diameter to be driven or drilled into the ground. Steel pipes to be perforated or slotted to allow sufficient dewatering of perched water in sand/silt lenses or sand/silt layers and minimize migration of fines. At their proximal end the drain pipes shall be connected to the construction drainage system.

FACE BOLTS

A. Fiberglass face bolts shall be made from polyester resin, reinforced with glass fibers in continuous strands. The glass strands shall form 65 percent - 75 percent of the weight of the bolt with the balance being the resin.
B. Face plates made from fiberglass shall have dimensions as designed by manufacturer to match dowel or bolt capacity.
C. Resin Grout: Use resin cartridges of fast setting type conforming to manufacturer's specifications, and compatible to the soils where face bolts are installed and to fiberglass bolt.

GROUTING

A. For permeation and contact grouting use Microfine Portland cement grout or chemical grout depending on the ground conditions encountered.

ROCK DOWELS

A. Refer to Section 6-9 Rock Dowels of these Specifications.

6-3.03 PART 3 - EXECUTION

TEMPORARY VENTILATION

A. Provide, operate and maintain for duration of project temporary ventilation system that will conform to specified health and safety requirements of jurisdictional authorities or specified by the Engineer.
B. Use equipment that is adequate to maintain sufficient supply of fresh air in underground work areas.

SAFETY REQUIREMENTS

A. Perform Work in a manner that minimizes safety hazards and exposure of personnel and equipment to hazardous and potentially hazardous conditions in accordance with specified health and safety requirements.
B. Assess all ground and groundwater conditions, ground movement, and lining deformations at all times during the construction period and act prudently and react swiftly to all indicators and conditions.
C. Provide safe work spaces, temporary platforms and stands at all times.
D. Illuminate all underground spaces sufficiently to carry out inspections at all times during the construction period.

E. In case of emergency or work stoppage likely to endanger excavation or adjacent structures, continuously maintain full work force 24 hours per day including weekends and holidays until emergency or hazardous conditions no longer jeopardize stability and safety of the structures.
F. Perform SEM tunnel construction in a manner that minimizes ground movement in front of and surrounding the tunnels.
G. Support ground continuously in a manner that prevents loss of ground, keeps lining perimeters and maintains stability of tunnel faces, and other underground openings.
H. Provide tunnel and face support for tunneling stoppages as specified.
I. Comply with all applicable health and safety requirements.

SURVEILLANCE OF-HEADINGS

A. Maintain qualified personnel on duty to monitor conditions that might threaten stability of heading whenever tunnel excavation is suspended or shut down.
B. Have one SEM Tunnel Superintendent on duty at all times to monitor stability of face and roof during tunneling operations.

DETECTION OF MOVEMENT

A. Install and monitor instruments as shown on the plans and in accordance with Section 6-5, "Tunnel Instrumentation and Monitoring," of these special provisions.

EQUIPMENT

A. General Requirements:

1. Use equipment that can be controlled to desired line and grade, minimize over-excavation and loss of ground, and capable of excavating the ground materials. In particular consider requirements for excavation and drilling equipment to cut, drill, and excavate all materials identified in the GBR.
2. Use equipment and methods that satisfy the requirements of this section while preserving and protecting the inherent strength of the ground material surrounding the shafts and tunnels.

B. Grouting Equipment:

1. For pumping grout use approved pump capable of developing specified uniform pressure at grout hole connection.
2. Provide automatic shut-off control to prevent grouting pressure from exceeding that specified.
3. Keep equipment lines clean by constant circulation of grout and by periodic flushing with water.
4. Use equipment that allows flushing with grout-intake valve closed, water-supply valve open and grout pump running at full speed.
5. Provide two pressure gauges, one at the pump, the other on manifold hookup at collar of hole being grouted. Use pressure gauge ranges as necessary for each part of the grouting program.

6. Furnish accurately calibrated, high precision gauge to periodically check accuracy of pressure gauge.
7. Provide suitable stop valves at collar of hole to maintain necessary pressure until grout has set.
8. Provide grouting equipment with means of accurately determining amount of grout injected.

SEM TUNNEL EXCAVATIONAND SUPPORT

A. General Requirements

1. Tunnel excavation will primarily be carried out using mechanized excavation techniques such as tunnel excavators and road headers, and drilling and blasting where required by ground conditions.
2. Expect excavation in all materials identified in the GBR.
3. Use suitable installation equipment and methods to avoid damage to reinforcing bars, lattice girders, and instrumentation in the vicinity of the tunnel circumference.
4. Provide continuous tunneling operation without stoppages except for scheduled shutdowns, emergency situations, and as directed by the Engineer.
5. Theoretical excavation lines, grades and dimensions as shown and specified in the plans do not include tolerances for construction and deformations. To maintain the theoretical dimensions required, over-excavation, which also contains 30 mm of space for protection and smoothing layers for the waterproofing system, etc. must be accounted for by the Contractor. Neither the shotcrete lining nor other support measures shall intrude into clearances required for the placement of the final lining.
6. Unless otherwise noted on the plans or approved by the Engineer, excavate the next round only after the complete installation of all support elements of the previous round. The total unsupported length shall not exceed the maximum round length as shown on the plans plus a maximum handling space of 0.5 m.
7. Have sufficient amount of fiber reinforced shotcrete available to be applied at each excavation face during the entire excavation period for immediate application to complete excavation round. No excavation shall be permitted in the absence of sufficient amount of shotcrete available at the tunnel heading.
8. Temporary Invert Protection: Protect the initial shotcrete lining in the invert area of all tunnels and mined openings from damage caused by construction equipment traffic until placing of the final invert concrete by means of a working slab, gravel bed, heavy duty plastic work sheet, or other suitable material approved by the Engineer. Any damage to the initial invert lining must be repaired to the satisfaction of the Engineer.
9. Dispose of excavated material in accordance with the Contract Documents.

B. Probing and Exploratory Drilling

1. Exploratory drillings without core extraction are probing and confirmatory drillings, as well as drainage drillings. Probe holes ahead of the excavation face shall use impact or rotary drilling techniques, and are intended to confirm the predicted geological situation and to detect voids, groundwater, sand lenses, zones of wet silt and other potentially unstable soils. The probe holes shall be located as indicated on the plans or as approved or directed by the Engineer.

2. Drilling will require casings in unstable ground. Minimum diameter shall be as shown in the Drawing, or as approved by the Engineer. A log shall be kept of the drilling works indicating drilling progress, loose ground, voids, installation of casing tubes, observation of drilling water, water ingress and any extraordinary events.
3. Core drilling is applied for additional exploration and probing purposes, the main objective being to recover cores with a minimum diameter of NWX, NMX. Triple tube core drilling will be required to provide better recovery in poor ground. During drilling the drilling pressure shall be adapted to varying ground conditions. Excessive pressure as well as core compressions must be avoided. Use dry core drilling method where feasible. Cores shall be extracted over the defined probe length. Cores shall be placed in foil lined cases and labeled with permanent writing and made available for inspection immediately after extraction. Color pictures to be taken immediately after placing of the cleaned cores into the marked casings using a tripod which allows for a perpendicular shot of the cores. Core cases shall be stored on site to render them accessible for inspection at all times. An accurate log must be kept from each drilling operation indicating drilling progress as related to time, installation and removal of core sample, advancing of casing tube, description of core and all extraordinary events such as water ingress. The logs shall be submitted to the Engineer within 24 hours after completion of the respective core drilling.
4. Position and number of probe drill holes as shown and specified Standard on the plans. Alter position of probe drill holes as approved or directed by the Engineer.
5. Where a probe hole indicates significant water inflow apply further investigation by drilling an additional probe hole approximately 0.6 meter below the water bearing probe hole. Repeat this procedure until invert level of the heading or the bottom of the water bearing strata is reached.
6. Overlap probe holes in longitudinal direction as shown in plans.
7. The Engineer shall be notified in advance of every probe and exploratory drilling.
8. Interpret cores and discharge of probe holes with regard to soil behavior during excavation ahead of the tunnel heading.

C. In-tunnel Water Control

1. Drain, collect and lead to construction drainage all infiltrating groundwater.
2. Dispose of groundwater and wastewater from the operation as quickly as possible without causing damage. Maintain ditches and pump sumps. Dispose of groundwater in an environmentally approved manner to meet or exceed all code requirements.
3. Provide equipment and material capable of pumping as much flow as necessary to keep heading workably dry.
4. Prior to application of the shotcrete lining, collect all seeping groundwater or local groundwater inflow by means of drain hoses and/or drainage mats to prevent build-up of hydrostatic pressure behind the shotcrete lining and deterioration or reduction of the strength properties of the fresh shotcrete. Collect water seepage through shotcrete and drain away by means of drain hoses.
5. Install and maintain at all times temporary drainage systems to control inflow of water into the excavation in order to permit all work to be performed in workably dry conditions.
6. Use exploratory holes, additional holes or drain holes to dewater sand lenses or any other strata ahead of the tunnel face by gravity.

D. Excavation Sequence and Support Measures

1. The sequence and direction of shaft and tunnel excavation shall be as specified on the plans or as approved by the Engineer.
2. The Contractor is responsible for the integrity of the tunnel support and the proper execution of the work, regardless of the actions or inactions of the Engineer.
3. Excavation and support shall be in accordance with the details shown on the plans, and Contingency Procedures, as required by the ground conditions and developed by the Contractor and subject to approval by the Engineer, or as directed by the Engineer.
4. SEM support items shall be applied or installed wherever prevailing ground conditions require the Contractor to do so. Utilization of SEM support items is subject to approval or direction by the Engineer.
5. Evaluation of the ground conditions, excavation and support sequence, and utilization of SEM support items shall be made at the tunnel heading upon assessment of the anticipated subsurface conditions immediately ahead of the top heading and in the bench and invert area.
6. Face support with minimum 130 mm of fiber reinforced shotcrete is mandatory for stoppages longer than 24 hours but not exceeding 72 hours. For stoppages longer than 72 hours full face support shall be applied using a minimum 260 mm thick l fiber reinforced shotcrete layer including the installation of a minimum 260 mm thick fiber reinforced temporary invert for all tunnels. Curvatures of the tunnel faces as shown on the plans shall be maintained at all times. Shotcrete has to be punctured by coring, drilling, installation of drain pipes, or other means on a five foot grid for groundwater pressurere1ief.
7. Apply and install Standard Support Measures as specified herein.
8. Apply and install SEM support items as specified herein.
9. Top Heading, Bench, Invert Excavation:

    a) For SEM tunnel structures use top heading, bench, invert excavation sequence and maximum round lengths as shown and specified on the plans.

E. Standard Support Measures

1. Standard Support Measures including initial shotcrete lining as shown on the plans, and in- tunnel water control are to be applied or installed regardless of geologic and groundwater conditions, and are considered to be the minimum support requirements for a safe tunneling operation.
2. Initial Shotcrete Lining: See Section “Shotcrete Tunnel Lining” of these special provisions. Install shotcrete lining.
3. In-tunnel Water Control described herein.

F. Local Support Measures:

1. Determine required SEM support items for each round of each heading based on interpretation of probe drilling, performance on previous rounds in similar conditions and any other available information. Utilization of SEM support items as approved or directed by the Engineer.
2. The Contractor shall be prepared to apply or install each of the SEM support items during excavation of tunnels.

3. Rebar Spiling: Installed by driving the spites into the ground ahead of the tunnel excavation face or inserting them into pre-drilled holes in the arrangement shown on the plans. If rebars will be inserted into pre-drilled holes, the holes shall be filled with grout prior to rebar insertion Use self-drilled grouted anchors in lieu of rebar spiles as approved by the Engineer.
4. Grouted Pipe Spiling: install grouted pipe spile by driving or jacking the perforated steel pipes into the ground ahead of the face or inserting them into pre-drilled holes. Subsequently, grout the pipes until grout returns. Adjust grouting pressure as required. Use self-drilled grouted anchors and pipes in lieu of rebar spites as approved or directed by the Engineer.
5. Face Stabilization Wedge: Leave wedge of unexcavated material in place during excavation to support the face as shown and specified on the plans as required by ground conditions or as approved or directed by the Engineer. Utilization and removal of the face wedge shall be at no additional cost to the Engineer.
6. Face Bolts: Installation of fiberglass bolts and end hardware into pre-drilled holes ahead of the tunnel heading to increase face stability as shown and specified on the plans. Face bolts are fully resin grouted over their full length and installed with a length as shown in plans. The detailed procedures to be adopted for the installation of the face bolts shall be in accordance with the method statement provided by the Contractor. Installation of face bolts as approved or directed by the Engineer.

FIELD QUALITY CONTROL

A. Shotcrete lining shall not encroach on final lining clearance line as shown on the plans. Consider inaccuracy of construction, material tolerances, and initial lining deformations and deflections of actual excavation and all support and pre-support elements.

   1. Submit survey protocol and plotted profiles with a maximum spacing of 20 feet no later than 14 days after excavation.

B. Document stability of SEM tunnels by monitoring as specified. Prove the absence of any continuing and significant deflection, deformation or increase of stress before installing the waterproofing system and the final lining.

   1. Submit monitoring protocols as part of the weekly geotechnical reports.

C. Allowable Tolerances:

   1. Place initial shotcrete lining to the following tolerances:

      a) Deviation of tunnel alignment from theoretical line or grade shown on the plans as measured from working point of tunnel: One inch.

D. Variation in thickness of lining at any point: Minus zero inch.

END OF SHIFT

A. Contractor shall not leave the work site each day until satisfied that all excavated areas have been supported as specified on the plans. Contractor shall not leave exposed, un-

shotcreted surfaces except where indicated on the plans. The entire structural lining system (welded wire fabric, lattice girders and shotcrete) shall be installed prior to the Contractor leaving the work site each day.

6-3.04 PART 4 - MEASUREMENT AND PAYMENT

Tunnel excavation and support of categories and locations as listed in the Engineer's Estimate by tunneling sequential excavation method will be measured by the meter in conformance with the dimensions shown on the plans.

The contract prices paid per meter for tunnel excavation and support of categories and locations as listed in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and doing all the work involved in initial lining construction, complete in place, including excavation, rock dowels, spiles, face bolts, grouted steel pipes, lattice girders, bore holes for probing ahead, and reinforced shotcrete, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Enlarged tunnel excavation and support of categories and locations as listed in the Engineer's Estimate by tunneling sequential method will be measured by the meter in conformance with the dimensions shown on the plans.

The contract prices paid per meter for enlarged tunnel excavation and support of categories and locations as listed in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and doing all the work involved in initial lining construction, complete in place, including excavation, rock dowels, spiles, face bolts, grouted steel pipes, lattice girders, bore holes for probing ahead, and reinforced shotcrete, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per meter for bore holes for conduits/vents ducts shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and doing all the work involved in bore holes for conduits/vents, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract lump sum price paid for shotcrete canopies at south portals shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and doing all the work involved in tunnel excavation and initial lining construction, complete in place, including rock dowels, lattice girders, and shotcrete, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per meter for bore holes for probing ahead shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and doing all the work involved in bore holes for probing ahead, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per meter for bore holes for conduits/vents ducts shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and doing all the work involved in bore holes for conduits/vents, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

SECTION 6-4. SHOTCRETE TUNNEL INITIAL LINING

6-4.01 PART 1 - GENERAL

DESCRIPTION

This section includes Specifications for the installation of initial shotcrete linings for the Sequential Excavation Method (SEM) tunnels as shown on the plans.

The Work of this Section shall conform to the Section, "Tunnel Shotcrete," of these special provisions.

REFERENCES

A. American Concrete Institute (ACI)
   ACI 506R Guide to shotcrete
   ACI 506.2 Specification for Shotcrete

DEFINITIONS

Shotcrete Initial Lining -Shotcrete layers of specified thickness, including final layer, shown on the plans for the initial support of mined tunnels; the final tunnel support is a reinforced, cast-in-place concrete lining. The initial lining, except the final layer, is reinforced with either steel or synthetic fibers, lattice girders, and starter bars. Intersections between tunnels and cross passages, access passages, and chambers shall be reinforced with welded wire mesh reinforcement.

Shotcrete – Portland cement concrete propelled by compressed air and applied by spraying from a nozzle.

Lattice Girder - Lightweight, three-dimensional steel frame member, shop-fabricated from steel bar stock, embedded in the shotcrete lining, and used to provide both supporting strength, and dimensional guidance by defining the configuration of the inner surface of the Initial Lining.

Starter Bar - Reinforcing bar installed to provide mechanical connection of shotcrete in the circumferential direction between heading and bench or invert shotcrete construction joints.

Spacer Bar - Reinforcing bar installed between two lattice girders to maintain the correct advance length of one round, and provide lateral bracing before girder is enclosed within shotcrete.

Wet-mix Shotcrete - Shotcrete that is supplied from on-site batch plant or ready-mix concrete supplier with water already in the mix. Wet mix is specified for all shotcrete, except that dry mix shotcrete may be used in emergencies when wet mix has not been batched and made ready for application.

Smoothing or Regulating Layer – A layer of shotcrete that does not contain fiber reinforcing, and is used to cover irregularities and smoothen sharp edges protruding from the initial lining surface. This layer is applied in order to avoid damaging the waterproofing membrane that will be applied onto the lining surface.

Welded Wire Mesh- A prefabricated reinforcement consisting of parallel series of high-strength, cold-drawn wires welded together in square or rectangular grids; required for reinforcement at intersections of tunnels and cross passages and access ways. See Section 6-3, "SEM Tunneling," of these special provisions.

SUBMITTALS

A. Samples

   1. Submit:

a) One meter long piece of full cross-section and lacing. Two samples.
b) Butt plate splice mock-up.
c) Lap splice mock-up

B. Working Drawings

1. Shotcrete lining working drawings indicating all structural and construction details and geometry including:

   a) Required dimensions and tolerances.
   b) Plan and sequence of excavation and lining installation.

2. Lattice girder working drawings, including fabrication details.

C. Product Information: Manufacturer's certifications for lattice girders.

QUALITY CONTROL

A. Shotcrete Lining:

1. Visual Inspection:

   a) Surface Smoothness Criteria: The depth to wavelength ratio measured with a 1.50 meter straight edge at any random location, in any orientation within plus or minus 15 degrees of the horizontal direction, shall not exceed 1 to 20 or a maximum wave height of 75 mm. The smoothness criteria required by the manufacturer of the waterproofing membrane. The more smooth of the criteria of either of the two above shall govern.
   b) Thickness indicators: Install appropriate thickness indicators to indicate lining thickness while spraying, and confirm afterwards by scanning survey.
   c) Lattice girders shall not deviate from the shape defined on the plans by more than 50 mm.
   d) The length of a complete lattice girder shall not deviate from the required length nor from the shape defined on the plans by more than 50 mm.
   e) The lattice girders shall be erected within + 150/ -0 mm of the longitudinal positions shown on the plans unless otherwise approved by the Engineer. The erected profile shall not deviate by more than 1 % of the internal dimensions.

2. Recording: for every application of shotcrete, record the following information into the daily shift report:

   a) Date, shift, tunnel temperature.
   b) Nozzelman name.
   c) Test cylinders cast and cores drilled, including name of technician and sample identification, including time and location of sampling.
   d) Results of visual inspection.
   e) Locations and volumes of shotcrete applied.

B. Lattice Girders:

1. Test lattice girders prior to the start of construction as follows:

   a) One random sample of girders to be installed, selected by the Engineer, shall be tested either by the fabricator or an independent laboratory.
   b) The test piece shall consist of a straight length of lattice girder with a length of 4.5 m restrained by a pinned support at one end, and a pinned roller support at the other end.
   c) A uniformly distributed vertical loading of 520 kgf/m shall be incrementally applied over the entire length of the girder. At the same time a horizontal compressive load of 12,700 kgf shall be applied at the roller support.
   d) The Contractor shall test to maximum loading, recording load and deflection, to verify that the girder satisfies specified requirements. The Engineer will witness all tests.

DELIVERY, STORAGE AND HANDLING

A. General:

1. Load, transport, unload and store all structural materials so that they remain clean and protected from damage.
2. Store cementitious materials in dry, protected enclosures and in accordance with manufacturer's recommendation.
3. Store materials on platforms, skids or other supports above the ground surface.
4. Damaged materials to be clearly marked and removed from site immediately.
5. Have shotcrete on hand in adequate quantities and ready for application at the face at all times.

B. LatticeGirders:

1. Bent, scraped, or overstressed members shall be rejected. Inspector may measure excessive deflection as a basis for rejection.
2. Projecting parts bent or damaged during handling shall be rejected. Inspector may measure excessive deflection as a basis for rejection.
3. Replace pieces bent or damaged unless repair is reviewed and accepted by the Engineer.

6-4.02 PART 2 - PRODUCTS

MATERIALS

A. Shotcrete: Shotcrete shall be wet-mix, or dry-mix for possible emergency use, as specified in “Shotcrete,” herein.
B. Lattice Girders:

1. All lattice girders shall consist of three primary reinforcing bars connected by stiffening elements as shown on the plans or of the manufacturer's design.

2. The lattice girder shall be as shown on the plans or designed to allow shotcrete to penetrate into and behind the girder without spray shadows.
3. Section properties:

   a) As shown on the plans.
   b) A minimum of 5 percent of the moment of inertia about the neutral axis shall be provided by the stiffening elements. This percentage will be calculated as an average along a repeatable length of the girder.
   c) The maximum centerline spacing of stiffening elements shall be less than three times the height of the girder to ensure stability against buckling, with a tolerance of plus or minus 25 mm.

4. Material properties:

   a) Minimum physical properties of steel:

      i.) Tensile Strength: 552 MPa minimum at a minimum elongation of 10%
      ii.) Yield Strength: 483 MPa minimum

   b) The connection elements at the end of the girder shall be constructed of structural angle or plate meeting the minimum properties of ASTM A36.

5. Welding:

   a) Welding process to meet the requirements set forth by AWS for gas metal arc welding (GMAW). All welders shall be certified in accordance with AWS D1.1.
   b) All fillet welds of lacing elements shall be 6mm minimum size and run parallel to the main bars with a minimum length of 25mm.

D. Lattice Girder Accessories

1. Bolts: ASTM A325.
2. Starter Bars: Fabricated from No. 16 reinforcing bar in accordance with Section xxxx, Concrete Reinforcement of the Standard Specifications.

F. Welded Wire Mesh: ASTM A185, WWR 152x152 – MW52x52, Min yield 517MPa.
G. Reinforcing Steel: Conform to Section “Reinforcement,” of these special provisions.

6-4.03 PART 3 - EXECUTION

LATTICE GIRDERS

A. Immediately after excavation place first layers of shotcrete (except for Categories I and II) as shown on the plans until required stand-off thickness is in place. Then install girders to conform to the required configuration of the initial lining cross section. Consider variability of materials, excavation and erection tolerances and initial lining deformation to determine actual dimensions. Categories I and II in bench and cross passages require installation of rock dowels before shotcreting.
B. Secure lattice girder segments by means of temporary wood blocking or other means (spacer bars) to maintain position during shotcreting.

C. Locate butt splice plates for lattice girder segment as shown on the plans. Ensure tight connection of all elements. Install stirrup channels and starter bars at radial construction joints as shown on the plans.
D. Remove temporary blocking prior to continuing shotcrete lining into bench and invert.
E. Remove all foreign material from splices prior to connection of subsequent lattice girder segment.

SHOTCRETE

A. Apply minimum 50mm layer of steel fiber-reinforced shotcrete immediately after excavation on all exposed surfaces, except for invert, to seal and protect the ground from deterioration and initial loosening. Except Categories I and II in bench and cross passages require installation of rock dowels before shotcreting.
B. Apply shotcrete as specified in Section “Shotcrete” of these special provisions.
C. Install shotcrete linings to provide thickness shown on the plans. Use thickness indicators to ensure design thickness of shotcrete is achieved, and verify with scanner system.
D. Shotcrete not meeting specified quality shall be removed, and fresh shotcrete resprayed.
E. Shotcrete finish shall be created by the smoothing layer sprayed in accordance with these specifications.
F. Remove all laitance, loose material, and rebound.

JOBSITE PRODUCTION AND SAFETY

A. Maintain supply of fibers, reinforcing steel, welded wire mesh, and lattice girders on site equal to 5 days production on all tunnels under construction, based on a rate of progress equal to the greater of the average rate achieved or the rate assumed in the Construction Schedule.
B. Maintain a constant and adequate supply of shotcrete at the tunnel heading during excavation to permit shotcrete to be applied at any time during the construction.
C. Sufficient shotcrete to support one full excavation round shall be on site at all times during the excavation period. No excavation is permitted without sufficient shotcrete and other required support measures on site.

6-4.04 PART 4 – MEASUREMENT AND PAYMENT

Full compensation for shotcrete tunnel initial lining shall be considered as included in the contract prices paid per meter for various tunnel excavation and support of categories and locations as listed in the Engineer's Estimate and no separate payment will be made therefore.

SECTION 6-5. TUNNEL INSTRUMENTATION AND MONITORING

6-5.01 PART 1 - GENERAL

DESCRIPTION

A. This Section specifies furnishing, installing, maintaining and removal of the geotechnical instrumentation required to observe deflections and pressures of the initial shotcrete lining during construction of all SEM tunnels. This section also specifies the reading,

collecting, reducing, processing, plotting interpreting and reporting of data from these instruments.

REFERENCES

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions and Division 1 Specification Sections, apply to this Section.
B. Related Sections include the following:

1. Section 6-3, "Tunneling by Sequential Excavation Method"
2. Section 6-4, "Shotcrete Tunnel Lining"
3. Section 6-6, “Shotcrete"
4. Section 6-7, "Waterproofing"

DEFINITIONS

A. Subsurface Instrumentation: Instrumentation installed from within the tunnel and shaft during mining operations.
B. Instrument Monitoring: The reading of installed instruments at defined time intervals, plotting and calculating data to include: vertical and horizontal displacements, earth pressure on and stresses induced in the shotcrete lining.
C. Survey Control: Precise field measurements as specified herein, taken by qualified personnel using approved methods and equipment capable of accurately determining elevations, distances and coordinates that are essential for the prosecution of this section's work.
D. Monitoring Bolts: Devices used as targets to measure deformations of the initial shotcrete lining. Measurements are made by optical survey methods.
E. Roof Leveling Points: Devices used to monitor the vertical displacement at the highest point of the initial shotcrete lining. Measurements are made by optical survey methods.
F. Shotcrete Stress Cells: Measuring systems used for monitoring the actual circumferential stress within the initial shotcrete lining during and after the excavation process.
G. Earth Pressure Cells: Measuring systems used for monitoring the actual stress on the initial shotcrete lining during and after the excavation process.
H. Monitoring Cross Section: Tunnel cross section defining installation location of monitoring bolts and roof leveling points, and shotcrete stress cells and earth pressure cells as shown in the Contract Documents.

PURPOSE OF GEOTECHNICAL INSTRUMENTATION PROGRAM

A. Provide early information on the interaction of the construction process and its effect on ground and structures.
B. Permit timely implementation of proper procedures, such as change in excavation sequence and additional support measures, as and when required to maintain a stable tunnel.
C. Document ground movement and lining movement that may occur as a result of construction operations.
D. SEM is a construction method where the type and amount of tunnel and shaft support designed is based on the anticipated subsurface conditions. Assumptions have to be

verified by monitoring and in-situ measurements. Information during tunneling about the interaction of ground and tunnel support help to foresee problems of lining and face stability and provide basis for adjustment of excavation and support if needed.

1. Displacement measurements and roof leveling provide time-varying observation of the initial shotcrete lining, and provide, in combination with stress measurements, information about stability of the installed tunnel support.
2. Measurement of the ground pressure on the initial shotcrete lining and axial stresses in the shotcrete also provide necessary information about long-term stability of the shotcrete lining and the verification of the load assumptions used for the design of the final lining.

E. When in the judgment of the Contractor and the Engineer, the instrumentation data indicate potentially damaging ground or structure displacements or stresses, the Contractor shall adjust the excavation and support procedures as approved by the Engineer, to reduce the ground and structural displacements and pressures and stresses to lie within monitoring response values.

RESPONSIBILITIES OF THE CONTRACTOR

A. Reading of Instruments: Reading of all instruments specified herein shall be performed by the Contractor.
B. Monitoring Data:

1. The Contractor shall submit monitoring data to the Engineer in the form of files stored on compact disks (CD's) with a corresponding hard copy (print out) of the data. The data format shall be approved by the Engineer and shall be compatible with the Engineer's data analysis software. Each set of data shall clearly indicate the instrument identification number and location, reference elevation and depth for readings as appropriate, directions of movement as appropriate, the date and time that the readings were taken, and names of individuals who performed the measurement.
2. The Contractor shall submit the monitoring data to the Engineer within the following time limits:

   a) Data from roof leveling and displacement measurements shall be submitted immediately following reading and plotting, but at the latest 12 hours after the readings are taken.
   b) Data from all other instruments shall be submitted within 24 hours after the readings are taken.
   c) The Contractor shall make his own interpretations of instrument monitoring data for his own use and make such interpretations available to the Engineer within 48 hours.

3. Mining operations will be stopped when monitoring data is not available within the specified timeframes, and commenced once data becomes available.
4. Submit reading data of instruments in mined tunnels along with any conversion procedure, if necessary and including an excavation progress graph showing:

a) Distance between the instrument and the excavation face at the time of the initial reading.
b) Distance between the instrument and the excavation face at subsequent readings.
c) Station of other headings which may influence the results including bench or invert heading and any other headings within the tunnel. Other construction activities in the vicinity which may influence the results.
d) Detailed list of reading results.
e) Names of the monitoring surveyor and the monitoring technician.
f) Ground water inflows conditions if applicable.
g) Include in the report location diagrams and data plots related to the above items, and descriptive interpretation as necessary.

C. Calculate, record and plot the change in elevation, location, ground water table, stress or pressure of each individual instrument with respect to the initial reading. Plots shall be "cumulative change" data, showing absolute changes versus time. Each plot shall be on an 8' inch x 11 inch sheet. Furnish hard copy plots when required.
D. Scheduling: Except where otherwise specified, maintain access to all monitoring instruments and facilities. Temporary stoppage or interruption of certain portions of the work may be required to monitor and take readings. Minimum instrument monitoring schedule as specified.
E. Access to Instruments: Provide and facilitate access to instruments for the Engineer.

QUALIFICATIONS OF THE CONTRACTOR'S INSTRUMENTATION PERSONNEL

A. Engage qualified survey personnel with previous experience performing the type of survey control required. Assign a Registered Land Surveyor licensed in the State of California, with a minimum of three years experience in the supervision and direction of survey parties, to be responsible for survey control.
B. Engage qualified technicians with experience in the installation of the instruments specified herein. Assign a Professional Engineer or Land Surveyor licensed in the State of California with three years experience in instrument installations to supervise and be responsible for the instrument installation.
C. Engage an Engineer, experienced in tunneling, and in the installation of instruments of the type specified in this section to supervise and direct installation technicians and to be responsible for instrument installation.
D. Engage a Professional Engineer, experienced in SEM tunneling and in interpretation of instrument readings of this type, to interpret monitoring results with respect to structural stability of the shotcrete lining.

QUALITY ASSURANCE

A. Codes Regulations, Reference Standards and Specifications:
B. Codes and regulations of jurisdictional authorities.
C. A final quality control inspection shall be made for each instrument, at the manufacturer's facility, prior to shipment. During inspection, a checklist shall be completed to indicate each inspection and test detail. A completed copy of the checklist shall be supplied with each instrument.
D. Survey Control:

1. Establish a secondary control system consisting of horizontal and vertical reference points for constructing the shafts and tunnels and placing the final lining. Install horizontal control points either as a brass disc or lead and tack. Install vertical control points either as a brass disc anchor bolt with nut and washer.

    a) Employ survey procedures and equipment that are in accordance with the FGCC "Standards and Specifications for Geodetic Control Networks" using Second Order Class 2 specifications for horizontal and vertical control work.
    b) All tunnel horizontal traverses shall be closed loops and adjusted by the least squares method. All tunnel vertical traverses shall be closed loops and adjusted by distributing the error of closure equally through the turning points. Provide the Engineer with all traverse adjustments results within 24 hours.
    c) Advance and verify all underground tunnel control after every 300 feet maximum of initial tunnel lining placement.
    d) Install vertical control points maximum 100 m on center throughout the tunnels.
    e) Install inter-visible theodolite instrument platform mounting brackets in the shotcrete lining at or below spring line at maximum intervals of 100 m on center throughout the tunnels, for the purpose of maintaining the secondary horizontal control system. Install additional platform mounting brackets where tunnel alignment does not allow for line-of-site between instrument locations.
    f) Provide each platform mounting bracket with a forced centering hole.
    g) Survey Data Collection:

        1) Provide and maintain all equipment and software necessary to record all secondary survey control measurement observations.
        2) All survey data provided to the Engineer shall contain: a time and date stamp for each observation, original field measurements, and the correctly computed coordinates and elevations in addition to the survey data tags necessary to re-compute the data if required.
        3) Preserve original unedited data and provide one copy of the data to the Engineer.

    h) Survey Equipment Adjustment and Calibration:

        1) Adjust instrument for culmination error every six months or whenever difference between direct and reverse readings of theodolite depart from 180 degrees by more than 15 seconds. Readjust cross hairs and level bubble whenever their misadjustments affect instrument reading by amount of least count.
        2) The National Geodetic Survey (NGS) has established specific calibration baselines for the purpose of comparing survey equipment to known monumentation to verify correct instrument operation and verification of compliance with manufacturer's specifications. Service every six months and check frequently all electronic distance measuring instruments (EDMI's) and retroreflectors over lines of known distances at an approved NGS baseline. Re-calibrate any EDMI if physical damage is incurred.
        3) Compute calibration results using procedures in NOS NGS-10 "Use of Calibration Base Lines". Record actual measurements, apply atmospheric

corrections and then adjust by least squares to compute a constant, as well as, a relative correction factor (scale correction). Calibrate all prisms at the same facility.

4) Forward results of this calibration to the Engineer. Post correction factors in Contractor's office for computing area and apply them as required to maintain specified accuracy.
5) Immediately remove and repair, or replace instruments found to be in disrepair or misadjustment.
6) Provide a certification of adjustment to the Engineer for all instruments to be utilized before commencement of any survey work.
7) Provide and maintain the ability in-house to check and adjust all tribrachs for eccentricity. Perform adjustment checks at least once a week. A record of adjustments to all tribrachs shall be kept current and made available to the Engineer monthly or upon request. Number and tag each tribrach with date of last adjustment.

E. Tolerances:

1. Displacement Measurement: Measure and record the absolute displacements of the respective monitoring bolts to 0.006 foot.
2. Roof Leveling: Measure and record the elevation of the bolt to 2mm.
3. Shotcrete Stress Cell: Measure and record the confining (axial) stress in the shotcrete to10.34 kPa.
4. Earth Pressure Cell: Measure and record the radial pressure on the shotcrete to 4.8 kPa.

SUBMITTALS

A. Working Drawings:

1. Survey control layout: Show survey bench marks, and baselines.
2. Instrument layout and installation details: After instrumentation installation is complete, submit the following:

   a) Instrument identification numbers and locations, with initial elevations, stations and offsets, and coordinates, as applicable for each instruments.
   b) As-built installation details of each instrument, including elevations, materials used, and dimensions of key elements.
   c) A separate statement describing the procedure used for the installation of each.
   d) Other data pertinent to instrument installation.

B. Submit proposed schedule and procedures for instrumentation installation in accordance with this section.
C. Submit installation report of instruments in accordance with this section and in addition:

1. Sketch of exact location of instrument at cross section with date and time of installation and:

a) Geologic and groundwater conditions relevant to installation and reading of instrument.
b) Thickness of initial shotcrete lining at instrument location. In conjunction with shotcrete stress cells measure thickness at re-pressurizing tube.

2. Variation in the above schedule requires the approval of the Engineer.

D. Product Data: Manufacturer's catalog cuts, drawings, material specifications, installation and maintenance instructions, and other data pertinent to manufactured items used in the work of this Section. Submit information minimum 30 days prior to installation of instruments or commencement of shaft and tunnel excavation, whatever occurs first.
E. Qualifications: Documentation regarding the qualifications of supervisory personnel and technicians performing the instrumentation work have to be submitted in accordance with the requirements of this specifications. Submit information minimum 30 days prior to installation of instruments or commencement of shaft and tunnel excavation, whatever occurs first.
F. Certification: Manufacturer's certification that products, materials, and equipment furnished meet the specified requirements. Submit information minimum 30 days prior to installation of instruments or commencement of shaft and tunnel excavation, whatever occurs first.
G. Structure and Instrumentation Damage Reports: Submit three copies of notes on approved forms to the Engineer immediately after observations have been made. In addition, report immediately to the Engineer all damaged or otherwise non-functioning instrumentation.
H. Daily Log: In addition to the requirements specified above submit daily, in an approved format, a log of construction events and observations to include the following:

1. Detailed progress of excavation operations each day, location, type and time of installation of excavation supports.
2. Construction loading in the vicinity of instrumentation.
3. Amount and description of water seepage observed in excavation.
4. Cause and duration of any interruptions or delays to excavation.
5. Location or elevation of significant soil strata boundaries contacts, discontinuities, and a brief soil description.
6. Temperature, rainfall, and other environmental factors that may affect readings or results.

QUALITY CONTROL

A. GENERAL

1. The Standard Specifications specifies the general requirements for the Contractor's Construction Control Program.
2. The following describes the minimum inspection and testing required in the Contractor's Quality Control (C.Q.C.) Plan and Program for the work of this section and is for C.Q.C. only. The implementation of the Contractor Quality Control Program does not relieve the Contractor from the responsibility to provide the work in accordance with the Contract Documents, applicable codes, regulations and governing authorities. The C.Q.C. Plan and Program shall include, but not be limited

to, the following testing and inspection elements. These elements are provided only as a minimum starting point for the Contractor to use to generate his complete C.Q.C. Program.

B. QUALITY CONTROL PERSONNEL

1. Employ personnel as specified herein to supervise the following instrumentation related activities:

   a) Submission of instruments for approval.
   b) Review of instrumentation layout and location in the field.
   c) Supervision of installation and calibration, if necessary, of instruments.
   d) Production of as-built drawings.
   e) Reading of instruments.
   f) Gathering and processing of data.
   g) Plotting of tables and graphs.
   h) Submission of data to the Engineer.
   i) Maintenance of instruments and replacement of damaged instruments or damaged portions of instruments.
   j) Contact and coordination with the Engineer after instrument reading above threshold value is received.

6-5.02 PART 2 - PRODUCTS

GENERAL

A. Any request from the Contractor for consideration of a substitution shall clearly state the nature of the deviation from the product specified.

MONITORING BOLTS

A. Monitoring Bolt with a fine threaded end (with cap for tread protection) for attachment to a tape survey target or prism as approved by the Engineer.

ROOF LEVELING POINTS

A. Monitoring Bolt with a fine threaded end (with cap for thread protection) for attachment to a survey target or prism and a suspension plate for positioning of survey rod to allow backup roof deformation readings as approved by the Engineer.

STRESS AND PRESSURE CELLS

A. General: It is important that very flat hydraulic pressure cells are used which minimize hard or soft inclusion effects and permit the monitoring of radial or tangential stress directly. Strain gages measuring strain rather than stress will not be accepted.
B. Shotcrete Stress Cell: Provide oil filled pressure cell (hydraulic stress cells) with repressurizing tube, or vibrating wire type cell.

C. Earth Pressure Cell: Provide oil filled pressure cell (hydraulic stress cells), or vibrating wire type cell.

FACTORY CALIBRATION

A. A factory calibration shall be conducted on all instruments at the manufacturer's facility prior to shipment. Certification shall be provided to indicate that the test equipment used for this purpose is calibrated and maintained in accordance with the equipment manufacturer's calibration requirements and that, where applicable, calibrations are traceable to the National Institute of Standards and Technology.

6-5.03 PART 3 - EXECUTION

LOCATIONS AND SEQUENCE OF INSTALLATION

A. Install instruments in accordance with the following schedule:

1. Install subsurface instrumentation during mining operations.

   a) Monitoring bolts and roof leveling points shall be installed as close as practicable to the excavation face at locations shown on the Contract Drawings such that initial reading can be taken no more than 6 hours following excavation.
   b) Earth pressure and shotcrete stress cells shall be installed concurrently with the installation of the initial shotcrete lining.

2. Install elements of the typical Monitoring Cross Section for the safety of structure, personnel and equipment as shown on the Contract Drawings and wherever indicated by subsurface conditions, or otherwise directed by the Engineer.
3. Actual point of instrument installations relocated more than three feet from a scaled location shown on the Contract Drawings or approved Working Drawings shall require the Engineer's approval.

INSTALLATION OF MONITORING BOLTS AND ROOF LEVELING POINTS

A. Install monitoring bolts in the initial shotcrete lining such that the bolts protrude from the shotcrete horizontally at the side walls and vertically in the roof. Assure sufficient anchoring of the bolts into the shotcrete to avoid loosening of the bolts over the entire construction period. Install bolts in predrilled holes in the shotcrete bonded with epoxy resin.

INSTALLATION OF STRESS AND PRESSURE CELLS

A. Install all stress and pressure cells, connection hoses, read out manifold, and oil pump platform as shown on the Contract Drawings and specified hereafter.

1. Install shotcrete stress cells and earth pressure cells in pairs for measuring stresses and pressures within and on the initial shotcrete lining and on the shotcrete lining. Locate the ground load cell directly above the shotcrete stress cell.

2. Install a read out manifold and a platform next to the cell pairs for the hydraulic pump. Connect read out manifold with pressure gages through previously installed pressure hoses. These hoses shall be installed within the shotcrete to prevent damage.
3. First reading (zero reading) shall be done before application of initial shotcrete. Record the location of the pump for this.
4. Apply shotcrete first to completely fill up the areas below the cells. Remove all rebound from the exposed surface of the shotcrete stress cells, then complete encapsulation of gages.
5. Accurately measure the thickness of the shotcrete around the stress cell by either marking the repressurizing tube of the concrete cell or by installing a marked splice bar next to the gage prior to shotcrete application. Mark the position of the cell on the finished shotcrete surface.

INSTALLATION OF LATTICE GIRDER STRAIN GAGES

A. Install strain gage arrays at Monitoring Cross Sections indicated on the Contract Drawings.
B. At each instrumentation location within the monitoring cross section provide the following:

1. Install strain gage elements on each of the three the lattice girder bars as shown on the contract drawings.
2. If deformed bars are used for the lattice girders, grind off deformations two inches on each side of the element location.
3. Orient the strain gage elements to measure longitudinal strain.
4. Prepare the substrate and fix the strain gage element assemblies to the chord bar with an approved adhesive.
5. Protect the gage element assemblies in accordance with the Engineer-approved installation methodology, including wire leads and terminals.
6. Secure terminals to the face of the cured shotcrete.

SURVEY CONTROL

A. Prior to start of construction, install cased bench marks.
B. Establish the elevation of each cased bench mark by running level circuits started and closed at the specified existing bench mark.

1. Establish turning points during leveling so that foresight and backsight distances are approximately equal.
2. Do not exceed sight distances of 60 m.
3. Establish an error of closure less than 0.001m for level circuit closures. If an error of closure greater than 0.001 m is achieved for any level circuit, resurvey the circuit.
4. Prove the established elevations of cased bench marks by obtaining consistent results on at least three separate and complete level circuits. If an inconsistent elevation for any cased bench mark results, resurvey the level circuit until correct and repeatable elevations are obtained.

PROTECTION AND MAINTENANCE

A. Protect from damage due to construction operations, weather, and traffic all survey reference and control points, instruments and appurtenant fixtures, instrument leads, connections, and other instrumentation system components.
B. Protect and maintain all instrument systems. Maintenance shall include draining or flushing protective terminal boxes, and repairs or replacement of damaged or missing system components. Damaged or missing instrumentation shall be repaired or replaced by the Contractor at no expense to the Engineer using approved materials and procedures. Repair or replace damaged or missing instrumentation components or entire instruments for shaft and tunnel geotechnical instrumentation as required and practicable within 24 hours.

INSTRUMENT MONITORING

A. General

1. As a minimum, perform monitoring of tunnel geotechnical instrumentation, and follow the minimum schedule as specified herein.
2. When instruments detect sudden changes in deformation or changing ground water levels, take additional readings in number and frequency as directed by the Engineer.

B. Responsibility for Monitoring:

1. The Contractor shall monitor all existing installed instrumentation specified herein during construction operations. Instrument monitoring schedules are as specified herein.
2. The Contractor shall be responsible for providing all necessary assistance in the form of labor and equipment to also enable the Engineer to access and monitor the instruments.

C. Initial Readings:

1. Obtain initial readings from all instrumentation.
2. Provide initial readings by conducting three separate and complete sets of readings on each instrument. Readings will be taken with sufficient accuracy to produce similar results in each of the three readings.

D. Reading Frequency:

1. Monitoring Bolts and Roof Leveling Bolts:

a) Obtain initial and subsequent readings of convergence bolts and roof leveling points by use of optical survey methods.
b) Read instrument daily from installation to completion of SEM excavation and support activities.
c) Continue daily readings after completion of SEM works until movements have stabilized. Continue reading weekly until the installation of the waterproofing system.

2. Pressure and Stress Cells:

   a) Obtain initial and subsequent readings on shotcrete stress cells and ground load cells by use of an appropriate readout unit. Secure the distribution box in a manner which will allow consistent readings.
   b) Read instrument daily from installation to completion of SEM excavation and support activities.
   c) Continue reading instruments after completion of SEM works until movements have stabilized as approved or directed by the Engineer.

E. Instrumentation Monitoring Response Values:

1. Instrumentation monitoring response values are defined in Table 1 of this Section and in the plans, Sheet S2.25.
2. The displacement values in Table 1 are expressed as percentages of the excavated tunnel width. These values are also applied to the side wall drifts with their respective excavated widths.

Table 1 - Monitoring Response Values

INSTRUMENT TYPE	INSTRUMENT RESPONSE VALUES	
	THRESHOLD	LIMITING
Shotcrete Stress Cells	Shotcrete Stress 2400 psi	Shotcrete Stress 3250 psi
Ground Pressure Cells	None	none

3. Implement excavation and support sequence changes and SEM support items as specified when instrumentation data indicates settlement of ground or movement of the initial shotcrete lining or stresses in the shotcrete lining or stresses onto the shotcrete lining beyond the instrument response values specified in Table 1 and/or sheet S2.25.

F. Exceeding Monitoring Response Values:

1. Threshold Values - Verify measurement and notify the Engineer immediately after obtaining any measurement that exceeds the Threshold Value for that instrument. Double the frequency of future monitoring of that instrument and adjacent instruments until movements have stabilized to the satisfaction of the Engineer. Implement procedures (e.g. Vary advance rates and initial support or pre-support measures) in order to limit further movements.
2. Limiting Instrument Response Values - Verify measurement and notify the Engineer immediately after obtaining any measurement that exceeds the Limiting Value for that instrument. For all Limiting Instrument Response Values exceeding those indicated, and depending on conditions, the Engineer may suspend excavation and associated activities at that location, and require the Contractor to submit alternative proposals i.e. change of excavation and support sequence and installation of SEM support items as specified in Section 6-3 or any other measures to stop further

movements. If work is suspended, the Contractor shall obtain approval from the Engineer prior to restarting excavation at that location, under approved procedures.

3. Monitor geotechnical instruments continuously until the ground and the structure have been stabilized. Inform the Engineer of the results of the implemented procedures.

6-5.04 PART 4 – MEASUREMENT AND PAYMENT

The contract lump sum price paid for tunnel monitoring system shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals including all attachments, and for doing all the work involved in tunnel monitoring system, complete in place, including removal of the monitoring devices after work is completed, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

SECTION 6-6. SHOTCRETE

6-6.01 PART 1 - GENERAL

DESCRIPTION

A. This Section includes specifications for materials, proportioning, and application of shotcrete used for the tunnel initial lining. Unless indicated otherwise, the requirements specified apply to both temporary and permanent shotcrete.

B. This Section covers both wet mix and dry mix shotcrete. Dry mix shotcrete may be used in an emergency where shotcrete is immediately required and wet mix is unavailable.

REFERENCE STANDARDS

A. American Concrete Institute (ACI)

ACI 506.1: State-of-the-Art Report on fiber Reinforced Shotcrete
ACI 506R: Guide to Shotcrete
ACI 506.2: Specification for Materials, Proportioning, and Application of Shotcrete
ACI 506.4R: Evaluation of In-Place Shotcrete
ACI C 660: Shotcrete Nozzleman Certification

B. American Society for Testing and Materials (ASTM)

ASTM A185: Specifications for Wire Fabric, Plain, Welded Steel for Concrete Reinforcement.
ASTM A820: Specifications for Steel Fibers for Fiber-Reinforced Concrete.
ASTM C31: Practice for Making and Curing Concrete Test Specimens in the Field.
ASTM C42: Test Methods for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
ASTM C78: Standard Test Method of Flexural Strength of Concrete.

ASTM C192: Standard Method of Making and Curing Concrete Test Specimens in the Laboratory.
ASTM C94: Standard Specification for Ready Mix Concrete.
ASTM C94: Standard Specification for Ready Mix Concrete.
ASTM C192: Standard Method of Making and Curing Concrete Test Specimens in the Laboratory.
ASTM C288: Standard Test Method for Potential Alkali-Silica Reactivity of Aggregates (Chemical Method)
ASTM C595: Specification for Blended Hydraulic Cements
ASTM C618: Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
ASTM C642: Test Method for Specific Gravity, Absorption, and Voids in Hardened Concrete
ASTM C685: Specification for Concrete Made by Volumetric Batching and Continuous Mixing
ASTM C989: Specification for Ground Granulated Blast-Furnace Slag for use in Concrete and Mortars
ASTM C1018: Test Method for Flexural Toughness and First-Crack Strength of Fiber-Reinforced Concrete (Using Beam with Third-Point Loading)
ASTM C1074: Standard Practice for Estimating Concrete Strength by the Maturity Method
ASTM C1116: Specification for Fiber-Reinforced Concrete and Shotcrete
ASTM C1140: Standard Practice for Preparing and Testing Specimens from Shotcrete Test Panels
ASTM C1141: Standard Specification for Admixtures for Shotcrete
ASTM C1240: Specification for Silica Fume for Use in Hydraulic-Cement Concrete, Mortars, and Grout
ASTM C1385: Standard Practice for Sampling Materials for Shotcrete
ASTM C1436: Standard Specification for Materials for Shotcrete.

DEFINITIONS

Initial Lining (Shotcrete Lining).-- Shotcrete layer of minimum thickness, including sealing shotcrete layer as shown on the plans installed for the support of the tunnel, but considered temporary, sometimes called primary lining. The initial lining is reinforced with steel or synthetic fibers and lattice girders, starter bars, and spacer bars. A final, permanent lining, sometimes called secondary lining, of cast-in-place concrete is placed afterwards for the permanent support of the tunnel.

Steel Fiber, Synthetic Fiber.-- Discrete, hard drawn, bent steel fibers, or fibers composed of synthetic (plastic) materials, uniformly distributed in shotcrete to improve the bending capacity, durability and especially the yield resistance of shotcrete, as measured by the toughness index property.

Defective shotcrete.-- Shotcrete that does not meet requirements of specifications or contract plans, including shotcrete that does not meet strength requirements, or which lacks uniformity, exhibits segregation, honeycombing, or lamination, shows significant cracking, contains dry patches or sand pockets, is hollow, or in the Engineer’s opinion does not meet the project requirements.

Corrective Shotcrete.-- Shotcrete used to replace defective shotcrete at the Contractor’s own expense.

Smoothing or Regulating or shotcrete.-- A minimum 25 mm thick layer of unreinforced (without fibers) shotcrete applied prior to the installation of waterproofing linings to cover steel parts and smoothen sharp edges protruding from the initial lining surface. The Waterproofing System consists of both Smoothing shotcrete layer and two waterproofing layers. See Section 6-7, “Tunnel Waterproofing,” of these special provisions.

SUBMITTALS

A. Working drawings, material lists, descriptive data, samples and other submittals specified in these special provisions shall be submitted for approval in accordance with the provisions in "Working Drawings," of these special provisions. Submit within 90 working days after contract has been awarded or at the latest 30 days prior to commencement of shotcrete application, unless otherwise permitted in writing by the Engineer, the following:

1. Product Data: For each type of manufactured material and product indicated.
2. Samples: Upon request by the Engineer, up to seven specimens from each field test panel, proposed for use in the work together with relevant data, which demonstrate conformance with specified requirements shall be tested by request of the Engineer to verify conformance.
3. Certification: Material Certificates, signed by manufacturers certifying that each of the following items complies with requirements: Cementitious materials and aggregates. Steel fibers; Synthetic fibers; Reinforcement bars; Admixtures.
4. Design Mixes: For each shotcrete mix. Submit mix designs for approval by the Engineer.
5. Personnel: Submit resumes of proposed nozzle men and shotcrete foreman for approval by the Engineer.
6. Documentation: Prior to making laboratory compatibility tests, submit detailed plan showing methods and proportions to be used in such tests. The Engineer may inspect such tests and materials at any time.
7. Material Test Reports: From a qualified testing agency, certified test reports with or without adjustment for type or size of specimen, in conformance with ASTM or other applicable testing standards.
8. Proposed type of fiber (steel or synthetic), including fiber characteristics.

B. Submit preconstruction testing results at the latest 30 days prior to commencement of shotcrete work.
C. Submit resumes for proposed shotcrete nozzlemen and foremen at the latest 90 days prior to commencement of shotcrete work.
D. Submit details of shotcrete equipment to be used on the Contract, including brand name, model and capacity of pump and air compressor, and accelerator and fiber dosing devices at the latest 90 days prior to commencement of shotcrete work.
E. Details of proposed methods for control and disposal of waste materials, including waste shotcrete, fibers, rebound and overspray.

QUALITY CONTROL

A. Shotcrete Crew Qualifications: Shotcrete crew foremen and nozzlemen shall meet the following requirements.

1. Furnish proof that each shotcrete crew foreman has at least 4 years experience in underground shotcrete application on projects of a similar character to this Contract. References from persons responsible for supervision of these projects may be accepted by the Engineer in lieu of some experience time. Include name, address and telephone number for all references.
2. Furnish proof that all nozzlemen are certified to ACI C 660 for application of shotcrete to vertical and overhead surfaces for both wet- and dry-mix shotcrete. Alternatively the Engineer may accept a nozzleman's qualifications upon demonstration of the nozzleman's skill in shooting test panels oriented in vertical and in overhead positions. Furnish proof that nozzlemen have successfully completed three projects of similar character to this Contract. All nozzlemen must shoot test panels that fulfill the requirements as specified herein.

B. Preconstruction testing

1. Test Panels: Prepare preconstruction test panels for examination by the Engineer prior to job shotcrete placement. Preparation and testing shall comply with ASTM C1140, except as modified below:

   a) Test panel size shall be 700mm by 700mm minimum; with a minimum depth of 115 mm. Panels shall be made with sloped sides.
   b) Coring and testing shall be in compliance with ASTM C 42, except that minimum core size shall be 100 mm diameter by 115 mm deep, trimmeds100mm. Apply ASTM C 42 length-to-diameter correction factors to the compressive strength results.
   c) Cores shall not be taken closer than 100mm from any edge of the panel.

2. Concrete Mix Design and Testing:

   a) Develop shotcrete mix by laboratory compatibility tests and field trials as specified at least 30 days prior to the actual application of shotcreteb). Material requirements shall satisfy ASTM C 1436, latest revision. Fiber reinforced concrete shall satisfy the requirements of ASTM C 1116, latest revision.
   c) Test admixtures for compatibility with cement in accordance with ASTM C 1141.
   d) Confirm design slump for each wet-mix shotcrete mix.
   e) Adjust shotcrete mix and repeat laboratory compatibility tests and field trials, in case testing during construction does indicate a failure in meeting the specified requirements.
   f) To ascertain compatibility of ingredients and optimum proportions, develop shotcrete mix having strength and characteristics necessary for actual application.
   g) Perform compatibility tests to determine cements and additives to be used in field trial mixes. Determine initial and final set for additive concentrations of varying percentages of cement content by weight contemplated for use in the tunnel lining.
   h) Make laboratory and field trial mixes with ingredients identical to those proposed for use in the tunnel lining.
   i) Proportion shotcrete mixes equivalent to those of concrete mix having between 365 kg and 475 kg of cement per cubic meter of concrete.
   j) Accelerating admixture.

1) Determine time of setting in accordance with ASTM C266 with the following additional requirements:

   i. Use minimum possible time interval to attain proper mixing without disturbing initial set of paste.
   ii. Additional modifications to accommodate quick-set accelerators: As approved by the Engineer.

2) Use approved accelerating admixture to develop quick set as follows:

   i. Time of initial setting: Three minutes maximum.
   ii. Time for final setting: Twelve minutes maximum.

3) Sodium silicate admixtures shall not be used.

3. Nozzleman Qualification: Produce test panels for each proposed nozzleman and each anticipated shooting orientation.

   a) Provide test panels with fiber reinforced shotcrete at least two of which shall also contain WWR fixed to the sides of the panel forms so that the WWR is approx 75 mm in front of the panel form's base.
   b) Test panels shall be shot using the same nozzleman, assistant, and equipment that will be used under the Contract, and with each of the approved concrete mix designs and at orientations to be used under the Contract.
   c) Shotcrete used shall be within + or – 15 mm of the design slump.
   d) Test panels for nozzleman qualification shall not be shot until the shotcrete mix is approved. Cores from test panels shall be examined by the Engineer for continuity, absence of voids, delaminations, and rebound, and general quality
   e) When the prequalification test panel is rejected, a second panel may be shot. When the second test panel is rejected, the nozzleman may not be permitted to shoot on the Contract as determined by the Engineer.

4. Fiber-reinforced shotcrete: Produce test specimens for testing flexural strength and toughness in accordance with the Specifications.
5. Reference concrete cylinder testing:

   a) Choose material and proportions so that three cast cylinders 150mm by 300 mm made with no additive will achieve average minimum strength at 28 days of 27.6 MPa. Cast cylinders in accordance with ASTM C192 and test in accordance with ASTM C39. Cast and test three cylinders minimum for each combination of materials proposed.

6. Field trial:

   a) After completion and approval of laboratory tests, make field trials using selected mixes to accommodate capability of equipment, workmanship and material under field conditions prior to actual application of shotcrete.

b) Make field application of each mix selected for field trial on at least three vertical test panels.
c). Shoot test panels into a box of dimensions as specified above.
d). Cure test panels in accordance with ASTM C31.
e). Within 24 hours after applying shotcrete, obtain an appropriate number of full-depth, 100 mm diameter cores, from each panel.
f). Average three cores from each panel to comprise one test.
g) Perform field trial work in the presence of the Engineer.
h) Achieve progressive compressive strengths as follows:
i) Initial lining shotcrete:

1) Average strength of six tests with the penetration needle on three vertical panels, at 10 minutes: 275 kPa minimum.
2) Average strength of six tests with the penetration needle on three vertical panels, at 1 hour: 485 kPa minimum.
3) Average strength of six tests with the bolt driving method on three vertical panels, at 10 hours: 2.1 MPa minimum.
4) Average strength of six core compressive strength tests on three vertical panels, at 24 hours: 9.7 MPa minimum.
5) Average strength of six core compressive strength tests on three vertical panels, at 7 days: 22.1 MPa minimum
6) Average strength of six core compressive strength tests on three vertical panels, at 28 days: 27.6 MPa minimum.
7) No individual strength test falls below the required 28-day strength by more than 3.5 MPa.

C. Construction testing

1. Produce a material test panel for each mix and every 10 m advance or every 50 cubic m placed, whichever is less. Test panel shall be kept moist and at 70 degrees F +/- 10 degrees F until moved to test laboratory. Test specimens from test panels in compliance with ASTM C 1140, except as modified below:

a) Test panel size shall be as in B. Preconstruction testing
b) Test panels shall be shot at the same orientation and in the same manner as the work.
c) Test panels shall be marked for later identification (mix, location, date, nozzleman).

2. Test specimens from core drilling of in-place shotcrete:

a) Coring and testing shall be in compliance with ASTM C42, except that minimum core size shall be 100 mm diameter by at least 100 mm deep, trimmed smooth. Apply ASTM C42 length-to-diameter correction factors to the compressive strength results.
b) Perform core sampling and testing at locations determined by the Engineer up to a maximum of two hundred fifty 3-core sets.

c) Fill all core holes from in-place t shotcrete with non-shrink grout with a 28-day compressive strength of 28 MPa minimum. Prepare hole in accordance with grout manufacturer's instructions and finish flush with the surrounding shotcrete.
d) In-place coring of permanent shotcrete shall not penetrate within a distance of 100 mm from a construction joint.
e) Cores shall be clearly marked for later identification (mix, location, date, nozzleman).

3. The mean compressive strength of a set of three cores shall equal or exceed 0.85 f'c with no individual core less than 0.75 f'c.

E. Evaluation of in-place shotcrete

1. Remove and replace shotcrete that is delaminated, exhibits laminations, voids, or sand pockets exceeding the limits for the specified grade of shotcrete. Remove and replace shotcrete that does not comply with the specified material properties. Repair core holes in accordance with Chapter 9 of ACI 301 and 1.04 C.2.c) above. Do not fill core holes in permanent shotcrete by spraying.
2. If the shotcrete fails to meet the compliance requirements specified herein, the validity of the test results shall be checked prior to implementing one of the following courses of action:

a) Confirm the requirements for remedial action by assessing the results of geotechnical measurements and/or back analysis.
b) Make good deficiencies by the application of additional thickness of shotcrete at past or future works until the compliance with the requirements is confirmed.
c) Following an approved procedure remove the defective shotcrete and replace by new shotcrete.
d) Additional rock dowels, or other reinforcement measures, may also be installed upon approval by the Engineer

3. Shotcrete strength requirements determined by testing during construction

a) Average strength of three tests with the penetration needle from one area, at 10 minutes: 275 kPa minimum.
b) Average strength of three tests with the penetration needle from one area, at 1 hour: 485 kPa minimum.
c) Average strength of three core compressive strength tests from one area: 9.7 MPa when tested at 24 hours after application.
d) Average strength of three cores from one area: 22.1 MPa minimum when tested at 7 days.
e) Average strength of three cores from on area: 27.6 MPa minimum when tested at 28 days.

4. Toughness - Fiber Reinforcement Shotcrete shall have the following flexural strength and toughness properties:

a) Average first Crack flexural strength at seven days: greater than 4.8 MPa, determined in accordance with ASTM C1018.

b) Average energy absorption after 7 days, 1,000 Joules at 25 mm deflection.
c) Energy absorption determined by ASTM C 1550, latest edition.

F. Acceptance

1. The Engineer has the authority to accept or reject shotcrete work. Shotcrete which does not conform to the Specifications may be rejected either during the shotcrete application process, or on the basis of tests from either test panels or the completed work.
2. Deficiencies observed during the shotcrete application process such as, but not limited to, the following constitute a cause for shotcrete rejection:

   a) Failure to properly control and remove build-up of overspray and rebound;
   b) Incomplete consolidation of reinforcing steel, mesh and anchors;
   c) Incorporation of sand lenses, excessive voids, delaminations, sags or sloughing;
   d) Failure to apply shotcrete to the required line and grade and tolerance.

3. Wherever possible perform remedial work to correct deficiencies while shotcrete is still plastic.
4. Hardened shotcrete will be examined by the Engineer for any evidence of excessive plastic or drying shrinkage cracking, tears, feather-edging, sloughs or other deficiencies. Sounding or coring shall be used to check for delaminations.
5. If the results of compliance tests from shotcrete test panels, or assessment of the plastic or hardened shotcrete indicate non-conformance of the shotcrete, the Engineer will implement a program of evaluation of the in-place shotcrete. Such evaluation shall include, but not be limited to:

   a) Extraction of cores from in-place shotcrete at locations selected by the Engineer and testing of such cores for compliance.
   b) Checking for delaminations using sounding or other appropriate non-destructive testing procedures.
   c) Bond pull-off testing.
   d) Diamond saw cutting or coring to check adequacy of encasement of reinforcing steel and anchors.

6. Rejected shotcrete shall be removed and the lining rebuilt to the satisfaction of the Engineer at no cost to the Engineer.

6-6.02 PART 2 - PRODUCTS

CEMENT

A. Portland cement: ASTM C 150, Types, I, II, or III.

AGGREGATE

A. Normal weight aggregate: ASTM C 33. Aggregate not meeting ASTM C 33 may be used provided preconstruction tests demonstrate the shotcrete meets all other specified requirements.
B. Lightweight aggregate: not permitted.
C. Aggregate size: Uniformly graded and not exhibiting extremes of gradation, in accordance with ASTM C33, grading size No. 67. Alternative gradation may be used provided the shotcrete meets strength and toughness requirements. Specific gravity: 2.55 minimum. Maximum aggregate size: 13 mm, or as approved by the Engineer.
D. Additional requirements for permanent shotcrete: Potential reactivity of aggregates: Use only aggregates classified as innocuous in accordance with ASTM C 289.

REINFORCEMENT

A. Deformed steel reinforcement: ASTM A615.
B. Welded wire fabric: ASTM A 185.
C. Fibers: Steel fibers shall conform to ASTM A820, Type I or II, with an aspect ratio of 45 to 85. Fibers shall have bent or deformed ends. Fibers shall be of a single length ranging from 20 mm to 40 mm. Fibers shall be of the deformed end type. Straight or continuously corrugated fibers shall not be used. Synthetic fibers shall conform to ASTM C-1116, Section 4.1.3 and Note 3. In addition, the following requirements apply: International Code Council ES, Acceptance Criteria 32, Sec. 3.1.1 and 3.1.2.D. Glass fibers: Not permitted.

WATER

A. Clean and potable.
B. Mixing water for shotcrete shall meet requirements of ASTM C94.

ADMIXTURES

A. Water-reducing and superplasticizer: ASTM C1141.
B. Retarding: ASTM C 1141.
C. Accelerating: ASTM C 1141. Admixtures shall be used to provide quick set, high early strength and improved adhesion.
D. Air-entraining: ASTM C 1141.
E. Fly ash and natural pozzolans: ASTM C 618.
F. Ground granulated blast-furnace slag: ASTM C 989.
G. Silica fume: ASTM C1240.

PROPORTIONING

A. Select shotcrete proportions to produce the specified material properties.
B. Minimum slump of wet-mix shotcrete shall be25 mm. Actual value shall be determined from preconstruction trials C.

FIBER-REINFORCED SHOTCRETE (FRS)

A. SFRS to conform to ASTM C1116.

B. Toughness Performance Level Testing:

1. Perform toughness performance level testing in accordance with ASTM C 1550, latest revision.

PRE-BAGGED MATERIALS

A. Pre-bagged materials are allowable with pre-dampening prior to use.

DELIVERY, STORAGE, AND HANDLING

A. Deliver, store, and handle materials to prevent contamination, segregation, corrosion, or damage.
B. Store shotcrete materials, including steel fibers, in a dry place.
C. Uae aggregate materials at a temperature of no less than 40 degrees F.
D. Store liquid admixtures to prevent evaporation and freezing. Store admixtures at all times in clearly marked and labeled containers (including admixture name, type, storage requirements, use-before date, instructions for use, safety precautions, and manufacturer's recommended dosage range).

EQUIPMENT

A. Use batching equipment that proportions aggregate and cement mixtures on a mass basis or volume basis.
B. Use an air supply system that delivers air uncontaminated by oil or any other contaminant and that is capable of maintaining a constant pressure.
C. Shotcrete delivery equipment shall be capable of delivering a steady stream of uniformly mixed material to the discharge nozzle at the proper velocity and rate of discharge.
D. Use positive displacement pumps equipped with hydraulic or mechanically powered pistons, with compressed air added at the discharge nozzle, for wet-mix shotcrete application.
E. Monitor air ring at nozzle for signs of blockage of individual air holes. Stop shooting and clean air ring if non-uniform discharge of shotcrete becomes apparent.
F. Clean shotcrete delivery equipment thoroughly at the end of each shift, Regularly inspect and clean air ring and nozzle; replace if required.
G. Provide a separate air hose and blow pipe, capable of simultaneous operation with shotcreting operation, for removal of rebound and dust
H. Equipment will be subject to approval of the Engineer. Maintain equipment in proper working order. Provide additional test panels and test cores as required by the Engineer to demonstrate that the equipment is functioning properly during shotcreting operation.
I. Provide standby equipment on site and in good working order at all times during shotcreting operations.

6-6.03 PART 3 - EXECUTION

EXAMINATION

A. Verify that placement and clearance around reinforcement (including wire mesh at tunnel intersections) is adequate for complete encasement.
B. Verify that surfaces to receive shotcrete have been properly prepared according to the specifications.
C. Remove rebound and any other foreign material from construction joints prior to continuing shotcrete installation.
D. Rebound shotcrete shall not be reused or incorporated into the work.
E. Sequence of shotcrete installation shall be as shown on the Contract Drawings. Thickness indicated is the minimum thickness at any point. Use thickness indicators to control thickness while spraying, and verify thickness with scanning equipment as required and directed by the Engineer.

BATCHING AND MIXING

A. Weight batching shall comply with the accuracy specified in ASTM C 94.
B. Volume batching shall comply with the accuracy specified in ASTM C 685. Calibrate batching equipment in accordance with ASTM C 685 at the start of every shift, or every 30 cubic meters batched. Volume batching shall be verified once a week by a weight batching check.
C. Use batching and mixing equipment capable of proportioning and mixing the required materials.
D. Use feed systems for all materials that are interconnected such that if one feed stops, all feeds stop.
E. Shoot dry-mix shotcrete material within 45 minutes after batching or pre-dampening.
F. Shoot wet-mix shotcrete material within 90 minutes after batching.
G. Dosing of admixture by hand is not permitted.
H. Permanent shotcrete delivered to shotcrete pump with a slump that is outside the confirmed design range will be rejected.

SURFACE PREPARATION

A. Soils - Prepare surfaces to line and grade. Do not apply shotcrete to frozen surface. Dampen surface immediately prior to shooting.
B. Shotcrete - Remove all deteriorated, loose, unsound material or contaminants that may inhibit bonding. Chip areas to be repaired to remove offsets causing abrupt changes in thickness. Surface shall be saturated surface dry (SSD) immediately prior to placing shotcrete.
C. Structural reinforcement, including wire mesh - The surface shall be free of deleterious materials that inhibit bonding. Reinforcement shall be secured to prevent movement.
D. Water leaks - Securely fix drainage pipes, channels or similar water control devices prior and during shotcreting.

JOINTS

A. Construction joints -. Form square joints where joints are subject to compression loads. Surface preparation of joints shall comfort to “FINISHING,” of these special provisions. Continue reinforcement through construction joint.

ALIGNMENT CONTROL

A. Install taut ground wires, lattice girders and other means such as laser controls to establish thickness and plane of required surface.

APPLICATION

A. Shotcrete Placement Technique

1. Provide a platform that permits nozzleman unobstructed access to the receiving surface. Remove rebound and overspray from previously prepared surfaces prior to shotcrete placement.
2. Apply shotcrete from the bottom and continue upwards to avoid the inclusion of rebound in the lining.
3. For invert lining, use separately controlled air blowpipe during spraying to remove rebound from the lining.
4. Place shotcrete first in corners, recesses, and other areas where rebound or overspray cannot escape easily. Place shotcrete with nozzle held at approximately 90 degree angle to the receiving surface. In corners, direct nozzle at approximately 45 degree angle or bisect the corner angle.
5. Velocity and spraying distance shall be the optimum for maximum shotcrete adherence and compaction.
6. Apply shotcrete so sags or sloughing do not occur. Where movement of shotcrete has occurred adjacent to a slough-off, the shotcrete in question shall be removed.
7. Do not reuse rebound, sprayed fibers, or overspray.
8. Remove laitance and any foreign material from shotcrete surfaces to receive additional shotcrete layers. Surface preparation after final set shall comply with Article 3.03 B.
9. Do not apply shotcrete on surfaces with standing water or running water.
10. Remove hardened overspray and rebound from adjacent surfaces, including exposed reinforcement.

B. Encasement of Reinforcement including spacer bars, and starter bars wire fabric: Place shotcrete to completely encase reinforcing steel. Encase reinforcement by shooting with sufficient velocity and plasticity so material flows around and behind the reinforcement. Front face of reinforcement shall remain clean during encasement. Place shotcrete to provide the cover over reinforcement required by ACI 301.

FINISHING

A. Shotcrete: Spray finish. Shotcrete: Natural curing is permitted.

HOT WEATHER SHOTCRETING

A. Do not place shotcrete when shotcrete material temperature is above 32.2 degrees celsius for wet mix; 37.8 degrees celsius for dry mix. Lower temperature of reinforcement and receiving surfaces below 37.8 degrees celsius prior to placing shotcrete.

COLD WEATHER SHOTCRETING

A. Placing shotcrete may proceed when ambient temperature is 4.4 degrees celsius and rising Placing shotcrete shall discontinue when ambient temperature is 4.4 degrees celcius and falling unless protective measures are taken to protect shotcrete. Shotcrete material temperature, when placed, shall not be less than 10 degrees celsius. Shotcrete shall not be placed against frozen surfaces. Applicable procedures used for cold weather concreting may be used for cold weather shotcreting. Protection against frost shall be maintained until the shotcrete has developed a compressive strength of 13.8 MPa

PROTECTION

A. Protect surfaces not intended for shotcrete placement from deposit of rebound and overspray or impact from nozzle stream.
B. Remove rebound and hardened overspray from final shotcrete surfaces and from areas not intended for shotcrete placement.

6-6.04 PART 4 - PAYMENT

Full compensation for shotcrete of tunnel initial lining shall be considered as included in the contract prices paid per meter for tunnel excavation and support of categories and locations as listed in the Engineer's Estimate and no separate payment will be made therefore.

SECTION 6-7. MEMBRANE WATERPROOFING

6-7.01 PART 1 - GENERAL

DESCRIPTION

This section specifies furnishing and installing the permanent waterproofing system for the tunnels. The waterproofing system is installed between initial shotcrete and the final lining and between the excavation support and the structural walls.

REFERENCE STANDARDS

American Society for Testing and Materials (ASTM)

A. ASTM D638 Standard Test Method for Tensile Properties of Plastics
B. ASTM D1593 Standard Specification for Nonrigid Vinyl Chloride Plastic Film and Sheeting
C. ASTM D1621
D. ASTM D1777 Standard Test Method for Thickness of Textile Materials
E. ASTM D1785
F. ASTM D3776 Standard Test Methods for Mass Per Unit Area (Weight) of Fabric
G. ASTM D3786 Standard Test Method for Hydraulic Bursting Strength of Textile Fabric-Diaphragm Bursting Strength Tester Method
H. ASTM D4533 Standard Test Method of Trapezoid Tearing Strength of Geotextiles
I. ASTM D4632 Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
J. ASTM D4716 Test Method for Determining the (In-plane) Flow Rate per Unit Width and Hydraulic Transmissivity of a Geosynthetic Using a Constant Head

DEFINITIONS

A. Waterproofing: Layered system consisting of synthetic membrane, geotextile or geodrain, and protective layers to prevent intrusion of groundwater into the interior of the finished structures.
B. Geotextile: Non-woven fabric providing groundwater drainage channel and protection of the synthetic membrane from sharp projections of the shotcrete surface or the excavation support to which the membrane is applied.
C. Geodrain: Composite panel providing a groundwater channel and protection of the synthetic membrane from sharp projections on the surface to which membrane is applied.
D. Membrane: Synthetic waterproofing membrane specifically formulated for sealing underground structures against intruding groundwater.
E. Double Weld: Machine welded seams achieved by use of automatic hot-double-wedge welding equipment.
F. Single Weld: Hand welded seam consisting of a tack weld, a thin continuous weld and a rolled end weld. Single seams are sealed with liquid PVC at membrane welds.
G. Membrane Protection Layer. A 1.5 mm thick PVC membrane layer specifically designed to be attached to and completely cover the membrane to protect it from damage during reinforcement installation, formwork, backfilling (used in conjunction with protective boards), and other construction activities detrimental to the integrity of the membrane.
H. Protective Boards: Rigid material, for example plywood or Styrofoam, used in conjunction with a membrane protection layer to protect the membrane from damage during backfilling and other construction activities detrimental to the integrity of the membrane.
I. BA Anchor. Rigid PVC shell with an inside thread and PVC membrane flange used to aid in creating watertight penetrations through the membrane for temporary steel rod attachment.

PERFORMANCE REQUIREMENTS

No water leakage shall be acceptable and the membrane shall be watertight.

SUBMITTALS

A. Submit for approval prior to the start of waterproofing installation:

    1. Resume of waterproofing installation supervisor.
    2. Product Data and Catalogue Cuts:

        a) Geotextile
        b) Geodrain
        c) Membrane
        d) Membrane protection layer
        e) BA Anchor

B. Working drawings shall be submitted a minimum 60 days prior to the start of membrane waterproofing work for review. Do not proceed with waterproofing installation without approved working drawings. Submit plans, sections and details of the following:

1. Sequence of waterproofing installation relative to construction sequence.
2. Sheet layout of membrane splice locations and types of welds.
3. Layout of temporary construction drainage in tunnels in connection with temporary sumps and intended procedures for maintenance during construction.
4. Details of:

    a) Waterproofing terminations at the transition tunnels.
    b) Waterproofing at penetrations including but not limited to electrical ducts, mechanical pipes, and sleeves.
    c) Waterproofing at corners.
    d) Rebar support at reinforced tunnel sections.
    e) Attachment assembly.

C. Waterproofing protection plan and narrative and details describing the intended procedures to prevent damage during construction operations such as installation of formwork, reinforcement and embedded items, placement of concrete, application of shotcrete, backfilling, and grading.

D. Manufacturer's Recommendations and Procedures for:

1. Storage
2. Handling
3. Welding
4. Attachment
5. Smooth surfaces
6. Testing
7. Installation equipment
8. Detection of physical damage
9. Methods of local repair

E. Installer certification showing that the installer is approved for the installation work by the system supplier.
F. Material and Safety Data Sheets for all products and materials of membrane waterproofing system.
G. Certification of compliance with the requirements of this specification for geotextiles, geodrain, and membrane.
H. Material Samples:

1. Geotextile: 500 by 500 mm sample
2. Geodrain:. 500 by 500 mm sample
3. Membrane: 500 by 500 mm sample including double welded seam 500 mm long.
4. Membrane protection layer: One 250 by 500 mm attached to membrane.
6. Attachment assembly: Three each.
7. Silicone paste: Two four ounces jars.
8. Circumferential metal clamp: One each.
9. BA Anchor: One each (including threaded rod).
10. Remedial grout: Two four ounces jars.

I. Field Samples:

1. Double weld samples, one m long, from each double wedge welding machine, prior to the start of daily shift, two per work week.
2. Prepare and submit field samples daily prior to seam welding.

J. Reports and Records:

1. Surface Acceptance Form and Waterproofing Installation Acceptance Form
2. Completed and signed Surface Acceptance Form prior to start of installation.
3. Waterproofing Installation Acceptance Form immediately after completion of an installation testing area.
4. Reports of tests, repairs and retests

L. Leak Remediation Plan:

1. Submit leak remediation plan with product data and catalogue cuts.
2. Leak rernediation plan shall include, but not be limited to, for repair work outside.

QUALITY ASSURANCE

A. Products:

1. Supply and install only products specifically designed and manufactured for this type of construction.
2. Select manufacturers who are regularly engaged in the production of similar materials for underground structures.

B. Supervision and Training of Personnel:

1. Have a representative of the waterproofing membrane manufacturer present at the site to provide installation and testing instructions to the contractor's personnel during the time the first 10% of the total membrane lining work is being installed. The manufacturer's representative also should provide training to the Contractor's personnel prior to beginning installation. This training is only required if the Contractor intends to do the installation work with his own crew; it will not be necessary if the work is to be done by specialty subcontractor with trained crew and experience with this type of work.
2. Execute all installation and testing under the direct supervision of an individual with minimum five years experience in the installation of waterproofing systems for underground structures using membrane materials as specified.
3. Provide trained personnel for installation and testing operations. The installer must have a minimum of five years of experience in the installation of flexible membranes in underground waterproofing installations. The proficiency of each welder shall be demonstrated in the field for approval by the Engineer.

JOB CONDITIONS

A. Install waterproofing at shotcrete and support of excavation surfaces only after the surface is in compliance with smoothness criteria shown on the Contract Drawings and has been accepted by the waterproofing installer and the Engineer in writing.
B. Provide sufficient access to allow for thorough inspection.
C. Prior to waterproofing installation, prove the absence of any continuing and significant deflection or increase of stress.
D. Provide temporary construction drainage for water collection and discharge during waterproofing installation.
E. Prior to geotextile installation, place a four foot wide strip of geodrain at low point of invert to allow water seepage through shotcrete, surface water and construction water to drain to pump sump.
F. Collect all seepage through shotcrete with geodrain of required width and connect to geodrain placed in invert.
G. Prior to installation of waterproofing, install drainage system consisting of perforated pipe and drainage material at toe of open cut excavation support.

WARRANTY

The Contractor shall provide a warranty for the water tightness of the structure up to one year beyond the final contract completion date.

CONTRACTOR QUALITY CONTROL

A. Readiness Review Meeting

1. Before installation of waterproofing and associated work, meet at project site with installer, membrane manufacturer, installers of related work, and other entities concerned with waterproofing installation performance, including, where applicable, test agencies, governing authorities, and the Engineer.
2. Record discussions and agreements and furnish copy to each participant.
3. Readiness Review Meeting will be scheduled by the Engineer or as otherwise directed by the Engineer.

6-7.02 PART 2 - PRODUCTS

GENERAL

A. Geotextile: Non-woven polypropylene geotextile of uniform thickness and surface texture with the following minimum physical properties and testing methods:

Physical Properties	Values	Test Method
Thickness	7 mm	ASTM D1777
Unit Weight	7.3N/sm.	ASTM D3776
Grab Tensile Strength	1.27kN	ASTM D4632
Elongation	85 percent	ASTM D4632
Trapezoid Tear Strength	61kgf.	ASTM D4533
Burst Strength	2.76mPai	ASTM D3786
Chemical Resistance	pH-value 2 to 13	

B. Geodrain: Composite panel consisting of a rigid drain core and filter fabric bonded on one side with the following minimum physical properties and testing methods:

1. Fabric

Physical Properties	Values	Test Method
Unit Weight	0.136kgf/sm	ASTM D3776
Grab Tensile Strength	50kgf.	ASTM D4632
Elongation	60 percent	ASTM D4632
Trapezoid Tear Strength	22.7kgf.	ASTM D4533
Burst Strength	1480kPa	ASTM D3786

2. Core Properties

Physical Properties	Values	Test Method
Thickness	11mmh	ASTM D1777
Compressive Strength	0.72MPa	ASTM D1621
Flow Capacity	186lpm/ft.	ASTM D4716

C. Membrane: Polyvinyl chloride (PVC), waterproofing membrane or approved equal, of uniform thickness and surface texture. PVC membrane non-reinforced with the following minimum physical properties under respective testing methods:

Physical Properties	Values	Test Method
Thickness	2 mm	ASTM D374
Ultimate Tensile Strength	15 MPa	ASTM D638
Ultimate Elongation	230 percent	ASTM D638
Low Temperature Impact	Pass@-29degreesC	ASTM D1593
Chemical Resistance	pH-value 2 to 13	
Flammability	Self extinguishing	ASTM D568

D. Attachments: Membrane attachment disk manufactured of membrane compatible material with minimum 75mm diameter with one steel washer embedded in disk. Attachment of disks with min. 32mm nails.

E. Membrane Protection Layer: 1.5mm thick physical protection membrane, PVC REPRO PRODUCT #1842 as manufactured by HPG International or approved equal, or C-Drain 15K manufactured by Contech.

F. BA Anchor:

1. Rigid PVC shell with inside thread and 300mm diameter compatible flange for attachment to waterproofing membrane. Rigid PVC shell minimum 200 mm long with outside grooves and 16 mm diameter inside thread for application of threaded steel rod.
2. Epoxy resin to grout PVC shell and flange in place prior to attachment to membrane.

DELIVERY, STORAGE, AND HANDLING

A. Deliver materials and products in labeled packages. Store and handle in strict compliance with manufacturer's instructions, recommendations, and material safety data sheets. Place material on smooth surface free of rocks or other protrusions which may damage the material. Protect from damage from sunlight, weather, excessive temperatures, and construction operations. Remove damaged material from the site and dispose of in accordance with applicable regulations.

B. Store all flammable materials in a cool, dry area distant from sparks and open flames.

6-7.03 PART 3 - EXECUTION

PREPARATION OF SURFACE

A. General:

1. Prepare surface according to the criteria specified herein and shown in the Contract Drawings.
2. All surfaces shall be free of oils, grease, and gasoline.

B. At Shotcrete:

1. Remove all loose shotcrete, and debris.
2. Cut off and patch all projecting portions of dowels, flush with the face of the shotcrete surface and remove temporary supports and hangers installed in shotcrete lining for construction purposes. Any protrusions shall be covered with shotcrete, quick setting grout, or mortar such that no sharp edges are observed.
3. Ensure that all embedded elements of the shotcrete lining are covered by at least 25 mm of fiber-free shotcrete prior to installing geotextile and membrane.
4. Steel fiber reinforced concrete to be covered with plain shotcrete with a minimum thickness of 25 mm prior to waterproofing installation.
5. For overall smoothness of shotcrete surface apply General Smoothness Criteria as defined in Specification Section 6-4 Shotcrete Tunnel Initial Lining and as shown in the Contract Drawings.
6. Repair damaged or spalled surfaces, voids, and cracks having depths greater than 12 mm with shotcrete, quick setting grout, mortar, or equal.

C. Inspection and Testing

1. Surface Inspection and Acceptance:

a) Inspect all surfaces to which waterproofing will be applied to, in the presence of the waterproofing installer's quality control representative and the Engineer, prior to waterproofing installation for compliance with the surface preparation criteria specified.
b) Do not install any element of the waterproofing system until all deficiencies have been corrected. Re-inspect area after corrective action has been taken.
c) Do not install waterproofing outside an approved area.
d) Use approved Surface Acceptance Forms to release an area for waterproofing installation. Obtain the waterproofing installer's quality control representative and the Engineer's signature on the Surface Acceptance Form.
e) Distribute signed Surface Acceptance Forms with the Inspector Daily Reports in compliance with Specification Section 01452M, Contractor Construction Control Requirements.

INSTALLATION OF WATERPROOFING

A. Installation Inspection: During installation of any element of the waterproofing system inspect the following:

1. Use of specified materials.
2. Proper storing and handling of material.
3. Ambient temperature.
4. Installer qualifications.
5. Seam direction and layout as per contractor shop drawings.
6. Verify number of attachments.
7. Proper overlap of membrane at seams for welding.
8. Application of welds as specified.
9. Installation of corner patches.
10. Execution of penetrations and other details as per shop drawings or Contract Drawings.
11. Installation of protective layer at locations where permanent lining construction joints will be located.

B. Installation of Geotextile, Geodrain, and Membrane:

1. Attachment:

   a) Place attachment assemblies in surface depressions to achieve tight fit of geotextile.
   b) Provide attachments at maximum 750 mm centers horizontally and vertically, except on overhead areas, where attachments should be used as required.
   c) Provide additional attachment where necessary to achieve secure support and tight fit to shotcrete lining in tunnel and to excavation support.

2. Geotextile and Geodrain

   a) Place geotextile prior to the installation of waterproofing membrane in mined structures.
   b) Place continuous four foot wide panels of geodrain at the following locations in the tunnel:

      1) At tunnel cross passages, where shown in plans, in invert to allow seepage water, surface water, and construction water to drain to side drains after membrane is in place.

3. Membrane:

   a) Install membrane with sufficient overlap for welding. Trim overlap if necessary to achieve tight fit.
   b) Use circumferential seams in all typical tunnel cross sections unless otherwise directed.
   c) Use longitudinal seams in tunnel arch-sidewalls splice where required.
   d) Provide double wedge welded seams unless otherwise approved.

e) Test all welds as specified.

TESTING OF MEMBRANE WELDS

A. General:

1. Perform tests in the presence of the Engineer.
2. Perform tests as installation progresses. Repair and retest seams that fail before continuing installation.
3. The Contractor shall maintain and distribute to the Engineer written records of test results, repairs, and retesting every time an installation section is completed.

B. Double Welds: Perform test by applying internal air pressure between seams as follows:

1. Test Pressure: 200 kPa.
2. Performance requirements: Air pressure loss shall be less than 10 percent after 10 minutes.

C. Single Welds:

1. Including heat welding at water barriers or special fittings.
2. Check all welds for continuity by either of the following inspection methods. Single welds at membrane splices or patches to be tested prior to the application of liquid PVC:

   a) Run a rounded screwdriver along the joint after the weld has cooled.
   b) Blow stream of air under high pressure against the weld and observe opening of the weld. Re-weld and test any discontinuity.

D. Replace or repair sections of the membrane determined to be defective at no additional cost to the Owner.
E. Use approved Waterproofing Installation Acceptance form and Surface Acceptance form to release an area for waterproofing installation. Obtain the waterproofing installer's quality control representative, and the Engineer's signature on the Waterproofing Installation Acceptance Form.
F Distribute signed Waterproofing Installation Acceptance Forms with the Inspector Daily Reports in compliance with Specification Section 01452M.

PROTECTION OF WATERPROOFING

A. Place membrane protection as soon as possible and prior to any work which might damage the membrane.
B. Protect waterproofing after completion of waterproofing installation.
D. Where reinforcement is placed, use protective sheet and other approved methods to achieve required spacing between membrane and rebar.
E. Check integrity of waterproofing during installation of rebar, formwork, and during pouring concrete.
F. Check for and relieve, if necessary, water build-up behind membrane with established methods prior to concrete pours.

G. Do not allow penetration of waterproofing for any other than permanent purposes with approved methods or temporary purposes authorized by the Engineer.
H. Do not allow construction debris or equipment to accumulate on the waterproofing membrane.

6-7.04 PART 4 - MEASUREMENT AND PAYMENT

The contract price paid per square meter for tunnel waterproofing shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in tunnel waterproofing, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

SECTION 6-8. BLASTING

6-8.01 PART 1 – GENERAL

APPLICATION

This section covers the use of explosives in drill-and-blast operations to excavate portions of the proposed tunnels at the Devil's Slide project.

The work covered in this section includes blast design, blast limitations, and providing all materials, equipment, labor and supervision for the transportation and storage of explosives, drilling and loading of blast holes, protection of existing facilities, test blasts, post-blast inspections and damage repairs.

REFERENCES

A. Code of Federal Regulations (CFR)

1. U.S. Department of Labor, Occupational Safety and Health Administration (OSHA), Construction Standards and Interpretation, 29 CFR Part 1926

B. California Code of Regulations (CCR)

1. Title 8, Chapter 4, Subchapter 20, Tunnel Safety Orders
2. Title 8, General Industry Safety Orders, Subchapter 7, Group 18. Explosives and Pyrotechnics

C. Bureau of Alcohol Tobacco and Firearms (BATF)

1. Title XI, Regulation of Explosives (18 U.S.C. Chapter 40; 84 Statute 952), of the Organized Crime Control Act of 1970 (84 Statute 922) and 27 CFR 55.

D. Department Of Transportation (DOT)

1. Title 49 (49 CFR), Parts 106, 107, 171-179, 383 and 390-399

E. United States Bureau of Mines (USBM)

1. Report of Investigation 18507

DEFINITIONS

Smooth-wall Blasting.-- Sometimes referred to as trim or contour blasting. A form of controlled blasting used in tunnel, shaft, trench and other surface blasting excavations. With this method, lightly loaded charges are placed in relatively close-spaced holes and fired on subsequent delays to remove the final berm of rock between the trim holes drilled at the excavation limits and adjacent blast holes. By shooting with minimum delay between the holes, a shearing action is obtained which gives smoooth walls with minimum overbreak. This technique requires free relief of the perimeter and may require advance excavation of the production area to provide that relief.

Peak Particle Velocity (ppv).-- The maximum of any one of the three ground vibration velocities measured in the vertical, longitudinal and transverse directions. Velocity units are expressed in inches per second (ips).

Air blast (overpressure).-- The increase in ambient air pressure caused by blasting. Air blast is expressed in units of psi or decibel, dBL.

Scaled Distance.-- The distance from a blast measured in meters, divided by the square root of the charge per delay period measured in kilograms. These “square root” scaled distance values are used in calculations regarding ground vibration prediction and control. For air blast calculations, cube root scaling is used whereby distance is divided by the cube root of the maximum charge per delay.

Line Drilling.-- A method of controlling overbreak, in which a series of very closely spaced holes are drilled at the perimeter of the excavation. Line holes are generally not loaded with explosives; however, in some applications alternating holes may be loaded with light charges using detonating cord.

Pre-splitting.-- A blasting technique in which the perimeter charges are detonated first in the firing sequence or as a separate blast ahead of production blasting. This technique is designed to generate a fracture in the plane of the pre-split holes drilled along the perimeter of the excavation.

Production Holes.--Blast holes in the main body of the rock mass being removed by drilling and blasting.

Stemming.-- Crushed stone, tamped clay or some other inert earth material placed in the unloaded collar area of blast holes for the purpose of confining explosive charges and limiting rock movement and air blast.

Maximum Charge Weight per Delay.-- For purposes of vibration control, any charges firing within any 8 millisecond time period are considered to have a cumulative effect on vibration and air blast effects. Therefore, the maximum charge per delay equals the sum of the weight of all charges firing within any 8-millisecond time period. For instance, if two 4.5 kgm charges fire at 100 ms and one 6.75 kgm charge fires at 105 ms, the maximum charge per delay would be 15.88 kgm

Buffer Holes.--Holes with reduced energy charges drilled adjacent to smoothwall, trim or open line-drilled holes at the perimeter of the excavation. The explosive charge in buffer holes is generally between 50 and 75% of the charge used in normal production blast holes. Buffer holes are usually drilled parallel to adjacent holes at the excavation perimeter.

Primary Initiation.-- The method whereby the blaster initiates the blast(s) from a remote and safe location. Primary initiation systems use pneumatic tubing or shock-tubes to convey firing energy from blasters to blast locations.

Sub-drilling.-- The portion of a blast hole that is drilled below or beyond the desired excavation depth or limit. Subdrilling is generally required to prevent the occurrence of high or tight areas of unfractured rock between blast holes.

Controlled Blasting.-- Controlled blasting is a term that describes all techniques to reduce vibration, rock movement, air overpressure and damage to unfragmented rock.

SYSTEM DESIGN

A. Design Criteria

1. The firing systems for the general blast holes shall be controlled by the use of delay detonators. Explosives used for a single period of delay shall be the minimum required.
2. Blast designs shall include measures that prevent all forms of misfires and ensure the complete detonation of all explosives. Two independent detonator-primer assemblies shall be used to initiate all charges with lengths exceeding 6 meters. If any products or methods are causing excessive cutoffs or other forms of misfires, the Engineer can require the Contractor to suspend the use of problematic products or methods. All associated costs of redesigned blasts or delays caused by this action will be at the Contractor's expense.
3. Underground Blasting (including tunnels, enlarged tunnels, chambers, cross passages, niches).

    a) Excavation to final rock surfaces shall be carried out using smooth-wall blasting techniques to minimize the damage to the finished rock surface.
    b) The perimeter holes for smooth wall blasting shall conform to the following requirements:

        1) Hole spacing shall not exceed 460mm unless a variance is approved by the Engineer. Justification to increase hole spacing shall be based on results from the test blasts.
        2) Explosives shall be distributed evenly and de-coupled from wall of hole. The maximum charge weight per unit length of hole (loading factor) shall be limited to less than or equal to one half the loading factor of production hole charges.
        3) Burden: Between 1.2 and 1.4 times the hole spacing.
        4) Lookout of perimeter holes: Lookout shall be limited to the minimum necessary to collar the next round.

    c) The maximum drill round lengths in the tunnel shall be such that the excavated depth does not exceed the advance distances given in the construction plans of the tunnels. The Engineer may shorten this length if, in his opinion, the integrity of the excavation is threatened.

B Performance Requirements

1. The Contractor is responsible for acquiring and complying to all codes, regulations, ordinances and requirements of the Sate of California.
2. The peak particle velocity induced by blasting shall not exceed 50 mm per sec near any private off-site structures. The peak particle velocity induced by blasting during the excavation of the tunnels shall be measured by approved seismographic instruments.

3. The peak particle velocity induced in fresh shotcrete or concrete by blasting shall not exceed the following limits for concrete at the various ages specified below:

Concrete Age (From The Time of Batching)	Maximum Peak Particle Velocities in./sec (mm/sec)
up to 24 hours	0.50 (13)
from more than 24 hours to 3 days	1.00 (25)
from more than 3 days to 7 days	2.00 (50)
from more than 7 days to 10 days	5.00 (127)

These limitations may be increased if the Contractor can demonstrate that larger magnitudes of velocity will not damage the shotcrete such that support capacity is reduced.

SUBMITTALS

A. General

1. Refer to S Standard Specifications for submittal procedures.
2. Unless otherwise indicated, make required submittals at least 30 days prior to conducting any blasting operations, and before any explosives, blasting agents, primers, or initiators are delivered to the job site.

B. Working Drawings

1. Blasting safety plan: A blasting safety plans shall be prepared for the tunnels.. Plans simply stating that “all regulations will be followed” shall not be acceptable. Plans shall include:

   a) A complete description of the clearing and guarding procedures that will be employed to ensure personnel, staff, visitors, and all other persons are at safe locations during blasting. This information will include details regarding visible warning signs or flags, audible warning signals, method of determining blast area zones, access blocking methods, guard placement and guard release procedures, primary initiation method, and the system by which the blaster-in-charge will communicate with site security guards.
   b) Detailed description of how explosives will be safely stored, transported and used at the various project work sites. Plans will explain how storage magazines and explosive transport vehicles will satisfy all applicable BATF, Cal/OSHA, Federal, and County of San Mateo regulations. This plan will also indicate how explosives will be inventoried, secured, and guarded to prevent theft or unauthorized use of explosives.
   c) Include Material Safety Data Sheets (MSDS) and specific details about hazard communication programs for employees.
   d) Equipment that will be used to monitor the approach of lightning storms and in the event of such, evacuation and site security plans.
   e) Contingency plans for handling of misfires caused by cutoffs or other causes.
   f) Fire prevention plan details, including, smoking policies, procedures and limitations for work involving any open flames or sparks, description and location of all fire fighting equipment, and fire fighting and evacuation plans.
   g) Initial and ongoing blasting and fire safety training programs.

h) Description of the personal protective equipment that will be used by Contractor's personnel, including but not limited to safety glasses, hard-toe footwear, hard hats, gloves.
i) Description of blast monitoring equipment and listing of individuals that will operate such equipment. Submittal shall indicate that all equipment meets the standards defined in Article 2.02 of these specifications.

2. Obtain copies of all applicable codes, regulations, and ordinances, keep a copy in project files at all times, and provide the Engineer with a copy.
3. Copies of any required Cal/OSHA variances.
4. Submit a series of general blasting plans to the Engineer not less than 20 days prior to commencing test blasting, or at any time the Contractor proposes to change the drilling and blasting methods. A blasting plan shall be prepared for the Tunnels, including all parts of the tunnels requiring blasting in the Contractor's opinion. Review of the blasting plan by the Engineer shall not relieve the Contractor of his responsibility for the accuracy and adequacy of the plan when implemented in the field. Blasting plans shall include:

   a) Details of controlled blasting techniques. Include plan and vertical section drawings showing hole locations, spacing, diameter and loading details for typical blast holes, buffer holes and smooth-wall or perimeter trim holes. Controlled blasting plans and drawings should specifically cover all types of excavations including tunnel rounds, and breakthrough rounds or blasts.
   b) All blast plan drawings shall indicate explosive types, amounts, priming method, initiator types, delay periods, and locations, charge firing times, stemming type and quantities, and charge weights.
   c) Plans for coordinating blasting with blast monitoring. Include drawings showing locations of blast monitoring equipment for each blast.
   d) Methods of drilling, including equipment descriptions, hole alignment techniques and measures that will be used to prevent excessive blast hole deviation.
   e) Hole Charging Methods: Primer make-up, placement of charges and inert stemming and method of securing detonators until tie-in.
   f) Initiation system hook-up methods and method of primary initiation.
   g) Methods for preventing spills or losses of explosives, drilling fluids, oil, or any other pollutants to ground or lake water during all handling and hole charging operations. Include details of all containment and contingency plans for quickly and effectively cleaning up any spilled materials.
   h) Methods of safe and approved disposal of all explosive packaging materials.

5. Individual blast plans shall be submitted for each blast at least 24 hours prior to drilling any blast holes. No loading of explosives will be permitted until the individual blast plan has been approved by the Engineer. Individual blast plans shall include the following information:

   a) Scaled plan-view and cross-section drawings showing the location, orientation, number, diameter, and length of blast holes relative to specified stations, slopes and elevations.
   b) The amount, type, diameter, weight and linear loading density of explosives in all blast holes.

c) Maximum weight of explosive per hole or decked charge, total weight of explosives used, maximum charge weight per delay and powder factor.
d) Drawings or plan text shall clearly show detonator types, delays, quantities and charge firing times.
e) The proposed date and time of the blast.
f) Proposed location(s) of seismographs and/or instruments for monitoring, sound level, strain or other parameters.
g) The Contractor shall also submit other information as directed by the Engineer such as measures to control fly rock, vibration, or other blast effects.

6. An emergency response plan indicating types of explosive materials, storage locations and quantities shall be submitted to and approved by the Engineer. Upon approval by the Engineer, the emergency response plan shall be submitted to and approved by the local emergency response agency before explosives are allowed on site.

C. Product Data

1. Manufacturer's product information sheets and Material Safety Data Sheets (MSDS) for all explosives, blasting agents, primers and initiator products, blasting devices, lightning detectors, blasting mats, and all other blasting equipment.

D. Quality Control Submittals

1. A detailed description of the education, training, and experience of all proposed persons that will be immediately in charge of drilling and blasting operations. Separate qualifications shall be submitted for each supervising blaster-in-charge.. The Contractors' submittal shall include names, addresses and telephone numbers of persons who can verify such prior successful experience. Copies of valid California blasting licenses shall also be submitted for all blasting supervisors. Blasting licenses shall indicate the class of license held by proposed blasting supervisors, i.e. surface, underground, non-electric systems, etc.
2. The name and qualifications of a recognized blasting consultant(s) whom they plan to retain to facilitate the development or review of all blasting designs and blast-effect control measures. The qualifications of the blasting consultant(s) shall meet the requirements of these specifications. All blasting plans, test-blasting plans, and revisions to any of these plans shall be reviewed by and covered with a signed review letter by the blasting consultant(s). The blasting consultant shall not be required to sign the individual blast plans provided they are signed by an on-site licensed blaster.
3. After each blast, the results from the blast monitoring, including any misfires, shall be submitted to the Engineer prior to loading any subsequent blast holes.

SCHEDULING AND SEQUENCING

Schedule blasting operations to minimize disturbance of the public. Prior to blasting satisfy all schedule and sequence criteria of Sections 02303, 02304, 02305, 02306, 02400, and 02815.

QUALITY ASSURANCE

A. Qualifications

1. The blasting supervisors (blasters-in-charge) shall have a minimum of 10 years of experience, directly related to the specific types of excavation blasting they will oversee. All blasting supervisors shall be able to document the completion of at least three projects of similar scope and complexity.
2. All blasters and supervising shift foremen shall be properly qualified and licensed in accordance with applicable federal, state, and local government regulations.
3. Retain the services of an experienced blasting consultant with at least 10 years of experience in monitoring blasting operations (test blasts and production blasts) and interpreting ground vibration, air overpressure, peak water pressure and impulse amplitudes for similar construction projects.
4. Retain the services of an experienced blasting consultant(s) with at least 10 years of experience in preparing controlled blasting designs.

B. Monitor each blast using approved personnel and equipment conforming to the requirements outlined in Article 6-8.02 as follows:

1. Seismographs to measure ground motion and instruments capable of measuring air overpressure:

   a). In addition to the three required seismographs, an additional seismograph to measure ground motion and overpressure meeting requirements of subparagraph 2.02A.5 shall be provided for the Engineer.

DELIVERY, STORAGE AND HANDLING

Comply with federal, state, and local regulations, including Riverside County noise ordinances, applying to the purchase, transportation, storage, handling, and use of explosives, blasting agents, primers, initiators, and ancillary equipment and materials.

A. Transportation

1. When the amount of transported explosives exceeds 1,000 pounds, the delivering company shall possess a valid hazardous materials transportation license, endorsed for explosives, issued by the California Highway Patrol (CCR, Title 13).
2. Where explosives are transported on public roads, the carriage shall be in accordance with 49 CFR.
3. If explosives are to be transported in interstate or foreign commerce, a license or users permit shall be secured from the BATF (27 CFR 55).
4. All onsite transportation of explosives shall conform to the most stringent requirements of CCR, Title 8.

B. On Site Storage

1. The location, access, and construction of explosive storage magazines and day-use magazines shall meet all requirements outlined in Title 8, General Industry Safety Orders, Subchapter 7, Group 18 and be in accordance with 27 CFR and all other applicable regulations.

2. All second class magazines used for day storage shall be located at least 145 meters from active work areas as required by CCR Title 8, Article 114, Storage of Explosives
3. Maintain inventory control of all blasting equipment and supplies. Copies of inventory logs shall be kept as required by CCR Title 8 and be made available for review at the request of the Engineer.
4. Storage places shall be identified with signs stating clearly and boldly, DANGEROUS EXPLOSIVES. Signs shall be attached to poles in plain sight. Signs must not be attached directly to magazines. Signs shall also include the warning "Never Fight Explosive Fires."

The aforementioned review of specific regulations shall not relieve the Contractor from his/her responsibility of knowing about and complying with all applicable regulations.

C. Explosive Losses to Ground or Water

Use great care to ensure that all possible measures are used to prevent explosive losses to ground by spillage, misfires or any other cause. If poor handling practices or blasting malfunctions cause excessive losses of explosives based on the Engineer's judgment all blasting in affected excavations shall cease until the Contractor submits a new explosive loss prevention plan that is approved by the Engineer.

WORKSITE CONDITIONS

This Statement of Concern is expressly written to alert the Contractor (or prospective bidders) to the fact that ordinary practices that are customarily considered as standard for the blasting industry will not be acceptable on this project. Extra caution and skills will be required to accomplish this work in a satisfactory manner. Blasting shall be safely done in proximity to existing tunnel support as the tunnels are excavated, and open cut rock slopes. Because of these concerns, the Engineer will exercise his prerogative to examine carefully the qualifications of any persons whose knowledge and skills may bear on the outcome of the work. In addition, the Engineer will reject any persons who are deemed unqualified for any tasks that may be required.

6-8.02 PART 2 - PRODUCTS

EXPLOSIVE MATERIALS

Only fully non-electric blasting systems shall be used. Cap and fuse method shall not be used. All explosives used shall be water-resistant and explosives used in underground excavations shall have a fume class rating of 1 (produce less than 0.16 ft3 of toxic fumes per 200 g). Do not use ANFO or other flowable explosives for blasting in the tunnel.

Only explosives designed and manufactured for smooth-wall (trim) blasting shall be used in perimeter holes for blasting in the tunnel excavations. Such products include detonating cord as well as cartridge configurations. Loading density of charges in perimeter holes shall not exceed 0.4 kgm per lineal meter unless approved by the Engineer.

Explosives, blasting agents, primers, initiators, and ancillary blasting materials shall be kept in original packaging with clearly marked date codes. All explosives and initiating devices used shall be less than one year old.

If the Engineer determines that a blasting product appears to be in a damaged or deteriorated condition, the suspect product shall not be used until its condition can be determined. Products

found to be damaged or in a deteriorated condition shall be immediately returned to the supplier for safe disposal.

BLAST MONITORING EQUIPMENT

Equipment for on-site and off-site particle velocity and air overpressure monitoring shall be 4-channel (1 overpressure and 3 seismic channels) units capable of digitally storing collected data. Equipment must be capable of printing ground motion time histories and summaries of peak motion intensities, frequencies and USBM RI8507 ppv frequency plots. Printed report records must also include date, time of recording, operator name, instrument-number and date of last calibration.

1. Instruments shall have a flat frequency response between 2 and 250 Hz for particle velocity and from 2 to 200 Hz for air overpressure.
2. The digitizing sampling rate for peak particle velocity and air overpressure measurements shall be least 1,024 samples per second.
3. Seismographs shall be capable of performing a self-test of velocity transducers and printed event records shall indicate whether or not the sensor test was successful.
4. Seismographs used for on-site monitoring shall be self-triggering, and shall be capable of recording overpressure from 88 to 148-dB-L, and particle velocity from 0.005 to 10.0 in/sec.
5. Systems shall be capable of providing printed event reports that include all peak measurements, frequencies and complete waveform plots.
6. Seismographs shall have adequate memory to digitally record the entire duration of the blast-induced motion.
7. All seismograph/software systems shall be capable of saving back-up copies of all event files on floppy or Zip disks.

6-8.03 PART 3 - EXECUTION

GENERAL

Monitoring and recording of all blast effects, as required by these specifications, shall be performed by the Contractor. The Contractor shall monitor each blast at specified locations and other locations determined by the Engineer. If the locations are too far away to self -trigger the seismograph, the Contractor shall manually start the seismograph to ensure that recordings are made, when requested by the Engineer. Printed reports of all monitoring results including motion and overpressure time-histories shall be submitted to the Engineer before subsequent blasting occurs. The Contractor shall save all digital monitoring record files to at least two separate disk locations of which one location is either an IBM-compatible 3-1/2 inch floppy disk or a Zip disk, or other compatible portable storage device. Upon request, the Contractor shall submit copies of digitally recorded blast monitoring files to the Engineer. The Engineer may or may not perform blast monitoring.

The Contractor’s safety manager shall ensure that ongoing blasting work complies with all applicable regulations.

PREPARATION AND PROTECTION

The following warning systems, procedures and protection devices shall be established prior to blasting.

1. A system of audible signals to warn of impending blasts.
2. Signboards and flags indicating areas where blasting operations are occurring. These signs shall be clearly visible and legible from all points of access to the tunnel area. The signs shall clearly describe the audible signal system for warning of impending blasts. Blast area signs shall clearly indicate the length and nature of audible blast warning and all clear signals. All warning systems shall comply with the most stringent requirements of regulating local, state, and federal agencies.
3. The blaster-in-charge shall determine when to sound the five minute warning signal. Blasting shall be performed only after ensuring that all people and equipment have been removed to a safe location. The Engineer may have a representative with the blaster-in-charge.
4. Blasting shall occur only when a representative of the Engineer is present to witness each blast.
5. A “tag out" procedure to ensure that all persons are out of the blasting area prior to a blast.

A. Flyrock Control

Steel wire rope and/or rubber tire blasting mats shall be placed over faces or breakouts to be blasted as required to protect instrumentation, utilities, personnel, and equipment from flyrock.

BLASTING

Perform blasting operations in a manner to minimize air blast and ground motion near critical on-site structures. If blast-induced air overpressure (air blast) or particle velocity exceeds the performance requirements specified herein suspend blasting in the affected excavation(s) until a re-designed blasting plan is submitted to and approved by the Engineer.

The Contractor may need to employ special measures to meet the specified air blast limits. These measures might include, but are not be limited to, the use of: sound reducing enclosures around work areas, removable shaft covers, clay stemming in horizontal blast holes, extra crushed stone stemming in vertical blast holes, or other measures deemed necessary by the Engineer. Use the following controls to limit air blast (air overpressure) and flyrock as necessary for compliance with the specified air overpressure limits and for protection of both employees and the public.

1. Clean crushed stone ranging in size from 9 to 12 mm shall be used to stem all explosive charges in vertical and down-dipping blast holes. Stemming in all blast holes shall be lightly tamped, while loading, with an approved non-sparking loading pole to ensure that no gaps occur in the stemming column due to bridging.
2. If deemed necessary by the Engineer, additional measures to control air blast and flyrock shall include but not be limited to soil, sand, or blasting mat covers.

Use extreme care to prevent spillage or loss of any explosives, oils or other pollutants to the ground. If any explosives or other pollutants are spilled, immediately clean up the spilled explosives and dispose of them by approved means. Spills of any amount must be reported to the Engineer immediately.

For all surface and underground blasts, the drill holes shall be collared to within 6 inches of the locations shown on the Contractors approved blasting plans.

The centerline of drill holes for all surface and underground blasts shall not deviate more than 5 percent of the vertical depth from the theoretical centerline.

A. Limitations

1. Blasting shall not be permitted when in the opinion of the Engineer it may be detrimental to existing installations. The Engineer's decision will be final.
2. Controlled blasting techniques shall be used to prevent overbreak and minimize rock damage in all underground excavations. Blast patterns shall be designed so that the explosive energy is not directed into the back and sidewalls of the excavation but, instead, towards the developed free face.
3. Whenever, in the opinion of the Engineer, proposed blasting may cause harm to persons, cause damage to structures, or create unacceptable rock instability, cease blasting immediately and review the blast design. The Contractor can resume excavation of the rock with an approved re-designed blast plan or by mechanical means.
4. Explosives shall not be used as a means of transporting material outside the excavation prism or limits of excavation.
5. If the Contractor’s depth and alignment controls for drilling equipment are not sufficiently accurate to produce acceptable blast results, at the Engineer’s discretion, the Contractor may be required to use a drilling template or other applicable control measures necessary to improve drilling accuracy.

B. Misfires and Dangerous Conditions

1. After a blast has been fired, the blaster-in-charge and one assistant under his or her direct supervision shall make a careful inspection of the blast area. The Engineer’s representative may be present for this inspection. Inspections shall determine whether there are any indications that misfires might have occurred or whether the blast created any other imminent dangers like unstable ground conditions. If misfires or other dangerous conditions are found, the blaster-in-charge shall secure the area and properly correct all hazards before any other work is allowed in the affected area. The all clear signal, allowing other work to resume in the area, shall not be given until affected blast sites are clear of all hazards.

SUSPENSION OF BLASTING

Blasting operations may be suspended by the Engineer for any of the following reasons:

1. The Contractor’s safety precautions are inadequate.
2. Air blast, ground motion levels exceed specified limits.
3. Existing structural conditions on and off site are aggravated and are damaged by blasting.
4. Blasting causes instability of slopes or causes damage to rock outside the prescribed limits of excavation.
5. The results of the blasting, in the opinion of the Engineer, are not satisfactory.

Blasting operations shall not resume until the Engineer has approved the Contractor's revised blasting plan with modifications correcting the conditions causing the suspension.

PRE-BLAST/POST-BLAST INSPECTIONS

Prior to blasting, inspections shall be performed on all construction in progress and structures located on site. Inspections shall be performed by qualified specialists approved by the Engineer. Notify the Engineer at least 7 days prior to the inspections so a representative of the Engineer may be present. Inspections shall meet the following conditions:

1. Existing crack damage, other structural problems or defects occurring at the structures shall be thoroughly documented.
2. Close-up detailed photographs will be taken of all cracks, deterioration or cracks observed
3. Minimum size of all color photographic prints shall be 5 inches by 7 inches and based on standard 35 mm negative film format. Digital photography is also acceptable. In lieu of photographs, the Contractor may provide a HI-8 or equivalent quality video of the structures and features noted above.
4. Photographs or HI-8 videos shall include imprints of the survey date.

As construction progresses, re-inspect, as often as necessary or at the intervals prescribed by the Engineer, to verify that controlled blasting methods are not causing any new damage.

DAMAGE REPAIR

When blasting operations damage a portion of the work, or material surrounding or supporting the work, promptly repair or replace damaged items to the condition that existed prior to the damage, to the satisfaction of the Engineer.

Nothing contained herein shall relieve the Contractor of its responsibility for claims arising from its construction operations. Failure to inspect any structure required by these contract documents, or inadequacy of the inspections shall not relieve the Contractor of its responsibility.

6-8.04 PART 4 - MEASUREMENT AND PAYMENT

Full compensation for blasting shall be considered as included in the contract prices paid per meter for various tunnel excavation and support of categories and locations as listed in the Engineer's Estimate and no separate payment will be made therefore.

SECTION 6-9. ROCK DOWELS

6-9.01 PART 1 - GENERAL

DEFINITIONS

Rock Dowel.-- Cement or Resin Grouted: This type of rock dowel is an untensioned rod inserted into a drilled hole and grouted along its entire length using fast-setting cement grout, or fast-setting resin capsules. The rock dowel consists of either deformed billet-steel bar or high yield steel, deformed ribbed bar, with cut or rolled threads at one end, a faceplate, shim plates and nut.

Rock Dowel.-- Expandable Tube Type: This type of rock dowel is manufactured from a mechanically reshaped steel tube. High-pressure water (30 MPa) is injected into the steel tube after insertion into a drilled hole. This causes the steel tube to expand and to form it to the irregularities in the drilled hole. A 300 mm long sleeve tube made of steel shall prevent the bolt from swelling at the borehole mouth, thus protecting the fresh shotcrete from damage. The water

pressure is released after installation and the water allowed to drain out of the expanded steel tube. The drill hole diameter must be adjusted to suit the size of the tube type rock dowel.

Self Drilling.-- Grouted Bolt: This type of rock dowel is equipped with a sacrificial drill bit, and is made from high tensile steel, hollow rod. These bolts shall be used in very weak ground formations where drill holes are unstable. Couplings are used to increase the length of the bolts where required by the room available in he tunnel for drilling and installation.

Face Bolt.-- Fiberglass or steel rock dowels applied to strengthen excavated tunnel faces where subsequent tunneling work shall be carried out, or to provide temporary support to an excavation face during stoppages. The face bolts are cement or resin grouted dowels without faceplates or nuts. Fiberglass is preferable to steel because of the ease of cutting as excavation proceeds, but steel is permissible if fiberglass is (temporarily) unavailable.

Proof Test.-- Load applied to dowel to be certain it can carry its design load.

Design Load.-- Allowable load capacity after allowance for any time dependent losses.

SYSTEM DESCRIPTION

General.-- The work includes fabrication and installation of the rock dowels. The materials, design capacities, lengths and locations are shown in the plans. Rock dowels may be grouted, solid or hollow bar type, or hydraulically expanded tube type, or self-drilled and grouted type, at the locations shown in the plans. The dowel may be fixed to the rock using fast setting, cement or epoxy grout, or by mechanical means (expanded tube type). The Contractor shall be responsible determining drilling methods, and determining hole diameter. Payment for rock dowels, as specified in Article MEASUREMENT AND PAYMENT, shall include all costs in connection with fabricating, and installing the dowels.

DOWEL DESIGN REQUIREMENTS

Assumed soil or rock to grout bond strength will be verified from testing of the soil or rock in which the dowels are to be installed. The tests will be conducted upon first encountering the different rock types as they occur in the tunnel. Type of grouting material will be determined by site conditions and the tunnel rock type in the section being doweled.

The individual rock dowels shall be designed to meet the following criteria:

A. Dowel Location - as shown in the drawings.
B. Horizontal [and] [Vertical] Spacing - as shown in the drawings.
C. Hole Diameter – as recommended by the manufacturer.
D. Ultimate Load - as shown in the drawings.
E. Assumed Rock-Grout Bond Strength -as shown in the drawings.
F. Minimum Required Bond Length - as shown in the drawings.
G. Angle of Dowel Inclination - as shown in the drawings.
H. Corrosion Protection – Not required.

Dowel locations may be changed in order to avoid fissures and joints at the proposed locations.

The end bearing plate is fixed end position by manual tightening of the nut.

General.-- The work includes fabrication and installation of the rock dowels. The dowels shall be fabricated, and installed as shown on the drawings. The Contractor shall prepare an installation plan for approval by the Engineer. The materials, stressing, load testing, and acceptance shall be in accordance with manufacturer’s recommendations and these specifications. Rock Dowels shall be threaded or deformed bar, or tube type.

SUBMITTALS

Preconstruction Submittals

Fabrication and Installation Drawings:-- The design shall include: drawings and detailed installation procedures and sequences showing complete details of the installation procedure and equipment; dowel fabrication; grouting methods; grout mix designs; dowel placement and installation; testing procedures with lengths, forces, deformations, and elongations for the approval by the Engineer. Shop drawings for dowels. If different types of dowels are to be installed, each dowel type shall be readily identifiable. Once reviewed by the Engineer, no changes or deviation from shop drawings shall be permitted without further review by the Engineer.

Equipment.-- The Contractor shall submit catalog cuts, brochures, or other descriptive literature describing the equipment to be used for drilling, grouting, handling, and installing the rock dowels. Descriptions of stressing jacks, gages, dynamometers, load cells, or other devices for measuring test loads,

Installation Plan (E).-- The Contractor shall submit to the Engineer for review and comment a plan for installing the rock dowels. The proposal shall describe the sequence for installation and other restrictions as outlined on the drawings or specified. The dowel installation procedures shall be determined by the Contractor.

Test Reports

Dowel Steel.-- Certified test reports for each heat or lot of high strength steel shall be submitted with materials delivered to the site.

Cement Grout Mixture Proportions.-- Thirty days prior to installation of dowels, the Contractor shall submit the mixture proportions that will produce grout of the quality required. Applicable test reports shall be submitted to verify that the grout mixture proportions selected will produce grout of the quality specified.

Certificates

Dowel Steel.-- The Contractor shall furnish copies of mill reports and copies of a certificate from the manufacturer stating chemical properties, ultimate strengths, yield strengths, modulus of elasticity, and any other physical properties needed for the required computations, for the type of steel furnished.

Manufacturer's Instructions

A. Polyester Resin Grout
B. Resin Grouted Dowels
C. Expanded Tube Dowels
D. Self Drilled and Grouted Dowels

The Contractor shall submit the manufacturer's written instructions and recommendations for hole diameter, cartridge selection, and bar installation and rotation prior to installing the dowels.

Closeout Submittals

Dowel Records.-- Upon completion of installation of each dowel, the Contractor shall furnish length of dowel, grout mix, grouting pressure, a report of proof test (if tested). The proof test

results shall include measured lengths of drill holes and dowels, the loads recorded during testing, these reports may be added to and made a part of the daily construction activity report.

Qualifications

Dowel designer, fabricator and installer qualifications shall be submitted for approval in accordance with paragraph SUBMITTALS. The submittals shall, where applicable, identify individuals who will be working on this contract and their relevant experience. No changes shall be made in approved personnel without prior approval of the Engineer.

Fabricator Qualifications.-- The Dowels shall be fabricated by a manufacturer that has been in the practice of designing and fabricating rock dowels similar in size and scope to this project for at least ten years.

Installer Qualifications.-- The dowels shall be installed by the Prime Contractor or a Subcontracting firm which is regularly engaged in the installation of rock dowels and has at least ten years experience in the installation of similar dowels. The superintendent shall have installed dowels on at least three projects of similar scope and size.

PREPARATORY MEETING

Prior to commencing any work on the dowels, the Contractor, including all field personnel to be involved in drilling and installation of the dowels, shall meet with representatives of the Engineer to review the plans and specifications, work plans, and submittals. Drilling may commence upon approval of the dowel installation plan and procedures described in paragraph SUBMITTALS and after the conduct of the Preparatory Meeting.

DELIVERY, STORAGE AND HANDLING

Materials shall be suitably wrapped, packaged or covered at the factory or shop to prevent being affected by dirt, water, oil, grease, and rust. Materials shall be protected against abrasion or damage during shipment and handling. Materials stored at the site shall be placed above ground on a well supported platform and covered with plastic or other approved material. Materials shall be protected from adjacent construction operations. Grounding of welding leads to high strength steel shall not be permitted. High strength steel which is damaged by abrasion, cuts, nicks, heavy corrosions, pitting, welds or weld spatter shall be rejected and removed from the site. Bars or tubes shall be inspected prior to insertion into dowel holes for damage. Any such damage shall be repaired in a manner recommended by the dowel manufacturer and approved by the Engineer.

SITE CONDITIONS

A geotechnical investigation has been conducted at the site by the Engineer and data is presented on the foundation exploration drawings. Logs of core borings and Subsurface soil data logs are shown in the drawings. While the foundation information is representative of subsurface conditions at the respective locations of the borings, local variations in the characteristics of the subsurface materials may be anticipated. Local variations which may be encountered include, but are not limited to, classification and thickness of rock strata, fractures, and other discontinuities in the rock structure, and variation in the soil classifications. Such variations will not be considered as differing materially within the purview of the contract paragraph Differing Site Conditions.

6-9.02 PART 2 - PRODUCTS

MATERIALS

A. High-Strength Steel Bars.-- ASTM A 722/A 722M, Type [I] [or] [II], meeting all supplementary requirements.
B. Steel Bar.-- [ASTM A 615/A 615M] [ASTM A 108, Grade [?].
C. Structural Steel.-- ASTM A 572/A 572M, ASTM A 588/A 588M, ASTM A 709/A 709M Grade 248, 345.
D. Steel Pipe.--ASTM A 53/A 53M, Type E or S, Grade B.
D. Steel Tube.--ASTM A 500 or [API Spec 5CTMAPI Spec 5CT, Grade N-80, Oil Field Seconds / Mill Secondary Tubing. TBD
E. Smooth Polyethylene Tubing.-- ASTM D 3350, ASTM D 1248, Type III.
F. Smooth Polypropylene Tubing.-- ASTM D 4101, designation PP 210 B5542-11.
G. Smooth Polyvinyl Chloride (PVC) Tubing.-- ASTM D 1784.

MANUFACTURED ITEMS

Threaded dowel items for bars shall be designed to maintain the capacity of the dowel steel.

Dowel Steel Couplers.--Dowel steel couplers for bars shall be capable of developing 100 percent of the minimum specified ultimate tensile strength of the stressing steel.

Centralizers and Spacers.-- Centralizers and spacers, if required, shall be fabricated from plastic, steel or other approved material which is non-detrimental to the stressing steel. Wood shall not be used. The centralizer shall be able to support the bar in the drill hole and position the bar so a minimum of 13 mm of grout cover is provided. Centralizers and spacers shall permit grout to freely flow up the drill hole.

Where required by site conditions, the Contractor may use Self Drilling and Grouted Bolts.

GROUT

Cement.-- When the ambient rock temperature is below 10 degrees C, Type III cement may be necessary. ASTM C 150, Type I, II, III or V.

Water.-- Water shall be fresh, clean, potable, and free from injurious amounts of sewage, oil, acid, alkali, salts, or organic matter.

Aggregates.-- Fine aggregate for sand-cement grout shall conform to ACI 301, and ASTM C 33 for grout for backfilling holes, or ASTM C 144 for grout for pregrouting. Aggregates shall not contain substances which may be deleteriously reactive with alkalies in the cement.

Admixtures.-- Accelerators are permitted. Plasticizers or retarders are permitted when necessary for hot conditions. Admixtures which control bleed, improve flowability, reduce water content and retard set may be used in the grout. Any admixtures used shall be compatible with the dowel steel and shall be mixed in accordance with the manufacturer's recommendations. All admixtures are subject to the approval of the Engineer.

Grout for Dowels.-- Ground and rock ambient temperatures may have an effect on the grout only when they are below 10 degrees C or when polyester resin grout is used.

Cement Grout.-- Cement grout mixture proportions shall be the responsibility of the Contractor. Grout for grouting dowels shall consist of a homogenous, pumpable, stable mixture of Portland cement and water. The Contractor shall submit his proposed mix design to the Engineer for approval. The water content shall be the minimum necessary for proper placement but the water-cement ratio shall not exceed 0.45 by weight. Final proportions of materials shall be based on results of tests made on sample mixtures of grout. The minimum compressive strength of two-inch cubes, molded, cured, and tested in accordance with ASTM C 109/C 109M, shall be 7 MPa at the time of intalling, and 24MPa after 28 days. The Contractor shall be

responsible for taking, curing, and breaking of grout test cubes for determining mix design, and all testing shall be done by an independent laboratory approved by the Engineer. Rock conditions and temperatures shall be replicated in the curing process.

Polyester Resin Grout.-- Polyester resin grout shall consist of high strength, unsaturated polyester resin filled with nonreactive, inorganic aggregate and a separated catalyst contained in a tube of polyester film or glass. Gel time and cure time shall be appropriate for the installation procedures. The polyester resin grout shall have the following minimum properties:

A. Compressive Strength - 83 MPa.
B. Tensile Strength - 27.6 MPa.
C. Shear Strength - 20.7 MPa.
D. Resin cartridges with expired shelf life shall not be used.

Sand-Cement Grout.-- Grout for waterproofing holes, and for backfilling holes which are abandoned shall consist of a mixture of Portland cement, fine aggregate and water. The grout mix proportions shall be the responsibility of the Contractor. The Contractor shall submit his proposed mix design to the Engineer for approval. The water content shall be the minimum necessary for proper placement. Final proportions of materials shall be based on results of tests made on sample mixtures of grout. The minimum compressive strength of two-inch cubes, molded, cured, and tested in accordance with ASTM C 109/C 109M, shall be 24 MPa. The Contractor shall be responsible for taking, curing, and breaking of grout test cubes for determining mix design, and all testing shall be done by an independent laboratory approved by the Engineer. Rock conditions and temperatures shall be replicated in the curing process.

Grout for Dowel Plate Pads.--Grout for leveling bearing plates shall be non-shrink grout conforming to ASTM C 1107.

BAR FABRICATION

General.-- Fabrication of the dowels shall be as recommended by the suppliers. Dowels shall be completely assembled with all centralizers, grout and vent tubes prior to insertion into the hole. Fabricated dowels shall be protected, transported and stored in a manner to prevent contamination or damage to any components.

Bar.-- When required to maintain the bar location within the drill hole, centralizers shall be provided at a maximum of 2 meter intervals center-to-center throughout the bond length. The entire bond length of the bar shall be free of dirt, lubricants, loose rust, corrosion-inhibiting coatings or other contaminants.

Vent Tubes.-- Vent tubes used during grouting operations, if necessary, shall be any appropriate type for the job, as recommended by the supplier of the dowels.

Grout Tubes.-- Grout tubes shall be polyethylene tubing or as recommended by the dowel manufacturer and approved by the Engineer. Inside diameter of grout tubes shall be adequate to fully grout the entire hole.

TESTS, INSPECTIONS, AND VERIFICATIONS

The Contractor shall have required material tests performed on stressing steel and accessories by an approved laboratory to demonstrate that the materials are in conformance with the specifications. Grout shall be tested in accordance with ASTM C 109/C 109M. These tests shall be at the Contractor's expense. Dowel steel test results shall be furnished prior to beginning fabrication of any dowels. Grout test results shall be provided to the Engineer within 24 hours of testing.

6-9.03 PART 3 - EXECUTION

EQUIPMENT

The Contractor's Quality Control manager shall verify that the equipment used on site is the same as the equipment submitted for approval.

Drilling Equipment.-- Drilling equipment shall be suitable for advancing the drill tools to the depths and at the alignment specified/required.

Grout Mixer.-- The grout mixer shall be capable of continuous mechanical mixing that will produce uniform and thoroughly mixed grout which is free of lumps and undispersed cement. The mixer shall be equipped with a suitable water and admixture measuring devices calibrated to read in cubic centimeters and so designed that after each delivery the measuring device can be conveniently set back to zero.

Grout Pump.-- The grout pump shall be of the positive displacement type, and shall be capable of pumping at all flow rates below 75 liters per minute, shall be capable of pumping at the pressure of at least 345 kPa at zero flow rate. For neat cement grout, the pump shall have a screen with 3 mm maximum clearance to sieve the grout before being introduced into the pump. Screens are not required for shear type mixers. A pump shall also be available which is capable of pumping both neat cement grout mixes and sanded grout mixes. The pumping equipment shall have a pressure gage capable of measuring pressures of at least 1.0 MPa or twice the required grout pressure, whichever is greater.

Testing Equipment.-- Testing equipment shall consist of a hydraulic jack with calibrated pressure gage for applying the load and a dial gage or vernier scale to measure dowel movement. The ram travel of the stressing equipment shall be not less than the theoretical elastic elongation of the total dowel length at the maximum Test Load. The pressure gage shall be graduated in 500 kPa increments. The stressing equipment and pressure gage must have been calibrated as a unit no more than 30 calendar days prior to commencing work under this contract and at six-month intervals throughout the period of use. The movement measuring device shall have a minimum travel equal to the theoretical elastic elongation of the total dowel length at the maximum Test Load without resetting the device.

DRILLING HOLES

General.-- The physical conditions indicated on the drawings are the result of soil sampling and core borings. Holes shall be drilled at the locations, inclinations, and minimum depths shown, and to the depths and diameters determined by the Contractor to provide the design bond length and capacity indicated on the drawings. The locations of the holes may be changed only as approved by the Engineer.

Unless otherwise specified, the Contractor shall determine the drilling method to be used. Holes shall be drilled a maximum of 0.1m beyond the required dowel bond length. A temporary plug shall be provided for all holes drilled more than 10 days prior to installation of the dowel.

Drilling in Rock.-- Unless otherwise specified, holes in rock may be drilled by core drilling, rotary drilling, percussion drilling or down-the-hole hammer using equipment suitable for the intended purpose. Core drilling shall be performed with rotary drilling equipment using diamond-matrix coring bits. Dowel holes which are core drilled may require overdrilling with a roller bit or other approved means to roughen the circumference of the hole to promote bond with the grout.

Records.-- The presence of an Engineer inspector or the keeping of separate drilling records by the Engineer shall not relieve the Contractor of the responsibility for the work specified in this

paragraph. Payment will not be made for any work for which the required records have not been furnished by the Contractor.

Alignment Tolerances.-- The dowel hole shall be located within 300 mm of the plan location. The entry angle shall be within 3 degrees of the specified inclination. The alignment of the drilled hole shall be within 6 degrees of the theoretical alignment, unless a deviation is necessary to avoid installing the dowel in a joint or fissure.

INSTALLATION OF DOWELS

General.-- Demonstration test dowels shall be installed to verify the Contractor's installation methods and design assumptions. Demonstration test dowels shall be installed and approved prior to drilling for other dowels represented by the dowel to facilitate changes which may be required in dowel depth or drilling techniques. Demonstration test dowels must be performance tested to verify capacity.

The Contractor shall be responsible for each drilled hole until the dowel has been installed, grouted, stressed and accepted. Holes in rock and casings shall be cleaned by pressurized air and/or water to remove drill cuttings and mud. The dowels designated as demonstration test dowels shall be installed and tested prior to drilling for other dowels within the area represented by the demonstration test dowel.

Placing.-- All the equipment used in handling and placing the dowels shall be such that it does not damage or deteriorate the steel, or the dowel fittings. Each dowel shall be inspected prior to insertion into the hole. Any damage shall be repaired prior to insertion or, if determined by the Engineer to be not repairable, the dowel shall be replaced.

Resin Grouted Dowels.-- Insertion of resin-grouted dowels shall be in accordance with the resin manufacturer's written recommendations. Dowels shall be inserted until contact is made with the first cartridge. The bar shall then be rotated and advanced at the rate recommended by the resin grout manufacturer. After reaching its final position, the bar shall be rotated as recommended by the resin grout manufacturer to ensure complete mixing of the resin. Installed dowels not fully encapsulated with resin grout along the entire length of drill hole shall be replaced at the Contractor’s expense.

Cement Grouted Rock Dowels.-- Grouting equipment shall be of a type and capacity required for successful installation of the rock dowels. All dowels shall use single stage grouting to encase the dowel. Grouting shall be performed by a method subject to approval by the Engineer.

Dowel Installation.-- The bearing plate and nut shall be installed perpendicular to the bar, and centered on the bar without bending of the steel.

FIELD QUALITY CONTROL

One in 20 of all dowels shall be Proof Tested. All tests shall be run in the presence of the Engineer or his representative. The frequency of testing may be reduced by the engineer if results are satisfactory.

Proof Test.-- Proof test shall consist of incrementally loading the dowel. The maximum Proof test load shall be 110% of the design load. During the testing of each dowel, a record shall be kept of gage pressure and of anchor elongation at each stage of stressing to the Test Load required by PTI Rec. If the total movement at the end of 10 minutes at the Test Load exceeds 1 mm, the Test Load shall be held an additional 50 minutes and the movement readings shall be taken at intervals. Test records, including plots and graphical analysis of test data, shall be furnished upon acceptance of each proof tested dowel in accordance with paragraph SUBMITTALS.

Driller Logs.-- The Contractor shall keep accurate driller logs and records of all work accomplished under this contract and shall deliver complete, legible copies of these logs and

records to the Engineer upon completion of the work or at such other time or times as he may be directed. All such records shall be preserved in good condition and order by the Contractor until they are delivered and accepted, and the Engineer shall have the right to examine such records at any time prior to their delivery. Separate logs shall be made for each hole. The Contractor shall use an approved form which provides the required information for his logs. The following information shall be included on the logs or in the records for each hole: (Note: The information requested here is typical for exploration core holes, not drill holes for dowels.)

A. Hole number or designation of hole.
B. Inclination of the hole.
C. Dates and time when drilling operations were performed.
D. Depth at which groundwater is encountered or unusual occurrances.
E. Depth of hole, determined by measuring the drill steel length.

Rock Dowel Records.-- Upon completion of installation of each dowel, the dowel records shall be furnished to the Contracting Officer as specified in paragraph SUBMITTALS. In addition as-built drawings showing the locations of the completed installation of the dowels shall be furnished upon completion of installation of all dowels.

ACCEPTANCE

General.-- Acceptance of dowels shall be determined by the Engineer. The following criteria will be used in determination of the acceptability of each dowel:

Creep - Creep movement shall not exceed 1 mm at maximum Test Load during the first 10 minutes of the proof test. If the creep movement exceeds this limit, it shall not exceed 2 mm at the maximum Test Load at the end of 60 minutes. If the creep movement exceeds 2 mm at the maximum Test Load at the end of 60 minutes, the dowel shall be rejected.

Replacement of Rejected Rock Dowels.-- Any rock dowel that fails the proof test or is rejected by the Engineer shall be replaced. A replacement dowel, including a new drill hole, shall be provided by the Contractor at no expense to the State. The location of the replacement dowel shall be as directed by the Engineer. The Contractor shall provide all materials, supplies, equipment, and labor necessary to provide a new rock dowel assembly to the satisfaction of the Engineer. Payment will not be made for rejected or failed dowels.

6-9.04 PART 4 - MEASUREMENT AND PAYMENT

Full compensation for rock dowels shall be considered as included in the contract prices paid per meter for various tunnel excavation and support of categories and locations as listed in the Engineer's Estimate and no separate payment will be made therefore.

SECTION 7. (BLANK)

SECTION 8. MATERIALS

SECTION 8-1. MISCELLANEOUS

8-1.01 SUBSTITUTION OF NON-METRIC MATERIALS AND PRODUCTS

Only materials and products conforming to the requirements of the specifications shall be incorporated in the work. When metric materials and products are not available, and when approved by the Engineer, and at no cost to the State, materials and products in the United States

Standard Measures which are of equal quality and of the required properties and characteristics for the purpose intended, may be substituted for the equivalent metric materials and products, subject to the following provisions:

A. Materials and products shown on the plans or in the special provisions as being equivalent may be substituted for the metric materials and products specified or detailed on the plans.
B. Before other non-metric materials and products will be considered for use, the Contractor shall furnish, at the Contractor's expense, evidence satisfactory to the Engineer that the materials and products proposed for use are equal to or better than the materials and products specified or detailed on the plans. The burden of proof as to the quality and suitability of substitutions shall be upon the Contractor and the Contractor shall furnish necessary information as required by the Engineer. The Engineer will be the sole judge as to the quality and suitability of the substituted materials and products and the Engineer's decision will be final.
C. When the Contractor elects to substitute non-metric materials and products, including materials and products shown on the plans or in the special provisions as being equivalent, the list of sources of material specified in Section 6-1.01, "Source of Supply and Quality of Materials," of the Standard Specification shall include a list of substitutions to be made and contract items involved. In addition, for a change in design or details, the Contractor shall submit plans and working drawings in conformance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications. The plans and working drawings shall be submitted at least 7 days before the Contractor intends to begin the work involved.

Unless otherwise specified, the following substitutions of materials and products will be allowed:

SUBSTITUTION TABLE FOR PLAIN WIRE REINFORCEMENT
ASTM Designation: A 82

METRIC SIZE SHOWN ON THE PLANS mm2	SIZE TO BE SUBSTITUTED inch2 x 100
MW9	W1.4
MW10	W1.6
MW13	W2.0
MW15	W2.3
MW19	W2.9
MW20	W3.1
MW22	W3.5
MW25	W3.9, except W3.5 in piles only
MW26	W4.0
MW30	W4.7
MW32	W5.0
MW35	W5.4
MW40	W6.2
MW45	W6.5
MW50	W7.8
MW55	W8.5, except W8.0 in piles only
MW60	W9.3
MW70	W10.9, except W11.0 in piles only
MW80	W12.4
MW90	W14.0
MW100	W15.5

SUBSTITUTION TABLE FOR BAR REINFORCEMENT

METRIC BAR DESIGNATION NUMBER1 SHOWN ON THE PLANS	BAR DESIGNATION NUMBER2 TO BE SUBSTITUTED
10	3
13	4
16	5
19	6
22	7
25	8
29	9
32	10
36	11
43	14
57	18

1Bar designation numbers approximate the number of millimeters of the nominal diameter of the bars.
2Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.
No adjustment will be required in spacing or total number of reinforcing bars due to a difference in minimum yield strength between metric and non-metric bars.

SUBSTITUTION TABLE FOR SIZES OF:

(1) STEEL FASTENERS FOR GENERAL APPLICATIONS (ASTM Designation: A 307 or AASHTO Designation: M 314, Grade 36 or 55), and

(2) HIGH STRENGTH STEEL FASTENERS (ASTM Designation: A 325 or A 449)

METRIC SIZE SHOWN ON THE PLANS mm	SIZE TO BE SUBSTITUTED inch
6 or 6.35	1/4
8 or 7.94	5/16
10 or 9.52	3/8
11 or 11.11	7/16
13, 12.70, or M12	1/2
14 or 14.29	9/16
16, 15.88, or M16	5/8
19, 19.05, or M20	3/4
22, 22.22, or M22	7/8
24, 25, 25.40, or M24	1
29, 28.58, or M27	1-1/8
32, 31.75, or M30	1-1/4
35 or 34.93	1-3/8
38, 38.10, or M36	1-1/2
44 or 44.45	1-3/4
51 or 50.80	2
57 or 57.15	2-1/4
64 or 63.50	2-1/2
70 or 69.85	2-3/4
76 or 76.20	3
83 or 82.55	3-1/4
89 or 88.90	3-1/2
95 or 95.25	3-3/4
102 or 101.60	4

SUBSTITUTION TABLE FOR NOMINAL THICKNESS OF SHEET METAL

UNCOATED HOT AND COLD ROLLED SHEETS		HOT-DIPPED ZINC COATED SHEETS (GALVANIZED)	
METRIC THICKNESS SHOWN ON THE PLANS mm	GAGE TO BE SUBSTITUTED inch	METRIC THICKNESS SHOWN ON THE PLANS mm	GAGE TO BE SUBSTITUTED inch
7.94	0.3125	4.270	0.1681
6.07	0.2391	3.891	0.1532
5.69	0.2242	3.510	0.1382
5.31	0.2092	3.132	0.1233
4.94	0.1943	2.753	0.1084
4.55	0.1793	2.372	0.0934
4.18	0.1644	1.994	0.0785
3.80	0.1495	1.803	0.0710
3.42	0.1345	1.613	0.0635
3.04	0.1196	1.461	0.0575
2.66	0.1046	1.311	0.0516
2.28	0.0897	1.158	0.0456
1.90	0.0747	1.006 or 1.016	0.0396
1.71	0.0673	0.930	0.0366
1.52	0.0598	0.853	0.0336
1.37	0.0538	0.777	0.0306
1.21	0.0478	0.701	0.0276
1.06	0.0418	0.627	0.0247
0.91	0.0359	0.551	0.0217
0.84	0.0329	0.513	0.0202
0.76	0.0299	0.475	0.0187
0.68	0.0269	--------	--------
0.61	0.0239	--------	--------
0.53	0.0209	--------	--------
0.45	0.0179	--------	--------
0.42	0.0164	--------	--------
0.38	0.0149	--------	--------

SUBSTITUTION TABLE FOR WIRE

METRIC THICKNESS SHOWN ON THE PLANS mm	WIRE THICKNESS TO BE SUBSTITUTED inch	GAGE NO.
6.20	0.244	3
5.72	0.225	4
5.26	0.207	5
4.88	0.192	6
4.50	0.177	7
4.11	0.162	8
3.76	0.148	9
3.43	0.135	10
3.05	0.120	11
2.69	0.106	12
2.34	0.092	13
2.03	0.080	14
1.83	0.072	15
1.57	0.062	16
1.37	0.054	17
1.22	0.048	18
1.04	0.041	19
0.89	0.035	20

SUBSTITUTION TABLE FOR PIPE PILES

METRIC SIZE SHOWN ON THE PLANS mm x mm	SIZE TO BE SUBSTITUTED inch x inch
PP 360 x 4.55	NPS 14 x 0.179
PP 360 x 6.35	NPS 14 x 0.250
PP 360 x 9.53	NPS 14 x 0.375
PP 360 x 11.12	NPS 14 x 0.438
PP 406 x 12.70	NPS 16 x 0.500
PP 460 x T	NPS 18 x T"
PP 508 x T	NPS 20 x T"
PP 559 x T	NPS 22 x T"
PP 610 x T	NPS 24 x T"
PP 660 x T	NPS 26 x T"
PP 711 x T	NPS 28 x T"
PP 762 x T	NPS 30 x T"
PP 813 x T	NPS 32 x T"
PP 864 x T	NPS 34 x T"
PP 914 x T	NPS 36 x T"
PP 965 x T	NPS 38 x T"
PP 1016 x T	NPS 40 x T"
PP 1067 x T	NPS 42 x T"
PP 1118 x T	NPS 44 x T"
PP 1219 x T	NPS 48 x T"
PP 1524 x T	NPS 60 x T"

The thickness in millimeters (T) represents an exact conversion of the thickness in inches (T").

SUBSTITUTION TABLE FOR CIDH CONCRETE PILING

METRIC SIZE SHOWN ON THE PLANS	ACTUAL AUGER SIZE TO BE SUBSTITUTED inches
350 mm	14
400 mm	16
450 mm	18
600 mm	24
750 mm	30
900 mm	36
1.0 m	42
1.2 m	48
1.5 m	60
1.8 m	72
2.1 m	84
2.4 m	96
2.7 m	108
3.0 m	120
3.3 m	132
3.6 m	144
4.0 m	156

SUBSTITUTION TABLE FOR STRUCTURAL TIMBER AND LUMBER

METRIC MINIMUM DRESSED DRY, SHOWN ON THE PLANS mm x mm	METRIC MINIMUM DRESSED GREEN, SHOWN ON THE PLANS mm x mm	NOMINAL SIZE TO BE SUBSTITUTED inch x inch
19x89	20x90	1x4
38x89	40x90	2x4
64x89	65x90	3x4
89x89	90x90	4x4
140x140	143x143	6x6
140x184	143x190	6x8
184x184	190x190	8x8
235x235	241x241	10x10
286x286	292x292	12x12

SUBSTITUTION TABLE FOR NAILS AND SPIKES

METRIC COMMON NAIL, SHOWN ON THE PLANS Length, mm Diameter, mm	METRIC BOX NAIL, SHOWN ON THE PLANS Length, mm Diameter, mm	METRIC SPIKE, SHOWN ON THE PLANS Length, mm Diameter, mm	SIZE TO BE SUBSTITUTED Penny-weight
50.80 2.87	50.80 2.51	_____	6d
63.50 3.33	63.50 2.87	_____	8d
76.20 3.76	76.20 3.25	76.20 4.88	10d
82.55 3.76	82.55 3.25	82.55 4.88	12d
88.90 4.11	88.90 3.43	88.90 5.26	16d
101.60 4.88	101.60 3.76	101.60 5.72	20d
114.30 5.26	114.30 3.76	114.30 6.20	30d
127.00 5.72	127.00 4.11	127.00 6.68	40d
_____	_____	139.70 7.19	50d
_____	_____	152.40 7.19	60d

SUBSTITUTION TABLE FOR IRRIGATION COMPONENTS

METRIC WATER METERS, TRUCK LOADING STANDPIPES, VALVES, BACKFLOW PREVENTERS, FLOW SENSORS, WYE STRAINERS, FILTER ASSEMBLY UNITS, PIPE SUPPLY LINES, AND PIPE IRRIGATION SUPPLY LINES SHOWN ON THE PLANS DIAMETER NOMINAL (DN) mm	NOMINAL SIZE TO BE SUBSTITUTED inch
15	1/2
20	3/4
25	1
32	1-1/4
40	1-1/2
50	2
65	2-1/2
75	3
100	4
150	6
200	8
250	10
300	12
350	14
400	16

Unless otherwise specified, substitutions of United States Standard Measures standard structural shapes corresponding to the metric designations shown on the plans and in conformance with the requirements in ASTM Designation: A 6/A 6M, Annex 2, will be allowed.

8-1.__ PREQUALIFIED AND TESTED SIGNING AND DELINEATION MATERIALS

The Department maintains the following list of Prequalified and Tested Signing and Delineation Materials. The Engineer shall not be precluded from sampling and testing products on the list of Prequalified and Tested Signing and Delineation Materials.

The manufacturer of products on the list of Prequalified and Tested Signing and Delineation Materials shall furnish the Engineer a Certificate of Compliance in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications for each type of traffic product supplied.

For those categories of materials included on the list of Prequalified and Tested Signing and Delineation Materials, only those products shown within the listing may be used in the work. Other categories of products, not included on the list of Prequalified and Tested Signing and Delineation Materials, may be used in the work provided they conform to the requirements of the Standard Specifications.

Materials and products may be added to the list of Prequalified and Tested Signing and Delineation Materials if the manufacturer submits a New Product Information Form to the New Product Coordinator at the Transportation Laboratory. Upon a Departmental request for samples, sufficient samples shall be submitted to permit performance of required tests. Approval of

materials or products will depend upon compliance with the specifications and tests the Department may elect to perform.

PAVEMENT MARKERS, PERMANENT TYPE

Retroreflective With Abrasion Resistant Surface (ARS)

A. Apex, Model 921AR (100 mm x 100 mm)
B. Avery Dennison, Models C88 (100 mm x 100 mm), 911 (100 mm x 100 mm) and 953 (70 mm x 114 mm)
C. Ray-O-Lite, Model "AA" ARS (100 mm x 100 mm)
D. 3M Series 290 (89 mm x 100 mm)
E. 3M Series 290 PSA, with pressure sensitive adhesive pad (89 mm x 100 mm)

Retroreflective With Abrasion Resistant Surface (ARS)

(for recessed applications only)

A. Avery Dennison, Model 948 (58 mm x 119 mm)
B. Avery Dennison, Model 944SB (51 mm x 100 mm)*
C. Ray-O-Lite, Model 2002 (58 mm x 117 mm)
D. Ray-O-Lite, Model 2004 ARS (51 mm x 100 mm)*

*For use only in 114 mm wide (older) recessed slots

Non-Reflective, 100 mm Round

A. Apex Universal (Ceramic)
B. Apex Universal, Models 929 (ABS) and 929PP (Polypropylene)
C. Glowlite, Inc., (Ceramic)
D. Hi-Way Safety, Inc., Models P20-2000W and 2001Y (ABS)
E. Interstate Sales, "Diamond Back" (ABS) and (Polypropylene)
F. Novabrite Models Cdot (White) Cdot-y (Yellow), Ceramic
G. Novabrite Models Pdot-w (White) Pdot-y (Yellow), Polypropylene
H. Road Creations, Model RCB4NR (Acrylic)
I. Three D Traffic Works TD10000 (ABS), TD10500 (Polypropylene)

PAVEMENT MARKERS, TEMPORARY TYPE

Temporary Markers For Long Term Day/Night Use (6 months or less)

A. Vega Molded Products "Temporary Road Marker" (75 mm x 100 mm)

Temporary Markers For Short Term Day/Night Use (14 days or less)

(For seal coat or chip seal applications, clear protective covers are required)

A. Apex Universal, Model 932
B. Bunzl Extrusion, Models T.O.M., T.R.P.M., and "HH" (High Heat)
C. Hi-Way Safety, Inc., Model 1280/1281
D. Glowlite, Inc., Model 932

STRIPING AND PAVEMENT MARKING MATERIAL

Permanent Traffic Striping and Pavement Marking Tape

A. Advanced Traffic Marking, Series 300 and 400
B. Brite-Line, Series 1000
C. Brite-Line, "DeltaLine XRP"

D. Swarco Industries, "Director 35" (For transverse application only)
E. Swarco Industries, "Director 60"
F. 3M, "Stamark" Series 380 and 5730
G. 3M, "Stamark" Series 420 (For transverse application only)

Temporary (Removable) Striping and Pavement Marking Tape (6 months or less)

A. Advanced Traffic Marking, Series 200
B. Brite-Line, Series 100
C. Garlock Rubber Technologies, Series 2000
D. P.B. Laminations, Aztec, Grade 102
E. Swarco Industries, "Director-2"
F. Trelleborg Industri, R140 Series
G. 3M, Series 620 "CR", and Series A750
H. 3M, Series A145, Removable Black Line Mask
(Black Tape: for use only on Asphalt Concrete Surfaces)
I. Advanced Traffic Marking Black "Hide-A-Line"
(Black Tape: for use only on Asphalt Concrete Surfaces)
J. Brite-Line "BTR" Black Removable Tape
(Black Tape: for use only on Asphalt Concrete Surfaces)
K. Trelleborg Industri, RB-140
(Black Tape: for use only on Asphalt Concrete Surfaces)

Preformed Thermoplastic (Heated in place)

A. Avery Dennison, "Hotape"
B. Flint Trading, "Premark," "Premark 20/20 Flex," and "Premark 20/20 Flex Plus"

Ceramic Surfacing Laminate, 150 mm x 150 mm

A. Highway Ceramics, Inc.

CLASS 1 DELINEATORS

One Piece Driveable Flexible Type, 1700 mm

A. Bunzl Extrusion, "Flexi-Guide Models 400 and 566"
B. Carsonite, Curve-Flex CFRM-400
C. Carsonite, Roadmarker CRM-375
D. FlexStake, Model 654 TM
E. GreenLine Models HWD1-66 and CGD1-66

Special Use Type, 1700 mm

A. Bunzl Extrusion, Model FG 560 (with 450 mm U-Channel base)
B. Carsonite, "Survivor" (with 450 mm U-Channel base)
C. Carsonite, Roadmarker CRM-375 (with 450 mm U-Channel base)
D. FlexStake, Model 604
E. GreenLine Models HWDU and CGD (with 450 mm U-Channel base)
F. Impact Recovery Model D36, with #105 Driveable Base
G. Safe-Hit with 200 mm pavement anchor (SH248-GP1)
H. Safe-Hit with 380 mm soil anchor (SH248-GP2) and with 450 mm soil anchor (SH248-GP3)

Surface Mount Type, 1200 mm

A. Bent Manufacturing Company, Masterflex Model MF-180EX-48
B. Carsonite, "Super Duck II"
C. FlexStake, Surface Mount, Models 704 and 754 TM
D. Impact Recovery Model D48, with #101 Fixed (Surface-Mount) Base
E. Three D Traffic Works "Channelflex" ID No. 522248W

CHANNELIZERS

Surface Mount Type, 900 mm

A. Bent Manufacturing Company, Masterflex Models MF-360-36 (Round) and MF-180-36 (Flat)
B. Bunzl Extrusion, Flexi-Guide Models FG300PE and FG300UR
C. Carsonite, "Super Duck" (Flat SDF-436, Round SDR-336)
D. Carsonite, "Super Duck II" Model SDCF203601MB "The Channelizer"
E. FlexStake, Surface Mount, Models 703 and 753 TM
F. GreenLine, Model SMD-36
G. Hi-Way Safety, Inc. "Channel Guide Channelizer" Model CGC36
H. Impact Recovery Model D36, with #101 Fixed (Surface-Mount) Base
I. Repo, Models 300 and 400
J. Safe-Hit, Guide Post, Model SH236SMA
K. Three D Traffic Works "Channelflex" ID No. 522053W

Lane Separation System

A. Bunzl "Flexi-Guide (FG) 300 Curb System"
B. Qwick Kurb, "Klemmfix Guide System"
C. Recycled Technology, Inc. "Safe-Lane System"

CONICAL DELINEATORS, 1070 mm

(For 700 mm Traffic Cones, see Standard Specifications)

A. Bent Manufacturing Company "T-Top"
B. Plastic Safety Systems "Navigator-42"
C. Radiator Specialty Company "Enforcer"
D. Roadmaker Company "Stacker"
E. TrafFix Devices "Grabber"
F. Three D Traffic Works "Ringtop" TD7000, ID No. 742143

OBJECT MARKERS

Type "K", 450 mm

A. Bunzl, Model FG318PE
B. Carsonite, Model SMD 615
C. FlexStake, Model 701 KM
D. Repo, Models 300 and 400
E. Safe-Hit, Model SH718SMA

Type "K-4" / "Q" Object Markers, 600 mm

A. Bent Manufacturing "Masterflex" Model MF-360-24
B. Bunzl Extrusion, Model FG324PE

C. Carsonite, Super Duck II
D. FlexStake, Model 701KM
E. Repo, Models 300 and 400
F. Safe-Hit, Models SH8 24SMA_WA and SH8 24GP3_WA
G. The Line Connection, Model DP21-4Q
H. Three D Traffic Works "Q" Marker, ID No. 531702W

CONCRETE BARRIER MARKERS AND
TEMPORARY RAILING (TYPE K) REFLECTORS

Impactable Type

A. ARTUK, "FB"
B. Bunzl Extrusion, Models PCBM-12 and PCBM-T12
C. Duraflex Corp., "Flexx 2020" and "Electriflexx"
D. Hi-Way Safety, Inc., Model GMKRM100
E. Plastic Safety Systems "BAM" Models OM-BARR and OM-BWAR
F. Sun-Lab Technology, "Safety Guide Light Model TM-5"
G. Three D Traffic Works "Roadguide" 9304 Series, ID No. 903176 (One-Way), ID No. 903215 (Two-Way)

Non-Impactable Type

A. ARTUK, JD Series
B. Plastic Safety Systems "BAM" Models OM-BITARW and OM-BITARA
C. Vega Molded Products, Models GBM and JD

METAL BEAM GUARD RAIL POST MARKERS

(For use to the left of traffic)
A. Bunzl Extrusion, "Mini" (75 mm x 254 mm)
B. Creative Building Products, "Dura-Bull, Model 11201"
C. Duraflex Corp., "Railrider"

CONCRETE BARRIER DELINEATORS, 400 mm

(For use to the right of traffic)
A. Bunzl Extrusion, Model PCBM T-16
B. Safe-Hit, Model SH216RBM
C. Sun-Lab Technology, "Safety Guide Light, Model TM16," (75 mm x 300 mm)
D. Three D Traffic Works "Roadguide" ID No. 904364 (White), ID No. 904390 (Yellow)

CONCRETE BARRIER-MOUNTED MINI-DRUM (260 mm x 360 mm x 570 mm)

A. Stinson Equipment Company "SaddleMarker"

SOUND WALL DELINEATOR

(Applied vertically. Place top of 75 mm x 300 mm reflective element at 1200 mm above roadway)
A. Bunzl Extrusion, PCBM S-36
B. Sun-Lab Technology, "Safety Guide Light, Model SM12," (75 mm x 300 mm)

GUARD RAILING DELINEATOR

(Place top of reflective element at 1200 mm above plane of roadway)

Wood Post Type, 686 mm

A. Bunzl Extrusion, FG 427 and FG 527
B. Carsonite, Model 427
C. FlexStake, Model 102 GR
D. GreenLine GRD 27
E. Safe-Hit, Model SH227GRD
F. Three D Traffic Works "Guardflex" TD9100 Series, ID No. 510476

Steel Post Type

A. Carsonite, Model CFGR-327 with CFGRBK300 Mounting Bracket

RETROREFLECTIVE SHEETING

Channelizers, Barrier Markers, and Delineators

A. Avery Dennison T-6500 Series (For rigid substrate devices only)
B. Avery Dennison WR-6100 Series
C. Nippon Carbide Industries, Flexible Ultralite Grade (ULG) II
D. Reflexite, PC-1000 Metalized Polycarbonate
E. Reflexite, AC-1000 Acrylic
F. Reflexite, AP-1000 Metalized Polyester
G. Reflexite, Conformalight, AR-1000 Abrasion Resistant Coating
H. 3M, High Intensity

Traffic Cones, 330 mm Sleeves

A. Reflexite SB (Polyester), Vinyl or "TR" (Semi-transparent)

Traffic Cones, 100 mm and 150 mm Sleeves

A. Nippon Carbide Industries, Flexible Ultralite Grade (ULG) II
B. Reflexite, Vinyl, "TR" (Semi-transparent) or "Conformalight"
C. 3M Series 3840

Barrels and Drums

A. Avery Dennison WR-6100
B. Nippon Carbide Industries, Flexible Ultralite Grade (ULG) II
C. Reflexite, "Conformalight", "Super High Intensity" or "High Impact Drum Sheeting"
D. 3M Series 3810

Barricades: Type I, Medium-Intensity (Typically Enclosed Lens, Glass-Bead Element)

A. American Decal, Adcolite
B. Avery Dennison, T-1500 and T-1600 series
C. 3M Engineer Grade, Series 3170

Barricades: Type II, Medium-High-Intensity (Typically Enclosed Lens, Glass-Bead Element)

A. Avery Dennison, T-2500 Series

B. Kiwalite Type II
C. Nikkalite 1800 Series

Signs: Type II, Medium-High-Intensity (Typically Enclosed Lens, Glass-Bead Element)

A. Avery Dennison, T-2500 Series
B. Kiwalite, Type II
C. Nikkalite 1800 Series

Signs: Type III, High-Intensity (Typically Encapsulated Glass-Bead Element)

A. Avery Dennison, T-5500 and T-5500A Series
B. Nippon Carbide Industries, Nikkalite Brand Ultralite Grade II
C. 3M Series 3870

Signs: Type IV, High-Intensity (Typically Unmetallized Microprismatic Element)

A. Avery Dennison, T-6500 Series
B. Nippon Carbide Industries, Crystal Grade, 94000 Series
C. Nippon Carbide Industries, Model No. 94847 Fluorescent Orange
D. Nippon Carbide Industries, Model No. 94844 Fluorescent Yellow Green

Signs: Type VI, Elastomeric (Roll-Up) High-Intensity, without Adhesive

A. Avery Dennison, WU-6014
B. Novabrite LLC, "Econobrite"
C. Reflexite "Vinyl"
D. Reflexite "SuperBright"
E. Reflexite "Marathon"
F. 3M Series RS34 Orange and RS20 Fluorescent Orange

Signs: Type VII, Super-High-Intensity (Typically Unmetallized Microprismatic Element)

A. 3M LDP Series 3924 Fluorescent Orange
B. 3M LDP Series 3970

Signs: Type VIII, Super-High-Intensity (Typically Unmetallized Microprismatic Element)

A. Avery Dennison, T-7500 Series
B. Avery Dennison, T-7511 Fluorescent Yellow
C. Avery Dennison, T-7513 Fluorescent Yellow Green
D. Avery Dennison, W-7514 Fluorescent Orange
E. Nippon Carbide Industries, Nikkalite Crystal Grade Model 92802 White
F. Nippon Carbide Industries, Nikkalite Crystal Grade Model 92844 Fluorescent Yellow/Green
G. Nippon Carbide Industries, Nikkalite Crystal Grade Model 92847 Fluorescent Orange

Signs: Type IX, Very-High-Intensity (Typically Unmetallized Microprismatic Element)

A. 3M VIP Series 3981 Diamond Grade Fluorescent Yellow
B. 3M VIP Series 3983 Diamond Grade Fluorescent Yellow/Green

C. 3M VIP Series 3990 Diamond Grade

SPECIALTY SIGNS

A. Hallmark Technologies, Inc., All Sign STOP Sign (All Plastic), 750 mm
B. Reflexite "Endurance" Work Zone Sign (with Semi-Rigid Plastic Substrate)

SIGN SUBSTRATE

Fiberglass Reinforced Plastic (FRP)

A. Fiber-Brite
B. Sequentia, "Polyplate"
C. Inteplast Group "InteCel" (13 mm for Post-Mounted CZ Signs, 1200 mm or less)

Aluminum Composite

A. Alcan Composites "Dibond Material, 2 mm" (for temporary construction signs only)
B. Mitsubishi Chemical America, Alpolic 350 (for temporary construction signs only)

8-1.__ STATE-FURNISHED MATERIALS

Attention is directed to Section 6-1.02, "State-Furnished Materials," of the Standard Specifications and these special provisions.

The following materials will be furnished to the Contractor:

A. Sign panels for roadside signs and overhead sign structures.
B. Sign overlay panels for roadside signs and overhead sign structures.
C. Mast arm sign hanger assemblies
D. Laminated wood box posts with metal caps for roadside signs.
E. Hardware for mounting sign panels as follows:

1. Blind rivets for mounting overlapping legend at sign panel joints.
2. Closure inserts.
3. Aluminum bolts and nuts and steel beveled washers for mounting laminated sign panels on overhead sign structures.
4. Aluminum bolts, nuts, and washers for mounting overhead formed panels.

F. Padlocks for backflow preventer assembly enclosures, backflow preventer assembly blankets, walk gates, and irrigation controller enclosure cabinets.
G. Disks for survey monuments.
H. Marker panels, including reflectors, for Type N, Type P, and Type R object markers.
I. Model 170 controller assembly assemblies, including controller unit, completely wired controller cabinet, and loop detector amplifier modules.
J. Modems
K. Changeable message signs
L. Emergency call boxes
M. Water Meters as manufactured by Invensus per NCCWD Standards

Completely wired controller cabinets, with auxiliary equipment but without controller unit, will be furnished to the Contractor at _____.

Model 500 changeable message sign, wiring harness, and controller assembly, including the controller unit and completely wired cabinet, will be furnished to the Contractor at _____.

Sign panels and overlay panels will be furnished to the Contractor at the District Warehouse located at _____.

The Contractor shall notify the District Warehouse Manager, Telephone ___-___-____ and the Engineer not less than 48 hours before State-furnished material is to be picked up by the Contractor. A full description of the material and the time the material will be picked up shall be provided. The number, type, and size of the sign panels, and the contract number shall also be provided to the District Warehouse Manager.

The following recycled material will be available to the Contractor at the District Recycle Center at _____:

A. _____
B. _____
C. _____
D. _____
E. _____
F. _____

The Contractor shall notify the Engineer and the District Recycle Coordinator, Telephone ___-___-____ not less than 48 hours before recycled material is to be picked up, giving the District Recycle Coordinator a full description of the material, the time the material will be picked up, and the contract number of this project.

SECTION 8-2. CONCRETE

8-2.__ PORTLAND CEMENT CONCRETE

Portland cement concrete shall conform to the provisions in Section 90, "Portland Cement Concrete," of the Standard Specifications and these special provisions.

References to Section 90-2.01, "Portland Cement," of the Standard Specifications shall mean Section 90-2.01, "Cement," of the Standard Specifications.

Mineral admixture shall be combined with cement in conformance with the provisions in Section 90-4.08, "Required Use of Mineral Admixtures," of the Standard Specifications for the concrete materials specified in Section 56-2, "Roadside Signs," of the Standard Specifications.

The requirements of Section 90-4.08, "Required Use of Mineral Admixture," of the Standard Specifications shall not apply to Section 19-3.025C, "Soil Cement Bedding," of the Standard Specifications.

The Department maintains a list of sources of fine and coarse aggregate that have been approved for use with a reduced amount of mineral admixture in the total amount of cementitious material to be used. A source of aggregate will be considered for addition to the approved list if the producer of the aggregate submits to the Transportation Laboratory certified test results from a qualified testing laboratory that verify the aggregate complies with the requirements. Prior to starting the testing, the aggregate test shall be registered with the Department. A registration number can be obtained by calling (916) 227-7228. The registration number shall be used as the identification for the aggregate sample in correspondence with the Department. Upon request, a split of the tested sample shall be provided to the Department. Approval of aggregate will depend upon compliance with the specifications, based on the certified test results submitted, together with any replicate testing the Department may elect to perform. Approval will expire 3 years from the date the most recent registered and evaluated sample was collected from the aggregate source.

Qualified testing laboratories shall conform to the following requirements:

A. Laboratories performing ASTM Designation: C 1293 shall participate in the Cement and Concrete Reference Laboratory (CCRL) Concrete Proficiency Sample Program and shall have received a score of 3 or better on all tests of the previous 2 sets of concrete samples.
B. Laboratories performing ASTM Designation: C 1260 shall participate in the Cement and Concrete Reference Laboratory (CCRL) Pozzolan Proficiency Sample Program and shall have received a score of 3 or better on the shrinkage and soundness tests of the previous 2 sets of pozzolan samples.

Aggregates on the list shall conform to one of the following requirements:

A. When the aggregate is tested in conformance with the requirements in California Test 554 and ASTM Designation: C 1293, the average expansion at one year shall be less than or equal to 0.040 percent; or
B. When the aggregate is tested in conformance with the requirements in California Test 554 and ASTM Designation: C 1260, the average of the expansion at 16 days shall be less than or equal to 0.15 percent.

The amounts of cement and mineral admixture used in cementitious material shall be sufficient to satisfy the minimum cementitious material content requirements specified in Section 90-1.01, "Description," or Section 90-4.05, "Optional Use of Chemical Admixtures," of the Standard Specifications and shall conform to the following:

A. The minimum amount of cement shall not be less than 75 percent by mass of the specified minimum cementitious material content.
B. The minimum amount of mineral admixture to be combined with cement shall be determined using one of the following criteria:

    1. When the calcium oxide content of a mineral admixture is equal to or less than 2 percent by mass, the amount of mineral admixture shall not be less than 15 percent by mass of the total amount of cementitious material to be used in the mix.
    2. When the calcium oxide content of a mineral admixture is greater than 2 percent by mass, and any of the aggregates used are not listed on the approved list as specified in these special provisions, then the amount of mineral admixture shall not be less than 25 percent by mass of the total amount of cementitious material to be used in the mix.
    3. When the calcium oxide content of a mineral admixture is greater than 2 percent by mass and the fine and coarse aggregates are listed on the approved list as specified in these special provisions, then the amount of mineral admixture shall not be less than 15 percent by mass of the total amount of cementitious material to be used in the mix.
    4. When a mineral admixture that conforms to the provisions for silica fume in Section 90-2.04, "Admixture Materials," of the Standard Specifications is used, the amount of mineral admixture shall not be less than 10 percent by mass of the total amount of cementitious material to be used in the mix.
    5. When a mineral admixture that conforms to the provisions for silica fume in Section 90-2.04, "Admixture Materials," of the Standard Specifications is used and the fine and coarse aggregates are listed on the approved list as specified in these special provisions, then the amount of mineral admixture shall not be less than 7 percent by mass of the total amount of cementitious material to be used in the mix.

C. The total amount of mineral admixture shall not exceed 35 percent by mass of the total amount of cementitious material to be used in the mix. Where Section 90-1.01, "Description," of the Standard Specifications specifies a maximum cementitious content in kilograms per cubic meter, the total mass of cement and mineral admixture per cubic meter shall not exceed the specified maximum cementitious material content.

The Contractor will be permitted to use Type III portland cement for concrete used in the manufacture of precast concrete members.

SECTION 8-3. WELDING

8-3.__ WELDING

GENERAL

Flux core welding electrodes conforming to the requirements of AWS A5.20 E6XT-4 or E7XT-4 shall not be used to perform welding for this project.

Wherever reference is made to the following AWS welding codes in the Standard Specifications, on the plans, or in these special provisions, the year of adoption for these codes shall be as listed:

AWS Code	Year of Adoption
D1.1	2002
D1.4	1998
D1.5	2002
D1.6	1999

Requirements of the AWS welding codes shall apply unless specified otherwise in the Standard Specifications, on the plans, or in these special provisions. Wherever the abbreviation AWS is used, it shall be equivalent to the abbreviations ANSI/AWS or AASHTO/AWS.

Section 6.1.1.1 of AWS D1.5 is replaced with the following:

Quality Control (QC) shall be the responsibility of the Contractor. As a minimum, the Contractor shall perform inspection and testing of each weld joint prior to welding, during welding, and after welding as specified in this section and as necessary to ensure that materials and workmanship conform to the requirements of the contract documents.

Sections 6.1.3 through 6.1.4.3 of AWS D1.1, Section 7.1.2 of AWS D1.4, and Sections 6.1.1.2 through 6.1.3.3 of AWS D1.5 are replaced with the following:

The QC Inspector shall be the duly designated person who acts for and on behalf of the Contractor for inspection, testing, and quality related matters for all welding.

Quality Assurance (QA) is the prerogative of the Engineer. The QA Inspector is the duly designated person who acts for and on behalf of the Engineer.

The QC Inspector shall be responsible for quality control acceptance or rejection of materials and workmanship, and shall be currently certified as an AWS Certified Welding Inspector (CWI) in conformance with the requirements in AWS QC1, " Standard for AWS Certification of Welding Inspectors."

The QC Inspector may be assisted by an Assistant QC Inspector provided that this individual is currently certified as an AWS Certified Associate Welding Inspector (CAWI) in conformance with the requirements in AWS QC1, "Standard for AWS Certification of Welding Inspectors."

The Assistant QC Inspector may perform inspection under the direct supervision of the QC Inspector provided the Assistant is always within visible and audible range of the QC Inspector. The QC Inspector shall be responsible for signing all reports and for determining if welded materials conform to workmanship and acceptance criteria. The ratio of QC Assistants to QC Inspectors shall not exceed 5 to 1.

When the term "Inspector" is used without further qualification, it shall refer to the QC Inspector.

Section 6.14.6, "Personnel Qualification," of AWS D1.1, Section 7.8, "Personnel Qualification," of AWS D1.4, and Section 6.1.3.4, "Personnel Qualification," of AWS D1.5 are replaced with the following:

Personnel performing nondestructive testing (NDT) shall be qualified and certified in conformance with the requirements of the American Society for Nondestructive Testing (ASNT) Recommended Practice No. SNT-TC-1A and the Written Practice of the NDT firm. The Written Practice of the NDT firm shall meet or exceed the guidelines of the ASNT Recommended Practice No. SNT-TC-1A. Individuals who perform NDT, review the results, and prepare the written reports shall be either:

A. Certified NDT Level II technicians, or;
B. Level III technicians who hold a current ASNT Level III certificate in that discipline and are authorized and certified to perform the work of Level II technicians.

Section 6.5.4 of AWS D1.5 is replaced with the following:

The QC Inspector shall inspect and approve each joint preparation, assembly practice, welding technique, joint fit-up, and the performance of each welder, welding operator, and tack welder to make certain that the applicable requirements of this code and the approved Welding Procedure Specification (WPS) are met. The QC Inspector shall examine the work to make certain that it meets the requirements of Sections 3 and 6.26. The size and contour of all welds shall be measured using suitable gages. Visual inspection for cracks in welds and base metal, and for other discontinuities should be aided by strong light magnifiers, or such other devices as may be helpful. Acceptance criteria different from those specified in this code may be used when approved by the Engineer.

Section 6.6.5, "Nonspecified NDT Other than Visual," of AWS D1.1, Section 6.6.5 of AWS D1.4 and Section 6.6.5 of AWS D1.5 shall not apply.

For any welding, the Engineer may direct the Contractor to perform NDT that is in addition to the visual inspection or NDT specified in the AWS or other specified welding codes, in the Standard Specifications, or in these special provisions. Additional NDT required by the Engineer will be paid for as extra work as provided in Section 4-1.03D, "Extra Work," of the Standard Specifications. Should any welding deficiencies be discovered by this additional NDT, all costs associated with the repair of the deficient area, including NDT of the weld and of the weld repair, and any delays caused by the repair, shall be at the Contractor's expense.

Repair work to correct welding deficiencies discovered by visual inspection or NDT, or by additional NDT directed or performed by the Engineer, and any associated delays or expenses caused to the Contractor by performing these repairs, shall be at the Contractor's expense.

The Engineer shall have the authority to verify the qualifications or certifications of any welder, QC Inspector, or NDT personnel to specified levels by retests or other means approved by the Engineer.

Continuous inspection shall be provided when any welding is being performed. Continuous inspection, as a minimum, shall include having a QC Inspector within such close proximity of all welders or welding operators so that inspections by the QC Inspector of each welding operation at each welding location shall not lapse for a period exceeding 30 minutes.

Inspection and approval of all joint preparations, assembly practices, joint fit-ups, welding techniques, and the performance of each welder, welding operator, and tack welder shall be documented by the QC Inspector on a daily basis for each day welding is performed. For each inspection, including fit-up, Welding Procedure Specification (WPS) verification, and final weld inspection, the QC Inspector shall confirm and document compliance with the requirements of the AWS or other specified code criteria and the requirements of these special provisions on all welded joints before welding, during welding, and after the completion of each weld.

When joint weld details that are not prequalified to the details of Section 3 of AWS D1.1 or to the details of Figure 2.4 or 2.5 of AWS D1.5 are proposed for use in the work, the joint details, their intended locations, and the proposed welding parameters and essential variables, will be approved by the Engineer. The Engineer shall have 2 weeks to complete the review of the proposed joint detail locations. In the event the Engineer fails to complete the review within the time allowed, and if, in the opinion of the Engineer, completion of the work is delayed or interfered with by reason of the Engineer's delay in completing the review, the Contractor will be compensated for any resulting loss, and an extension of time will be granted, in the same manner as provided for in Section 8-1.09, "Right of Way Delays," of the Standard Specifications. Upon approval of the proposed joint detail locations and qualification of the proposed joint details, welders and welding operators using these details shall perform a qualification test plate using the WPS variables and the joint detail to be used in production. The test plate shall have the maximum thickness to be used in production and a minimum length of 180 mm and minimum finish welded width 460 mm. The test plate shall be mechanically and radiographically tested. Mechanical and radiographic testing and acceptance criteria shall be as specified in the applicable AWS codes.

In addition to the requirements specified in the applicable code, the period of effectiveness for a welder's or welding operator's qualification shall be a maximum of 3 years for the same weld process, welding position, and weld type. If production welding will be performed without gas shielding, then qualification shall also be without gas shielding. Excluding welding of fracture critical members, a valid qualification at the beginning of work on a contract will be acceptable for the entire period of the contract, as long as the welder's or welding operator's work remains satisfactory.

The Engineer will witness all qualification tests for WPSs that were not previously approved by the Department. An approved independent third party will witness the qualification tests for welders or welding operators. The independent third party shall be a current CWI and shall not be employed by the contractor performing the welding. The Engineer shall have 2 weeks to review the qualifications and copy of the current certification of the independent third party. In the event the Engineer fails to complete the review within the time allowed, and if, in the opinion of the Engineer, completion of the work is delayed or interfered with by reason of the Engineer's delay in completing the review, the Contractor will be compensated for any resulting loss, and an extension of time will be granted, in the same manner as provided for in Section 8-1.09, "Right of Way Delays," of the Standard Specifications. The Contractor shall notify the Engineer one week prior to performing any qualification tests. Witnessing of qualification tests by the

Engineer shall not constitute approval of the intended joint locations, welding parameters, or essential variables.

In addition to the requirements of AWS D1.5 Section 5.12 or 5.13, welding procedures qualification, for work welded in conformance with that code, shall conform to the following requirements:

A. Unless considered prequalified, fillet welds, including reinforcing fillet welds, shall be qualified in each position. The fillet weld soundness test shall be conducted using the essential variables of the WPS as established by the Procedure Qualification Record (PQR.)
B. For qualification of joints that do not conform to Figures 2.4 and 2.5 of AWS D1.5, two WPS qualification tests are required. The tests conforming to AWS D1.5 Section 5.13 shall be conducted using both Figure 5.1 and Figure 5.3. The test conforming to Figure 5.3 shall be conducted using the same welding electrical parameters that were established for the test conducted conforming to Figure 5.1.
C. The travel speed, current, and voltage values that are used for tests conducted per AWS D1.5 Section 5.12 or 5.13 shall be consistent for each weld joint, and shall in no case vary by more than 10 percent for travel speed, 10 percent for current, and 7 percent for voltage.
D. For a WPS qualified in conformance with AWS D1.5 Section 5.13, the values to be used for calculating ranges for current and voltage shall be based on the average of all weld passes made in the test. Heat input shall be calculated using the average of current and voltage of all weld passes made in the test for a WPS qualified in conformance with Section 5.12 or 5.13.
E. To qualify for unlimited material thickness, two qualification tests are required for WPSs utilized for welding material thicknesses greater than 38 mm. One test shall be conducted using 20-mm thick test plates, and one test shall be conducted using test plates with a thickness between 38 mm and 50 mm. Two maximum heat input tests may be conducted for unlimited thickness qualification.
F. Macroetch tests are required for WPS qualification tests, and acceptance shall be per AWS D1.5 Section 5.19.3.
G. When a weld joint is to be made using a combination of qualified WPSs, each process shall be qualified separately.
H. When a weld joint is to be made using a combination of qualified and prequalified processes, the WPS shall reflect both processes and the limitations of essential variables, including weld bead placement, for both processes.
I. Prior to preparing mechanical test specimens, the PQR welds shall be inspected by visual and radiographic tests. Backing bar shall be 75 mm in width and shall remain in place during NDT testing. Results of the visual and radiographic tests shall comply with AWS D1.5 Section 6.26.2, excluding Section 6.26.2.2. Test plates that do not comply with both tests shall not be used.

WELDING QUALITY CONTROL

Welding quality control shall conform to the requirements in the AWS or other specified welding codes, the Standard Specifications, and these special provisions.

Unless otherwise specified, welding quality control shall apply when any work is welded in conformance with the provisions in Section 49, "Piling," Section 52, "Reinforcement," Section 55, "Steel Structures," or Section 75-1.035, "Bridge Joint Restrainer Units," of the Standard Specifications.

In addition, welding quality control shall apply when welding is performed for the following work:

A. Miscellaneous Metal

The welding of fracture critical members (FCMs) shall conform to the provisions specified in the Fracture Control Plan (FCP) and herein.

The Contractor shall designate in writing a welding Quality Control Manager (QCM). The QCM shall be responsible directly to the Contractor for the quality of welding, including materials and workmanship, performed by the Contractor and subcontractors.

The QCM shall be the sole individual responsible to the Contractor for submitting, receiving, reviewing, and approving all correspondence, required submittals, and reports to and from the Engineer. The QCM shall be a registered professional engineer or shall be currently certified as a CWI or a CAWI.

The QCM shall not be employed or compensated by any subcontractor, or by other persons or entities hired by subcontractors, who will provide other services or materials for the project. The QCM may be an employee of the Contractor.

Welding inspection personnel or NDT firms to be used in the work shall not be employed or compensated by any subcontractor, or by other persons or entities hired by subcontractors, who will provide other services or materials for the project, except for the following conditions:

A. The work is welded in conformance with AWS D1.5 and is performed at a permanent fabrication or manufacturing facility which is certified under the AISC Quality Certification Program, Category Cbr, Major Steel Bridges and Fracture Critical endorsement F.
B. The welding is performed on pipe pile material at a permanent pipe manufacturing facility authorized to apply the American Petroleum Institute (API) monogram for API 5L pipe.

For welding performed at such facilities, the inspection personnel or NDT firms may be employed or compensated by the facility performing the welding.

Prior to submitting the Welding Quality Control Plan (WQCP) required herein, a pre-welding meeting between the Engineer, the Contractor's QCM, and a representative from each entity performing welding or inspection for this project, shall be held to discuss the requirements for the WQCP.

The Contractor shall submit to the Engineer, in conformance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications, 2 copies of a separate WQCP for each subcontractor or supplier for each item of work for which welding is to be performed.

The Contractor shall allow the Engineer 2 weeks to review the WQCP submittal after a complete plan has been received. No welding shall be performed until the WQCP is approved in writing by the Engineer. In the event the Engineer fails to complete the review within the time allowed, and if, in the opinion of the Engineer, completion of the work is delayed or interfered with by reason of the Engineer's delay in completing the review, the Contractor will be compensated for any resulting loss, and an extension of time will be granted, in the same manner as provided for in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

An amended WQCP or any addendum to the approved WQCP shall be submitted to, and approved in writing by the Engineer, for proposed revisions to the approved WQCP. An amended WQCP or addendum will be required for revisions to the WQCP, including but not

limited to a revised WPS; additional welders; changes in NDT firms, QC, or NDT personnel or procedures; or updated systems for tracking and identifying welds. The Engineer shall have 1 week to complete the review of the amended WQCP or addendum. Work affected by the proposed revisions shall not be performed until the amended WQCP or addendum has been approved. In the event the Engineer fails to complete the review within the time allowed, and if, in the opinion of the Engineer, completion of the work is delayed or interfered with by reason of the Engineer's delay in completing the review, the Contractor will be compensated for any resulting loss, and an extension of time will be granted, in the same manner as provided for in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

Information regarding the contents, format, and organization of a WQCP, is available at the Transportation Laboratory or the following website:

http://www.dot.ca.gov/hq/esc/Translab/smbresources.htm

After final approval of the WQCP, amended WQCP, or addendum, the Contractor shall submit 7 copies to the Engineer of the approved documents. A copy of the Engineer approved document shall be available at each location where welding is to be performed.

A daily production log for welding shall be kept for each day that welding is performed. The log shall clearly indicate the locations of all welding. The log shall include the welders' names, amount of welding performed, any problems or deficiencies discovered, and any testing or repair work performed, at each location. The daily report from each QC Inspector shall also be included in the log.

The following items shall be included in a Welding Report that is to be submitted to the Engineer within 10 days following the performance of any welding:

A. Reports of all visual weld inspections and NDT.
B. Radiographs and radiographic reports, and other required NDT reports.
C. Documentation that the Contractor has evaluated all radiographs and other nondestructive tests and corrected all rejectable deficiencies, and all repaired welds have been reexamined by the required NDT and found acceptable.
D. Daily production log.

The following information shall be clearly written on the outside of radiographic envelopes: name of the QCM, name of the nondestructive testing firm, name of the radiographer, date, contract number, complete part description, and all included weld numbers or a report number, as detailed in the WQCP. In addition, all innerleaves shall have clearly written on them the part description and all included weld numbers, as detailed in the WQCP.

Reports regarding NDT shall be signed by both the NDT technician and the person that performed the review, and then submitted directly to the QCM for review and signature prior to submittal to the Engineer. Corresponding names shall be clearly printed or typewritten next to all signatures.

The Engineer will review the Welding Report to determine if the Contractor is in conformance with the WQCP. Unless otherwise specified, the Engineer shall be allowed 10 days to review the report and respond in writing after a complete Welding Report has been received. Prior to receiving notification from the Engineer of the Contractor's conformance with the WQCP, the Contractor may encase in concrete or cover welds for which a Welding Report has been submitted. However, should the Contractor elect to encase or cover those welds prior to receiving notification from the Engineer, it is expressly understood that the Contractor shall not be relieved of the responsibility for incorporating material in the work that conforms to the

requirements of the plans and specifications. Material not conforming to these requirements will be subject to rejection. Should the Contractor elect to wait to encase or cover welds pending notification by the Engineer, and in the event the Engineer fails to complete the review within the time allowed, and if, in the opinion of the Engineer, completion of the work is delayed or interfered with by reason of the Engineer's delay in completing the review, the Contractor will be compensated for any resulting loss, and an extension of time will be granted, in the same manner as provided for in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

The QC Inspector shall provide reports to the QCM on a daily basis for each day that welding is performed.

Except for noncritical weld repairs, the Engineer shall be notified immediately in writing when welding problems, deficiencies, base metal repairs, or any other type of repairs not submitted in the WQCP are discovered, and also of the proposed repair procedures to correct them. The Contractor shall allow the Engineer one week to review these procedures. No remedial work shall begin until the repair procedures are approved in writing by the Engineer. In the event the Engineer fails to complete the review within the time allowed, and if, in the opinion of the Engineer, completion of the work is delayed or interfered with by reason of the Engineer's delay in completing the review, the Contractor will be compensated for any resulting loss, and an extension of time will be granted, in the same manner as provided for in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

The QCM shall sign and furnish to the Engineer, a Certificate of Compliance in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications for each item of work for which welding was performed. The certificate shall state that all of the materials and workmanship incorporated in the work, and all required tests and inspections of this work, have been performed in conformance with the details shown on the plans, the Standard Specifications, and these special provisions.

PAYMENT

Full compensation for conforming to the requirements of "Welding" shall be considered as included in the contract prices paid for the various items of work involved and no additional compensation will be allowed therefor.

SECTION 9. DESCRIPTION OF TUNNEL WORK

DEVIL'S SLIDE TUNNELS

The tunnel work to be done consists, in general, of constructing twin vehicular tunnels and other tunnel related structures in accordance with the details and to the limits shown on the plans titled "DEVIL'S SLIDE TUNNELS".

SECTION 10. CONSTRUCTION DETAILS

SECTION 10-1. GENERAL

10-1.01 ORDER OF WORK

Order of work shall conform to the provisions in Section 5-1.05, "Order of Work," of the Standard Specifications and these special provisions.

The approval of mix design of shotcrete and construction of preconstruction shotcrete test panels for soil nail wall at north portal shall be the first order of work.

10-1.__ MOBILIZATION

Mobilization shall conform to the provisions in Section 11, "Mobilization," of the Standard Specifications.

10-1.__ EARTHWORK

Earthwork shall conform to the provisions in Section 19, "Earthwork," of the Standard Specifications and these special provisions.

Backfill materials placed against sloping ground at cut-and-cover portals shall be benched into the existing sloping ground at least 2 m, measured horizontally from the face of the existing sloping ground. Materials excavated from the North Portal may be considered suitable for use in a compacted backfill in general backfill areas in conformance with the following requirements:

A. Materials shall be disintegrated to soil- and gravel-size particles and thoroughly mixed prior to placing as compacted backfill.
B. Rock or rock fragments less than or equal to 200 mm, in the largest dimension, may be utilized in the backfill provided they are well distributed throughout the backfill and not placed in concentrated pockets.
C. Rocks greater than 200 mm, in the largest dimension, shall not be used in the construction of backfill slopes, and shall be disposed in conformance with Section 7-1.13, "Disposal of Materials Outside the Highway Right of Way," of the Standard Specifications.

10-1.__ GEOSYNTHETIC REINFORCED EMBANKMENT

This work shall consist of placing geosynthetic reinforcement material between layers of compacted soil in accordance with the details shown on the plans, as specified in Section 19 "Earthwork," of the Standard Specifications, these special provisions, and as directed by the Engineer. Only one type of geosynthetic reinforcement material shall be used for an entire embankment, except as shown on the plans.If shown on the plans, a drainage system shall be constructed with the geosynthetic reinforced embankment. Specifications for the drainage system will be found elsewhere in these special provisions.

If shown on the plans, filter fabric shall be used within the geosynthetic reinforced embankment; specifications for the filter fabric will be found elsewhere in these special provisions or in the Standard Specifications.

MATERIAL CONFIGURATION SPECIFICATIONS

A certificate of compliance shall be furnished to the Engineer in conformance with Section 6-1.07, "Certificate of Compliance," of the Standard Specifications a minimum of one week prior to placement of geosynthetic reinforcement material. The Certificate of Compliance shall be prepared and signed by a representative of the manufacturer who is a California-registered Civil Engineer.

Geosynthetic reinforcement material shall be designed for use in subsurface geotechnical slope reinforcement applications. Geosynthetic reinforcement material shall be configured as a

geogrid material. Geogrid shall have a regular and defined open area. Geogrid shall obtain pullout resistance from the soil by a combination of soils shearing friction on the plane surfaces parallel to the direction of shearing and soils bearing on transverse grid surfaces normal to the direction of grid movement. The percentage of the open area for geogrids shall range from 50 to 90 percent of the total projection of a section of the material.

Geosynthetic reinforcement material shall meet the following requirements:

A. Long Term Design Strength (LTDS) for geosynthetic reinforcement material shall be determined by Geosynthetic Research Institute (GRI) Test Methods. LTDS for geogrid reinforcement and geotextile reinforcement shall be determined by Standard Practice GRI GG4 (a) and (b) and GT7, respectively. These values are minimum average roll values.

   1. Long Term Design Strength is the strength of the geogrid or the geotextile calculated by applying all partial factors of safety in accordance with GRI Standard Practice GG4 (a) and (b) or GRI GT7, except that the product of the partial factors of safety for installation damage (based on a soil gradation possessing a D_{50} between 2.36 and 4.75 mm), chemical degradation, and biological degradation of less than 1.30 shall not be allowed. The factor of safety for creep deformation shall be determined for a 75-year design life as determined by GRI GG4 (a) and (b) for geogrids or GRI GT7 for geotextiles. The 75-year design life strength is determined from the creep curve which becomes asymptotic to a constant strain line of 10 percent or less.
   2. In the absence of specific test data, the partial factor of safety default values (installation damage, creep deformation, chemical degradation, biological degradation, and joint) as indicated in the Standard Practice GRI GG4 (a) and (b) and GRI GT7 shall be applied to the calculations of the LTDS.

B. Geosynthetic reinforcement material shall be resistant to naturally occurring alkaline and acidic soil conditions, and to attack by bacteria.

All test results used in the calculations of the LTDS shall be submitted to the Engineer no less than two weeks prior to placement of the geosynthetic reinforced embankment. All test results which contribute to the calculations of the LTDS shall be prepared and signed by a California-registered Civil Engineer.

MATERIAL

Geosynthetic reinforcement material shall consist of main and secondary reinforcement layers. Geosynthetic reinforcement material shall consist of high density polyethylene, polypropylene, high density polypropylene sheets, high tenacity polyester yarn, or polyaramide and shall meet the following requirements:

High Density Polyethylene

Geosynthetic reinforcement material consisting of high density polyethylene shall be manufactured from high density polyethylene (HDPE) which conforms to ASTM Designation: D 1248, and shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans. Secondary geosynthetic reinforcement material shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans.

Polypropylene

Geosynthetic reinforcement material consisting of polypropylene or high-density polypropylene sheets shall conform to the requirements of ASTM Designation: D 4101, Group

1/Class1/Grade 2, and shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans. Secondary geosynthetic reinforcement material shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans.

High Tenacity Polyester Encapsulated

Geosynthetic reinforcement material consisting of high tenacity polyester yarn shall be manufactured from high tenacity polyester yarn as determined by ASTM Designation: D 629. Geogrid shall be encapsulated in an acrylic latex, PVC, polymer or similar coating. Geosynthetic reinforcement material consisting of high tenacity polyester yarn shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans. Secondary geosynthetic reinforcement material shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans.

Polyaramides

Geosynthetic reinforcement material consisting of polyaramide shall be manufactured from high tenacity polyester yarn as determined by ASTM Designation: D 629, and shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans. Secondary geosynthetic reinforcement material shall have a LTDS in the primary strength direction greater than or equal to values shown on the plans.

EMBANKMENT BACKFILL

The backfill material used in the geosynthetic reinforced embankment shall consist of imported material and/or material developed on site. The backfill shall be reasonably free from organic or other deleterious materials and shall conform to the following:

PROPERTY	VALUE	CA TEST NO.
Percent passing	Gradation	202
Sieve Size		
75-millimeters	100	
19-millimeters	70 - 100	
4.75-millimeters	20 – 80	
420-µm	0 - 70	
75-µm	0 – 55	
Sand Equivalent	10 minimum	217
Plasticity Index	20 maximum	204
pH	between 3 and 9	643

Backfill on cut-and-cover portals and soil nail walls shall be constructed using polymeric geogrids as shown on the plans or when slopes are steeper than 1V:2H. Materials consisting of only clay particles shall not be used as backfill in the reinforced zone. Materials used as backfill in the reinforced zone shall have at least 50 percent particles by weight retained on the No. 200 Sieve.

The reinforced zone, where the horizontal geogrids are placed, shall extend from the top of portal to the point where the temporary backcut daylights the existing ground surface. The reinforced zone shall consist of 2 sets of geogrids as shown on the plans. The primary geogrids shall have a minimum strength of 55 kN/m and the secondary geogrids shall have a minimum strength of 10 kN/m.

Unless otherwise directed by the Engineer, structure backfill shall be compacted to relative compaction of not less than 90 percent.

BACKFILL FOR EMBANKMENT FACING

The backfill material used at the facing of the geosynthetic reinforced embankment shall consist of imported material and/or material developed on site. The backfill shall be reasonably free from organic or other deleterious materials and shall conform to the following:

PROPERTY	VALUE	CA TEST NO.
Percent passing	Gradation	202
Sieve Size		
75-millimeters	100	
19-millimeters	70 – 100	
420-µm	35 - 70	
75-µm	35 minimum	
Plasticity Index	10 minimum	204

HANDLING AND STORAGE

Geosynthetic reinforcement material shall be handled and stored in accordance with the manufacturer's recommendations and these special provisions. Geosynthetic reinforcement material shall be furnished in an appropriate protective cover which shall protect it from ultraviolet radiation and from abrasion during shipping and handling. Geosynthetic reinforcement material shall be placed as much as can be covered with backfill in the same work shift.

CONSTRUCTION

The Contractor shall prepare the grade that is to receive the layers of geosynthetic reinforcement material to the compaction and elevation tolerances described in the Standard Specifications under Section 19-2.05, "Slopes," and these special provisions. The grade shall be free of loose or extraneous material and objects that may damage the geosynthetic reinforcement material during installation. Relative compaction of not less than 95 percent shall be obtained in the embankment foundation under the lowest layer of geosynthetic reinforcement material for a minimum depth of 0.15 meter.

The maximum loose thickness of each lift of embankment material shall not exceed 0.3 m and shall be compacted to 90% Relative Compaction.

Geosynthetic reinforcement material shall be handled and placed in accordance with the manufacturer's recommendations and these special provisions. The geosynthetic reinforcement material shall be placed horizontally on compacted backfill from within 150 millimeters of the face of the embankment to the required embedment length. The geosynthetic reinforcement material shall be placed in a wrinkle free manner, pulled taut, aligned, and anchored before backfill placement. Slack in geosynthetic reinforcement material shall be removed in a manner, and to a degree directed by the Engineer. Geosynthetic reinforcement material shall be placed at the intervals, elevations, and for the minimum embedment length shown on the plans. Each layer of geosynthetic reinforcement material shall not vary more than 0.15 meter from the theoretical horizontal plane established for that layer for the entire width and length of the reinforcement.

Geosynthetic reinforcement material shall extend the full width of the reinforced embankment. Geosynthetic reinforcement material shall be trimmed as necessary to avoid the obstructions and achieve the maximum embedment length possible.

Geosynthetic reinforcement material shall be secured in place with staples, pins, sand bags, or backfill, as required by construction or weather conditions, or as directed by the Engineer to prevent the displacement during compaction and placement of embankment material.

Geosynthetic reinforcement material shall not extend into the pavement structural section.

Secondary geosynthetic reinforcement material shall have an embedment length as shown on the plans. Secondary geosynthetic reinforcement material shall not extend into the pavement structural section. Secondary geosynthetic reinforcement material shall not vary more than 0.15 meter from the horizontal plane established for that layer for the entire width and length of the reinforced embankment.

Each layer of geosynthetic reinforcement materialshall be placed (unrolled) into the grade to form a continuous mat. Overlapping and splicing geosynthetic embankment material shall conform to the following:

Uniaxial geogrid and geotextile geotechnical fabric do not need to be overlapped along edges parallel to the direction of working tensile strength. Uniaxial geogrid and woven geotechnical reinforcement material shall not be overlapped or spliced along edges perpendicular to the direction of working tensile strength.

Biaxial geogrid shall be overlapped a minimum of 150 millimeters along edges parallel to the direction of working tensile strength, or as directed by the Engineer. Biaxial geogrid shall be overlapped a minimum of one meter along edges perpendicular to the direction of working tensile strength of reinforcement.

A layer of soil a minimum of 100 millimeters thick shall be spread between uniaxial geogrid or woven geotechnical reinforcement material layers in the area to be overlapped.

If a drainage feature or other feature is shown on the plans within or adjacent to the geosynthetic reinforced embankment, the construction of that feature shall be done in a time sequence relative to the geosynthetic reinforced embankment as best meets the project requirements.

The geosynthetic reinforcement material shall be placed with the direction of maximum strength in the direction of slope. The Contractor shall verify correct orientation of the geosynthetic reinforcement material . Each layer of geosynthetic reinforcement material shall be placed onto the embankment material to form a continuous mat. Adjacent strips of geosynthetic reinforcement material placed in this manner need not be overlapped.

During spreading and compacting of the backfill, at least 150 millimeters of backfill shall be maintained between the geosynthetic reinforcement material and the Contractor's equipment. Equipment or vehicles shall not be operated or driven directly on geosynthetic reinforcement material.

During spreading and compacting of the backfill, at the option of the Resident Engineer, rubber tired vehicles may be driven directly on the material, provided that such traffic is part of the placement operation, that the amount of traffic repetitions is minimized, that speeds or 6 mph or less are maintained, and that turning or stopping movements of the vehicle are minimized. Damaged areas shall be repaired as specified elsewhere in the special provisions. No tracked vehicles shall be allowed.

At locations where guard railing posts will be placed at the top of the geosynthetic reinforced embankment and the geosynthetic reinforcement material would interfere with placement of such posts, prior to backfilling the Contractor shall be allowed to cleanly the reinforcement material of the affected layers into a cross-shaped pattern to aid the later placement of the guard railing posts. The dimensions of the precutting shall not exceed the post dimensions by more than 750 millimeters.

Geogrid reinforcement material may be joined with mechanical connections. Joints shall not be placed vertically within 2 meters of the slope face, within 2 meters of the slope top, nor horizontally or vertically adjacent (within 1.2 meters) to another joint. The joint shall be made for the full width of the strip by using a similar material with similar strength, and using a connection device supplied or recommended by the manufacturer. Joints in geogrid shall be pulled and held taut during backfill placement. Joints shall not be weak links.

If the geosynthetic reinforcement material is damaged during construction operations, the damaged sections shall be repaired, at the Contractor's expense, by placing sufficient additional geosynthetic reinforcement material to cover the damaged area and to meet the following overlap requirements:

A. Edges of geogrid perpendicular to centerline shall be overlapped for entire lengths by the smaller of: three aperture openings or 100 millimeters. Edges of geogrid parallel to centerline shall be joined using a mechanical connection described elsewhere in these special provisions.
B. Edges of geotextiles shall be overlapped a minimum of 150 millimeters on all sides.

MEASUREMENT AND PAYMENT

Geosynthetic Reinforcement material will be measured and paid for by the square meter for the total area in each level (plan view) of the main geosynthetic reinforcement as shown on the plans and for any additional area as directed by the Engineer. Payment shall not include additional reinforcement required for overlaps nor for secondary geosynthetic reinforcement.

The contract price paid per square meter of geosynthetic reinforced embankment shall include full compensation for furnishing all labor and materials, including tools and equipment, and incidentals, for developing, placing and compacting native embankment backfill, and for doing all the work involved in placing the geosynthetic reinforcement layers complete and in place, including splicing, overlapping and anchoring as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Full compensation for revisions to drainage systems or other facilities made necessary by the use of an alternative geosynthetic reinforcement material embankment material shall be considered as included in the contract price paid per square meter for geosynthetic reinforced embankment and no adjustment in compensation will be made therefor.

Full compensation for geogrids as shown on the plans shall be considered as included in the contract price paid per cubic meter for structure backfill of types and locations as listed in the Engineer's Estimate and no additional compensation will be allowed therefor.

10-1.__ SOIL NAIL WALL EARTHWORK

Soil nail wall earthwork, consisting of excavating for soil nail wall construction and backfilling around completed soil nail walls at North Portal, shall conform to the provisions in Section 19-3, "Structure Excavation and Backfill," of the Standard Specifications, Section "Earthwork" of these special provisions.

Working Drawings

The Contractor shall submit a complete working drawing submittal for earthwork for each soil nail wall to the Engineer in conformance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications. Working drawings for soil nail wall earthwork shall be 559 mm by 864 mm in size. For initial review, 5 sets of drawings shall be submitted. After review, between 6 and 12 sets, as requested by the Engineer, shall be submitted

for final approval and use during construction.

Working drawings for wall earthwork shall show the State assigned designations for the contract number, structure number, full name of the structure as shown on the contract plans, and District-County-Route-Kilometer Post on each drawing and calculation sheet. The Contractor's name, address, and telephone number shall be shown on the working drawings. Each sheet shall be numbered in the lower right hand corner.

The working drawings for soil nail wall earthwork shall contain all information required for the construction and quality control of the earthwork, including the following:

A. A proposed schedule and detailed construction sequence. Construction sequence shall include measures to ensure wall and slope stability during all stages of wall construction including provisions for discontinuous rows of soil nails.
B. Methods of excavation to the staged lifts indicated and types of excavation equipment.
C. Temporary shoring plans.
D. Drilling methods and equipment including proposed drill hole size and any variation of these along the alignments.
E. Information on space requirements for installation equipment.
F. A detailed construction dewatering plan addressing all elements necessary to divert, control, and dispose of surface water and ground water.

A supplement to the working drawings shall include the following:

A. Independently checked calculations for wall and slope stability during all stages of wall construction including geotechnical assessment of information provided by the Department for this contract. At the Contractor's option, the Contractor may conduct additional geotechnical investigation for the purpose of developing soil nail wall earthwork working drawings.
B. Information on provisions for working in the proximity of underground facilities.

The working drawings and supplement shall be stamped and signed by an engineer who is registered as a Civil Engineer in the State of California.

The Contractor shall allow the Engineer 4 weeks to review the working drawings and supplement after a complete submittal has been received.

Should the Engineer fail to review the complete working drawing submittal within the time specified and if, in the opinion of the Engineer, the Contractor's controlling operation is delayed or interfered with by reason of the delay in reviewing the soil nail wall earthwork working drawing submittal, an extension of time commensurate with the delay in completion of the work thus caused will be granted in conformance with the provisions in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

Excavation

Care shall be taken during excavation for soil nail walls to prevent disturbing the natural foundation materials behind the face of excavation. During initial mass grading, the Contractor shall not excavate the full wall height to the wall alignment as shown on the plans, but the Contractor shall maintain a working berm of native material in front of the wall to serve as a work bench for the drill equipment. The working berm shall extend out from the wall to provide sufficient work bench space and shall be cut down from that point at the slope shown on the approved wall earthwork working drawings. The original ground beyond the wall alignment for the back or ends of the wall as shown on the plans shall not be over excavated. Any such over

excavation shall be restored by the Contractor, at the Contractor's expense, using methods and materials approved in writing by the Engineer. Soil stabilization methods or temporary backing or lagging placed behind the excavation face may be required to prevent disturbing the natural foundation materials.

Excavation for walls shall be limited to that area which can be nailed and covered with shotcrete during the same work shift in which the excavation is done. Subsequent excavation shall not be made within 3 m of previously nailed and covered portions of the wall until those nailed and covered portions are structurally complete. A portion of the wall will be considered structurally complete when the soil nail assemblies have been installed, the shotcrete cover has set, specified testing has been completed for that portion of the wall, and the test results have been furnished to the Engineer.

Excavation to the final wall alignment for the full wall height shall incorporate a working berm which shall be constructed from the top down in a staged lift sequence as shown on the approved wall earthwork working drawings. The ground level in front of the wall face shall not be excavated more than one meter below the level of the row of soil nails to be installed in that same lift.

At the option of the Contractor, the Contractor may maintain a stabilizing berm of undisturbed material to support the excavation face during soil nail installation.

After soil nails are complete in place for a given lift, the stabilizing berm shall be removed during excavation to the final wall alignment. The complete excavated face shall be cleaned of all loose materials, mud, rebound, and other materials that could prevent or reduce shotcrete bond to the excavated face and soil nails.

Temporary backing or lagging for excavation at soil nail walls may be left in place if approved in writing by the Engineer. There shall be no voids behind temporary backing or lagging that is left in place. Fillers used to eliminate voids between the excavation face and temporary backing or lagging shall be dimensionally stable, non-deteriorating material capable of supporting the earth pressures in both water saturated and dry conditions.

Timber backing or lagging at walls which is to remain in place and is greater than 25 mm total thickness shall be pressure treated with wood preservative for soil and fresh water use in conformance with the provisions in Section 58, "Preservative Treatment of Lumber, Timber and Piling," of the Standard Specifications. Wood preservative shall be one of the following: creosote, creosote-coal tar solution, pentachlorophenol, copper naphthenate, ammonia copper arsenate, ammoniacal copper zinc arsenate, acid copper chromate, or chromated copper arsenate.

The Contractor shall remove all cobbles, boulders or portions of boulders, rubble, or debris which are encountered at the final wall alignment during wall face excavation and which protrude from the excavated face more than 50 mm into the design shotcrete thickness as shown on the plans. Such over excavation shall be backfilled with shotcrete.

The Contractor shall immediately notify the Engineer of the occurrence of raveling or local instability of the final wall face excavation due to the presence of groundwater, soil conditions, equipment vibration, or other causes.

Unstable areas shall be temporarily stabilized by means of buttressing the exposed excavation face with an earth berm or other methods approved in writing by the Engineer. Construction of the wall in unstable areas shall be suspended until remedial measures, submitted by the Contractor, and approved by the Engineer, have been taken.

The Contractor shall protect installed soil nails during excavation and subsequent operations. Any soil nails damaged during construction shall be replaced by the Contractor, at the Contractor's expense.

Measurement and Payment

Excavation and backfill for soil nail wall construction will be measured and paid for as structure excavation (soil nail wall) and structure backfill (soil nail wall).

Full compensation for working drawings and supplements, and for furnishing, constructing and removing shoring, working berms, and stabilizing berms, if required, for soil nail wall construction shall be considered as included in the contract price paid per cubic meter for structure excavation (soil nail wall) and no additional compensation will be allowed therefor.

Full compensation for shotcrete used to fill voids created by the removal of cobbles and boulders or other obstructions shall be considered as included in the contract price paid per cubic meter for shotcrete and no additional compensation will be allowed therefor.

10-1.__ SOIL NAIL ASSEMBLY

Soil nail assemblies and test soil nail assemblies, consisting of drilling holes in natural foundation materials, installing and grouting steel bars in drilled holes, anchorage systems, and testing of test soil nail assemblies, shall conform to the details shown on the plans, the provisions of the Standard Specifications, and these special provisions.

Attention is directed to "Order of Work" and "Soil Nail Wall Earthwork" of these special provisions.

WORKING DRAWINGS

The Contractor shall submit a complete working drawing submittal for soil nail assemblies to the Engineer in conformance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications. All working drawings for soil nail assemblies shall be 559 mm by 864 mm in size. For initial review, 5 sets of drawings shall be submitted. After review, between 6 and 12 sets, as requested by the Engineer, shall be submitted to OSDfor final approval and use during construction.

Working drawing submittals for soil nail assemblies shall show the State assigned designations for the contract number, structure number, full name of the structure as shown on the contract plans, and District-County-Route-Kilometer post on each drawing and calculation sheet. The Contractor's name, address, and phone and FAX numbers shall also be shown on the working drawings. Each working drawing sheet shall be numbered in the lower right hand corner of the sheet.

The working drawing submittal for soil nail assemblies shall contain all information required for the construction and quality control of the soil nail wall, including the following:

A. The proposed schedule and detailed construction sequence of the installation and grouting of soil nails, application of shotcrete, and construction of cast-in-place reinforced concrete.
B. Complete details and specifications of the soil nail and test soil nail, including encapsulation materials and method of grouting the encapsulation, anchorage system, and type of packers or other appropriate devices to be used to ensure partial length grouting of test soil nails.
C. Grout mix designs and procedures involved in testing grout.
D. Grout placement procedures and equipment including minimum required cure time.
E. Details of the equipment proposed for testing soil nails, including jacking frame and appurtenant bracing, and the method and equipment for determining any displacement of the test soil nail relative to the grout during application of test loads.
F. Information on space requirements for installation equipment.

G. Drilling methods and equipment.

The working drawing submittal shall be stamped and signed by an engineer who is registered as a Civil Engineer in the State of California.

The Contractor shall allow the Engineer 4 weeks to review the soil nail working drawings after a complete submittal has been received. No soil nails shall be fabricated or installed until the Engineer has approved, in writing, the working drawing submittal for soil nail assemblies.

Should the Engineer fail to review the complete working drawing submittal within the time specified, and if, in the opinion of the Engineer, the Contractor's controlling operation is delayed or interfered with by reason of the delay in reviewing the soil nail working drawing submittal, an extension of time commensurate with the delay in completion of the work thus caused will be granted in conformance with the provisions in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

MATERIALS

The materials specified below shall be used for construction of soil nail assemblies and test soil nail assemblies.

Soil Nail

Soil nails shall conform to the provisions for bar reinforcement in Section 52, "Reinforcement," of the Standard Specifications. When Grade 420 soil nails are shown on the plans, the soil nails shall also conform to the requirements in ASTM Designation: A 615/A 615M or A706/A706M. When Grade 520 soil nails are shown on the plans, the soil nails shall also conform to the requirements in ASTM Designation: A 615/A 615M. The soil nail shall be either a reinforcing bar encapsulated full length in a grouted corrugated plastic sheathing or an epoxy coated reinforcing bar partially encapsulated in a grouted corrugated plastic sheathing. The bar shall be centered in the sheathing and the space between the sheathing and the bar shall be filled with grout. The epoxy coating shall have a minimum thickness of 305 µm.

Soil nail assemblies shall be lengthened or additional soil nail assemblies shall be installed when ordered by the Engineer. The lengthening or addition of soil nail assemblies, when ordered by the Engineer, will be paid for as extra work as provided in Section 4-1.03D, "Extra Work," of the Standard Specifications.

Soil nails shall have a minimum length of 150 mm of thread on the anchorage end. Threading may be continuous spiral deformed ribbing provided by the bar deformations or may be cut into a reinforcing bar. If threads are cut into a reinforcing bar, the bar size shall be the next larger bar designation number from that shown on the plans and coarse threads shall be used. The epoxy coating at the anchorage end of epoxy coated bars may be omitted for a maximum length of 150 mm. Metal surfaces of assembled splices of epoxy coated bars shall be epoxy coated.

Corrugated plastic sheathing shall be either polyvinyl chloride (PVC) or high density polyethylene (HDPE). The minimum sheathing wall thickness shall be 1.0 mm.

HDPE shall have a density between 0.940 and 0.960-g/cm3 when measured in conformance with the requirements in ASTM Designation: D 792, A-2.

The sheathing shall have sufficient strength to prevent damage during construction operations and shall be watertight, chemically stable without embrittlement or softening, and nonreactive with concrete.

Splicing of soil nails shall be made only at the locations shown on the plans or at ends of soil

nails which the Engineer has ordered to be lengthened.

Test Soil Nail

Test soil nails shall conform to the provisions for bar reinforcement in Section 52, "Reinforcement," of the Standard Specifications, and shall be of a size and grade determined by the Contractor.

Test soil nail assemblies shall be lengthened or additional test soil nail assemblies shall be installed when ordered by the Engineer. The lengthening or addition of test soil nail assemblies, when ordered by the Engineer, will be paid for as extra work as provided in Section 4-1.03D, "Extra Work," of the Standard Specifications.

Test soil nails need not be epoxy coated or encapsulated in grouted plastic sheathing.

Splicing of test soil nails shall be made only at locations outside of the bonded length.

Anchorage System

Anchorage for soil nails shall conform to the details shown on the plans and the provisions in Section 75-1.02, "Miscellaneous Iron and Steel," of the Standard Specifications, except that nuts, washers, wedges, and bearing plates to be fully encased in concrete, grout, or shotcrete need not be galvanized. Concrete anchors on the bearing plates shall conform to the provisions for stud connectors in Section 55-2, "Materials," of the Standard Specifications.

The ultimate strength of the soil nail anchorage shall be at least the value shown below for the size of the soil nail bar shown on the plans.

BAR SIZE	ANCHORAGE ULTIMATE STRENGTH (kilonewtons)	
		Grade 520
No. 29		446

Grout

Grout shall conform to the provisions in Section 50-1.09, "Bonding and Grouting," of the Standard Specifications. California Test 541 will not be required nor will the grout be required to pass through a screen with a 1.80-mm maximum clear opening prior to being introduced into the grout pump. Fine aggregate may be added to the grout mixture of portland cement and water in drilled holes 150 mm or greater in diameter, but only to the extent that the cement content of the grout is not less than 600 kilograms per cubic meter of grout. Fine aggregate, if used, shall conform to the provisions in Section 90-2, "Materials," and Section 90-3, "Aggregate Gradings," of the Standard Specifications. Grout with fine aggregate shall have a nominal penetration equal to or greater than 90 mm when measured in conformance with California Test 533, and shall have an air content of equal to or less than 2 percent when measured in conformance with California Test 504. Air entraining admixtures shall not be used for grout with fine aggregate.

The consistency of grout with fine aggregate shall be verified prior to use by producing a batch to be tested. The test batch shall be produced and delivered to the project under conditions and in time periods similar to those expected during the placement of grout in the soil nails. Grout for the test batch shall be placed in an excavated hole or suitable container of adequate size to allow testing in conformance with California Test 533. The test batch shall demonstrate

that the proposed grout mix achieves the specified nominal penetration. Upon completion of the testing, the grout shall be disposed of in conformance with the provisions in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

CONSTRUCTION

Soil nails shall be installed in drilled holes in an expeditious manner so that caving or deterioration of the drilled hole does not occur. No portion of the drilled hole shall be left open for more than 60 minutes prior to soil nail placement and grouting unless otherwise approved by the Engineer.

Difficult soil nail assembly construction is anticipated due to caving soils, ground water,cobbles and boulders, and tight work space on sloping ground.

Drilling

Drilling equipment shall be designed to drill straight and clean holes. The drilling method and the size and capability of the drilling equipment shall be as approved in the working drawings. Drill rigs shall have the capability of anchorage installation and grout placement through the use of drill casing or hollow-stem augers.

At locations where caving conditions are anticipated, sufficient casing and auger lengths shall be available on site to maintain uninterrupted installation of anchors.

At locations where hard drilling conditions such as rock, cobbles, boulders, or obstructions are anticipated, a down hole pneumatic hammer drill rig and drill bit shall be available on site to drill holes for soil nail assemblies.

Drilled holes for walls shall not extend beyond the right-of-way or easement limits as shown on the plans or as specified in these special provisions.

Holes shall be drilled in the natural slope materials. Holes for test soil nail assemblies shall be of the same diameter as those for the production soil nail assemblies they represent.

Holes shall be cleaned to remove material resulting from the drilling operations and to remove any other material that would impair the strength of the soil nail assemblies or test soil nail assemblies. Foreign material dislodged or drawn into the holes during construction of the assemblies shall be removed. Water for cleaning holes shall not be used, unless full hole length hollow-stem augers or casing is maintained in the same hole during cleaning and soil nail assembly installation. Soil nail assemblies and test soil nail assemblies shall not be installed in the drilled holes until the holes have been inspected by the Engineer.

Installing Soil Nails and Test Soil Nails

Soil nails and test soil nails shall be installed in the drilled holes using centralizers. Centralizers shall adequately support the bar in the center of the drilled hole and shall be spaced at a maximum of 1.5 m on center along the length of the bar, and 0.5-m from the end of the bar.

Where the soil nail cannot be completely inserted, the Contractor shall remove the bar and clean or redrill the hole to permit unobstructed installation. Partially installed bars shall not be driven or forced into the drilled hole and will be rejected. When open-hole drilling methods are being used, the Contractor shall have hole cleaning tools on-site suitable for cleaning drilled holes along their full length just prior to bar insertion and grouting.

Grouting

The length of drilled hole shall be verified and recorded by the Contractor before grouting.

Grout shall be injected at the low end of the drilled hole and shall fill the drilled hole with a dense grout free of voids or inclusion of foreign material. Cold joints shall not be used in grout placement. Soil nails shall be grouted full length.

Only the bonded length of test soil nails shall be initially grouted. Initial grouting shall be confined to the bonded length by packers or other approved devices. For test soil nails, grouting of the remainder of the drilled hole shall not be done until pullout tests have been completed and approved by the Engineer.

After placing the grout for soil nails and test soil nails, they shall remain undisturbed for the cure time stated in the approved soil nail working drawings.

Securing Soil Nails

Any remaining void at the exterior end of the drilled hole for a soil nail assembly shall be filled with shotcrete and the soil nail secured at the face of the shotcrete. The steel bearing plate shall be seated with full bearing on the shotcrete surface and the nut for the soil nail shall be hand tightened before the initial set of the shotcrete. The nut shall be made wrench tight after the shotcrete has set for 24 hours, unless a shorter time is approved by the Engineer.

Securing Test Soil Nails

Testing shall be performed against a temporary bearing yoke which bears directly on the shotcrete facing. Test loads transmitted through the temporary bearing yoke shall not fracture the shotcrete or cause displacement or sloughing of the soil surrounding the drilled hole. No part of the yoke shall bear within 150 mm of the edge of blockout.

Test soil nails shall be removed to behind the front face of the shotcrete after testing has been completed. The remaining length of void in the drilled hole shall be grouted and the blockout in the shotcrete facing filled with either grout or shotcrete.

TESTING

Test soil nail assemblies shall be pullout tested by the Contractor in the presence of the Engineer. A pullout test shall consist of incrementally loading the assembly until either the pullout test load has been held for one minute or the total measured movement of the soil nail exceeds 100 mm, at which point the load shall be recorded as part of the test data and submitted to the Engineer at the conclusion of each test.

The Contractor shall monitor and record total movement of the test soil nail relative to the grout during application of the test load.

Applied test loads shall be determined by using either a calibrated pressure gage or a load cell. Movements of the end of the soil nail, relative to an independent fixed reference point, shall be measured and recorded to the nearest 25 µm at each increment of load, including the ending alignment load, during the load tests.

The pressure gage shall have an accurately reading dial at least 150 mm in diameter. Each jack and its gage shall be calibrated as a unit with the cylinder extension in the approximate position that it will have at final jacking force, and shall be accompanied by a certified calibration chart. Each jack and pressure gage assembly shall be calibrated in conformance with Section 50-1.08, "Prestressing," of the Standard Specifications. The load cell shall be calibrated and shall be provided with an indicator capable of measuring the test load in the soil nail. The range of the load cell shall be such that the lower 10 percent of the manufacturer's rated capacity will not be used in determining the jacking force.

The test load may be verified by State forces with either State-furnished load cells or pressure cells, or with State-furnished Vibra-Tension equipment operated in conformance with

the requirements of California Test 677. The Contractor shall provide sufficient labor, equipment, and material to install and support such testing equipment at the soil nails and to remove the testing equipment after the testing is complete, as ordered by the Engineer.

The pullout test procedures shall conform to the following:

A. The pullout test shall be conducted by measuring and recording the test load applied to the test soil nail and the test soil nail end movement at each load listed in the following loading schedule.

PULLOUT TEST LOADING SCHEDULE

AL
0.20M
0.30M
0.40M
0.50M
0.60M
0.70M
0.80M
0.90M
1.00M (PULLOUT TEST LOAD)
AL

(M = MAXIMUM TEST LOAD (kN) = $0.0141\sigma_b D$)

Where σ_b=Ultimate bond stress between grout and drilled hole as shown on the plans, in kPa; and D=actual drilled hole diameter, in millimeters.

(AL = ALIGNMENT LOAD = 0.1M)

B. Each increment of load shall be applied in less than one minute and held for at least one minute but not more than 2 minutes, except that the load equal to 0.70M shall be held for 10 minutes. During the 10-minute load hold, the movement of the end of the soil nail shall be measured at 1, 2, 3, 4, 5, 6, and 10 minutes. The observation period for the 10-minute load hold shall start when the pump begins to apply the increment of load from 0.60M to 0.70M. If the creep movement measured between one minute and 10 minutes at 0.70M is less than one mm, the load shall continue to be increased incrementally to 1.00M, then reduced to the ending alignment load. The test soil nail assembly shall be considered acceptable if 1) the creep movement measured between one minute and 10 minutes is less than one mm, 2) the total measured movement is greater than 80 percent of the theoretical elastic elongation of the test nail unbonded length at the 1.0M load, and 3) the total measured movement is less than 100 mm.

C. If the load of 0.70M cannot be maintained for 10 minutes with one mm or less creep movement, the 0.70M load shall be maintained for an additional 50 minutes. Total movement shall be measured at 15, 20, 25, 30, 45, and 60 minutes. If the test load is held for 60 minutes, a creep curve showing the creep movement between 10 minutes and 60 minutes shall be plotted as a function of the logarithm of time. If the creep curve plotted from the movement data indicates a creep rate of less than 2.0 mm for the last log cycle of time, the load shall continue to be increased incrementally to 1.00M, then reduced to the ending alignment load. The test soil nail assembly shall be considered acceptable if 1) the creep curve plotted from the movement data indicates a creep rate of less than 2.0 mm for the last log cycle of time, 2) the total measured movement is greater

than 80 percent of the theoretical elastic elongation of the test nail unbonded length at the 1.0M load, and 3) the total measured movement is less than 100 mm.

D. The soil nail shall be unloaded only after completion of the test.

Test soil nails that fail to meet acceptance criteria shall be extracted when requested by the Engineer. Full compensation for extracting test soil nails shall be considered as included in the contract price paid per meter for soil nail assembly, and no separate payment will be made therefor.

The Contractor shall furnish to the Engineer complete test results for each soil nail assembly tested. Data for each test shall list key personnel, test loading equipment, test soil nail location, hole diameter and depth, bond length, type of soil, method of drilling, and amount of ground water encountered within the bond length. Test data shall also include the dates and times of drilling, test soil nail installation, grouting, and testing. The test load and amount of displacement shall be included in the test data when any displacement of the test soil nail relative to the grout occurs during application of the test load.

MEASUREMENT

Soil nail assembly and test soil nail assembly will be measured and paid for by the meter. The length to be paid for will be the length of soil nail assembly or test soil nail assembly measured along the bar centerline from the back face of shotcrete to the tip end shown on the plans or ordered in writing by the Engineer.

PAYMENT

The contract price paid per meter for soil nail assembly shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing the soil nail assemblies, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Test soil nail assemblies will be paid for as soil nail assembly.

Full compensation for testing of the test soil nail assemblies shown on the plans shall be considered as included in the contract price paid per meter for soil nail assembly, and no separate payment will be made therefor.

Full compensation for repair of all restoration of grade in subsided areas, and all other damage done by drilling shall be considered as included in the contract price paid per meter for soil nail assembly, and no additional compensation will be allowed therefor.

Full compensation for furnishing, installing, and removing casing shall be considered as included in the contract price paid per meter for soil nail assembly, and no additional compensation will be allowed therefor.

The quantities of trial batch grout will not be included in any contract item of work, and full compensation for furnishing, producing, and disposing of trial batches shall be considered as included in the contract price paid per meter for soil nail assembly, and no additional compensation will be allowed therefor.

10-1.__ CONTROLLED LOW STRENGTH MATERIAL

Controlled low strength material shall consist of a workable mixture of aggregate, cementitious materials, and water and shall conform to the provisions for slurry cement backfill in Section 19-3.062, "Slurry Cement Backfill," of the Standard Specifications and these special provisions.

Controlled low strength material shall be placed around underground ducts, pipes or conduits where controlled density fill (CDF) is shown on the plans or specified in these special provisions.

When controlled low strength material is used for structure backfill, the width of the excavation shown on the plans may be reduced so that the clear distance between the outside of the pipe and the side of the excavation, on each side of the pipe, is a minimum of 300 mm. This minimum may be reduced to 150 mm when the height of cover is less than or equal to 6.1 m or the pipe diameter or span is less than 1050 mm.

Controlled low strength material in new construction shall not be permanently placed higher than the basement soil. For trenches in existing pavements, permanent placement shall be no higher than the bottom of the existing pavement permeable drainage layer. If a drainage layer does not exist, permanent placement in existing pavements shall be no higher than 25 mm below the bottom of the existing asphalt concrete surfacing or no higher than the top of base below the existing portland cement concrete pavement.

The Contractor shall submit a mix design and test data to the Engineer for approval prior to excavating the trench for which controlled low strength material is to be used. The test data and mix design shall provide for the following:

A. A 28-day compressive strength between 345 kPa and 690 kPa for pipe or conduit having a height of cover of 6.1 m or less and a minimum 28-day compressive strength of 690 kPa for pipe or conduit having a height of cover greater than 6.1 m. Compressive strength shall be determined in conformance with the requirements in ASTM Designation: D 4832.
B. Cement shall be any type of portland cement conforming to the requirements in ASTM Designation: C 150; or any type of blended hydraulic cement conforming to the requirements in ASTM Designation: C 595M or the physical requirements in ASTM Designation: C 1157M. Testing of cement will not be required.
C. Admixtures may be used in conformance with the provisions in Section 90-4, "Admixtures," of the Standard Specifications. Chemical admixtures containing chlorides as Cl in excess of one percent by mass of admixture, as determined in conformance with the requirements of California Test 415, shall not be used. If an air-entraining admixture is used, the maximum air content shall be limited to 20 percent. Mineral admixtures shall be used at the Contractor's option.

Materials for controlled low strength material shall be thoroughly machine-mixed in a pugmill, rotary drum or other approved mixer. Mixing shall continue until the cementitious material and water are thoroughly dispersed throughout the material. Controlled low strength material shall be placed in the work within 3 hours after introduction of the cement to the aggregates.

When controlled low strength material is to be placed within the traveled way or otherwise to be covered by paving or embankment materials, the material shall achieve a maximum indentation diameter of 76 mm prior to covering and opening to public traffic. Penetration resistance shall be measured in conformance with the requirements in ASTM Designation: D 6024.

Full compensation for controlled low strength material for backfill around underground ducts, pipes and conduits shall be considered as included in the contract prices paid for the various items of work involved and no separate payment will be made therefor.

10-1.__ AGGREGATE BASE

Aggregate base shall be Class 2 and shall conform to the provisions in Section 26, "Aggregate Bases," of the Standard Specifications and these special provisions.

The restriction that the amount of reclaimed material included in Class 2 aggregate base not exceed 50 percent of the total volume of the aggregate used shall not apply.

10-1.__ LEAN CONCRETE BASE

Lean concrete base shall conform to the provisions in Section 28, "Lean Concrete Base," of the Standard Specifications.

10-1.__ ASPHALT CONCRETE

Asphalt concrete shall be Type A and shall conform to the provisions in Section 39, "Asphalt Concrete," of the Standard Specifications and these special provisions.

The asphalt content of the asphalt mixture will be determined in conformance with the requirements in California Test 379, or in conformance with the requirements in California Test 382.

When portland cement concrete is placed on asphalt concrete base, the finished surface of the asphalt concrete base shall not extend above the grade established by the Engineer. Asphalt concrete base with a surface higher than the grade established by the Engineer shall be cold planed until the surface of asphalt concrete base conforms to the tolerances specified. Cold planing equipment shall be power driven and specifically designed to produce a smooth surface that conforms to the straight edge requirements specified in Section 39-6.03, "Compacting" of the Standard Specifications. Asphalt concrete base with a surface lower than 15 mm below the grade established by the Engineer shall be removed and replaced with asphalt concrete base which complies with requirements of these specifications.

Paint binder (tack coat) shall be applied to existing surfaces to be surfaced and between layers of asphalt concrete, except when eliminated by the Engineer.

Paint binder (tack coat) shall be, at the option of the Contractor, either slow-setting asphaltic emulsion, rapid-setting asphaltic emulsion or paving asphalt. Slow-setting asphaltic emulsion and rapid-setting asphaltic emulsion shall conform to the provisions in Section 39-4.02, "Prime Coat and Paint Binder (Tack Coat)," and the provisions in Section 94, "Asphaltic Emulsions," of the Standard Specifications. When paving asphalt is used for paint binder, the grade will be determined by the Engineer. Paving asphalt shall conform to the provisions in Section 39-4.02, "Prime Coat and Paint Binder (Tack Coat)," and the provisions in Section 92, "Asphalts," of the Standard Specifications.

Paint binder (tack coat) shall be applied in the liter per square meter range limits specified for the surfaces to receive asphalt concrete in the tables below. The exact application rate within the range will be determined by the Engineer.

When asphaltic emulsion is used as paint binder (tack coat), asphalt concrete shall not be placed until the applied asphaltic emulsion has completely changed color from brown to black.

10-1. __CONCRETE PAVEMENT

GENERAL

Portland cement concrete pavement shall be constructed in conformance with the provisions in Section 40, "Portland Cement Concrete Pavement," of the Standard Specifications and these special provisions, and as shown on the plans.

Insert method for forming joints in pavement shall not be used.

PREPAVING CONFERENCE

Supervisory personnel of the Contractor and subcontractors who are to be involved in the concrete paving work shall meet with the Engineer at a prepaving conference, at a mutually agreed time, to discuss methods of accomplishing the paving work.

The Contractor shall provide a facility for the prepaving conference within 5 km of the construction site or at a nearby location agreed to by the Engineer. Attendance at the prepaving conference is mandatory for the Contractor's project superintendent, paving construction foreman, subcontractor's workers, including foremen and personnel performing saw cutting, joint sealing, concrete plant manager, and concrete plant operator. Conference attendees shall sign an attendance sheet provided by the Engineer. Production and placement shall not begin nor proceed unless the above-mentioned personnel have attended the mandatory prepaving conference.

JUST-IN-TIME TRAINING

Attending a 4-hour Just-In-Time Training (JITT) shall be mandatory, and consist of a formal joint training class on portland cement concrete and paving techniques. Construction operations for portland cement concrete paving shall not begin until the Contractor's and the Engineer's personnel have completed the mandatory JITT. The Contractor's personnel included in the list of participants for the prepaving conference as well as the Engineer's representatives shall attend JITT. JITT shall be in addition to the prepaving conference.

The JITT class will be conducted for not less than 4 hours on portland cement concrete pavement and paving techniques. The training class may be an extension of the prepaving conference and shall be conducted at a project field location convenient for both the Contractor and the Engineer. The JITT class shall be completed at least 15 days, not including Saturdays, Sundays or holidays, prior to the start of portland cement concrete paving operations. The class shall be held during normal working hours.

The JITT instructor shall be experienced in the construction methods, materials, and test methods associated with construction of portland cement concrete pavement and paving techniques. The instructor shall not be an employee of the Contractor or a member of the Engineer's field staff. A copy of the course syllabus, handouts, and presentation material shall be submitted to the Engineer at least 7 days before the day of the training. The Contractor and the Engineer shall mutually agree to course instructor, the course content, and training site. The instructor shall issue a certificate of completion to the participants upon completion of the class. The certificate of completion shall include the course title, date and location of the class, the name of the participant, instructor's name, location and telephone number.

The Contractor's or Engineer's personnel involved with portland cement concrete paving operations will not be required to attend JITT if they have completed equivalent training within the previous 12 months of the date of the JITT for this project. The Contractor shall provide a certificate of class completion as described above for each staff member to be excluded from the JITT class. The Engineer will provide the final determination for exclusion of staff member's participation. Attendees of the JITT shall complete, and submit to the Engineer, an evaluation of the training. The Engineer will provide the course evaluation form.

Just-In-Time Training shall not relieve the Contractor of responsibility under the contract for the successful completion of the work in conformance with the requirements of the plans and specifications.

TEST STRIP

At the beginning of paving operations, the Contractor shall construct an initial test strip of concrete pavement from 200 m to 300 m in length. The paving width for the test strip shall be the same as that intended by the Contractor for production work. The Contractor shall use the same equipment used to construct the test strip for the remainder of the paving operations, except as specified in this section. The Contractor shall not perform further paving until the test strip is evaluated in conformance with the provisions in Section 40-1.10, "Final Finishing," of the Standard Specifications regarding surface straight edge requirements, and "Profile Index" in this section; for dowel and tie bar alignment verification; concrete quality (except modulus of rupture); and pavement thickness. Additional test strips will be required when:

A. A portion of a test strip fails to conform to the provisions in Section 40-1.10, "Final Finishing," of the Standard Specifications for straight edge requirements;
B. A portion of the test strip fails to conform to profile requirements;
C. The Contractor proposes different paving equipment, including a batch plant, paver, dowel inserter, tie bar inserter, tining, or curing equipment;
D. The dowel bar tolerances are not met;
E. The pavement thickness deficiency is greater than 15 mm after grinding; or
F. A change in concrete mix proportions has occurred.

The Contractor shall perform coring of the test strips, as directed by the Engineer, as part of the dowel and tie bar placement tolerance verification, and pavement thickness verification. The Engineer will select a minimum of six dowels and six tie bars that will be cored for each test strip. After removal of cores, voids in concrete pavement shall be cleaned and filled with hydraulic cement grout conforming to the provisions in "Core Drilling for Dowel Placement Alignment Assurance Testing" in this section.

Before mechanical dowel inserters are used, the Contractor shall demonstrate that the insertion equipment will not leave surface irregularities such as depressions, dips, or high areas adjacent to the dowel bar insertion point, or voids or segregation around dowels.

Prior to placement of the test strip, the Contractor shall submit a written procedure to locate transverse weakened plane joints that will coincide with the center of the dowels being placed. This procedure shall be submitted prior to the prepaving conference, and shall describe the control of inadvertent covering of paint markings after applying curing compound, excessive paint spray producing too large a paint dot marking for the accuracy required, misalignment by transferring marking spots, and inadequate staking of joints.

Construction of concrete pavement shall not proceed until the Engineer has completed an evaluation of the test strip. The Engineer shall be allowed three days, not including Saturdays, Sundays and legal holidays, to evaluate the test strip. If, in the opinion of the Engineer, the Contractor's controlling operation is delayed or interfered with by reason of the Engineer not completing the evaluation of the test strip within the time specified, the delay will be considered a right of way delay in conformance with the provisions in Section 8-1.09, "Right of Way Delays," of the Standard Specifications. Test strips failing to conform to the specifications for concrete pavement shall be removed. Additional test strips shall be constructed until the Contractor constructs a test strip that conforms to the specifications for concrete pavement. Additional test strips shall conform to the requirements in this section, except the test strip shall be 200 m in length.

Prior to constructing additional test strips, the Contractor shall change methods or equipment to construct a test strip that conforms to the provisions in Section 40-1.10, "Final Finishing," of

the Standard Specifications, "Profile Index" of this section, and dowel bar alignment verification, without grinding or other corrective work.

The Engineer may waive the initial test strip if the Contractor proposes to use a batch plant mixer and paving equipment with the same personnel that were satisfactorily used on a Department project within the preceding 12 months. The personnel shall be individuals listed in the prepaving conference used on a preceding Department project.

Materials resulting from the construction and removal of rejected test strips shall become the property of the Contractor and shall be removed and disposed of in conformance with the provisions in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications and these special provisions.

MATERIALS

Concrete

Attention is directed to Section 90, "Portland Cement Concrete," of the Standard Specifications, regarding mix proportions for concrete being determined by the Contractor.

Primary aggregate gradings shall conform to the gradation requirements of Section 90-3, "Aggregate Gradings," of the Standard Specifications. When combined in the proportions determined by the Contractor, the percent passing the 9.5 mm sieve and retained on the 2.36 mm sieve shall not be less than 16 percent of the total aggregate.

The cementitious material content shall not exceed 400 kg/m3.

Tie Bars

Tie bars shall be deformed reinforcing steel bars conforming to the requirements of ASTM Designation: A 615/A 615M, Grade 300 or 420; ASTM Designation: A 616/A 616M, Grade 350 or 400; or ASTM Designation: A 706/A 706M. Tie bars shall be epoxy-coated in conformance with the requirements in ASTM Designation: A 934/A 934M or A 775/A 775M and the provisions in Section 52-1.02B, "Epoxy-coated Reinforcement," of the Standard Specifications, except the epoxy-coating thickness after curing shall be between 175 to 400 micrometers (7 and 16 mils). Fabrication, sampling and jobsite handling shall conform to the requirements in ASTM Designation: D 3963 and the provisions in Section 52-1.02B, "Epoxy-coated Reinforcement," of the Standard Specifications, except the two samples shall be 750 mm long. Epoxy-coated tie bars shall not be bent.

Dowels

Dowels shall be smooth, round, epoxy-coated steel conforming to the requirements in ASTM Designation: A 615/A 615M, Grade 300 or 420, the details shown on the plans and the provisions in Section 52-1.02B, "Epoxy-coated Reinforcement," of the Standard Specifications. Epoxy coating of dowels shall conform to the provisions in ASTM Designation: A 884/A 884M, Class A, Type 1 or Type 2, except that the bend test shall not apply. Fabrication, sampling and jobsite handling shall conform to the requirements in ASTM Designation: D 3963 and the provisions in Section 52-1.02B, "Epoxy-coated Reinforcement," of the Standard Specifications, except the two samples shall be 460 mm long.

Dowels shall be plain, smooth, round bars. Dowels shall be free from burrs or other deformations detrimental to free movement of the bars in the concrete.

Bond Breaker

Dowels shall be lubricated with a bond breaker over the entire bar. A bond breaker application of petroleum paraffin based lubricant or white-pigmented curing compound shall be

used to coat the dowels completely prior to placement. Oil and asphalt based bond breakers shall not be used. Paraffin based lubricant shall be Dayton Superior DSC BB-Coat or Valvoline Tectyl 506 or an approved equal. Paraffin based lubricant shall be factory applied. White pigmented curing compound shall conform to the requirements of ASTM Designation: C 309, Type 2, Class A, and shall contain 22 percent minimum nonvolatile vehicles consisting of at least 50 percent paraffin wax. Curing compound shall be applied in two separate applications, the last application not more than 8 hours prior to placement of the dowels. Each application of curing compound shall be applied at the approximate rate of one liter per 3.7 m2.

Load Transfer Assemblies (Dowel Basket)

Load transfer assemblies shall be manufactured with a minimum welded wire gage number of 3/0 (9.2 mm). Assemblies shall be either U-frame or A-frame shape. J-frame shapes shall not be used. Assemblies shall be fabricated in conformance with the requirements in ASTM Designation: A 82. Welding of assemblies shall conform to the requirements in AASHTO Designation: M 254. A broken weld will be a cause for rejection of the assembly. Assemblies shall be Class A, Type 1 epoxy-coated in conformance with the requirements in ASTM Designation: A 884/A 884M. Fabrication and job-site handling shall conform to the requirements in ASTM Designation: D 3963 and the provisions in Section 52-1.02B, "Epoxy-coated Reinforcement," of the Standard Specifications, except that sampling of epoxy-coated wire reinforcement will not be required. A Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," shall be furnished for each shipment of epoxy-coated wire reinforcement certifying that the coated bars conform to the requirements in ASTM Designation: A 884/A 884M and the provisions in Section 52-1.02B, "Epoxy-coated Bar Reinforcement," of the Standard Specifications. The Certificate of Compliance shall include the certifications specified in ASTM Designation: A 884/A 884M and a statement that the coating material has been pre-qualified by acceptance testing performed by the Valley Forge Laboratories, Inc., Devon, Pennsylvania.

Concrete fasteners shall be used for anchoring dowel bar assemblies to lean concrete base or asphalt concrete base. Concrete fasteners shall be driven fasteners (concrete nails), used specifically for fastening to hardened concrete, conforming to the requirements of ASTM Designation: F 1667. Shank diameter shall be a minimum of 4 mm with a minimum shank length of 64 mm. Clips shall be commercial quality manufactured for use with dowel assemblies.

The surface of concrete fasteners, and clips shall be either zinc electroplated or galvanized with a minimum coating thickness of 0.005-mm.

Tie Bar Assemblies and Chairs

Tie bar assemblies and chairs shall be fabricated in conformance with the requirements in ASTM Designation: A 82. Welding of assemblies shall conform to the requirements in AASHTO Designation: M 254. A broken weld will be a cause for rejection of the assembly. Assemblies shall be Class A, Type 1 epoxy-coated in conformance with the requirements in ASTM Designation: A 884/A 884M. Fabrication and job-site handling shall conform to the requirements in ASTM Designation: D 3963 and the provisions in Section 52-1.02B, "Epoxy-coated Reinforcement," of the Standard Specifications, except that sampling of epoxy-coated wire reinforcement will not be required. A Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," shall be furnished for each shipment of epoxy-coated wire reinforcement certifying that the coated bars conform to the requirements in ASTM Designation: A 884/A 884M and the provisions in Section 52-1.02B, "Epoxy-coated Bar Reinforcement," of the Standard Specifications. The Certificate of Compliance shall include the certifications specified in ASTM Designation: A 884/A 884M and

a statement that the coating material has been pre-qualified by acceptance testing performed by the Valley Forge Laboratories, Inc., Devon, Pennsylvania.

Preformed Compression Joint Sealant

Preformed compression seals shall conform to the requirements of ASTM Designation: D 2628. Preformed compression seals shall have 5 or 6 cells. Lubricant adhesive used with preformed compression seals shall conform to the requirements of ASTM Designation: D 2835. Compression seals and lubricant adhesive shall be installed in conformance with the manufacturer's recommendations. The manufacture's recommendations shall be submitted to the Engineer at the prepaving conference.

Each lot of compression seal and lubricant adhesive shall be accompanied by a Certificate of Compliance in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications, and shall be accompanied with storage instructions and precautionary instructions for use. The Certificate shall also be accompanied with a certified test report of the results of the required tests performed on the preformed compression joint sealant material within the previous 12 months prior to proposed use. The Certificate and accompanying test report shall be provided for each lot of joint seal prior to use on the project. The Contractor shall submit the manufacturer's data sheet with installation instructions and recommended type of preformed compression seal for the joint size and depth as shown on the plans. The manufacturer's selected compression seal shall show evidence that the seal is being compressed at level between 20 and 50 percent for the joint width and depth shown on the plans.

Hydraulic Cement Grout (non-shrink)

Hydraulic cement grout (non-shrink) shall conform to the requirements in ASTM Designation: C 1107. At the Contractor's option, clean, uniform rounded aggregate filler may be used to extend the grout. The extension of grout shall not exceed 60 percent of the mass or the maximum recommended by the manufacturer, whichever is less. The moisture content of the aggregate filler shall not exceed 0.5 percent. Grading of the aggregate filler shall conform to the following:

Sieve Size	Percentage Passing
12.5 mm	100
9.5 mm	85-100
4.75 mm	10-30
2.36 mm	0-10
1.10 mm	0-5

SUBMITTALS

If load transfer assemblies, or tie bar assemblies or chairs, are used, the Contractor shall submit working drawings in conformance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications. The working drawings shall contain details and a materials list with name, address, and telephone number of the supplier of concrete nails, and clips. The Contractor shall submit the working drawings 14 days prior to constructing the initial test strip. The Engineer will have 14 days to approve the working drawings. Should the Engineer fail to complete the review of the working drawings within the time allowance and if, in the opinion of the Engineer, the Contractor's controlling operation is delayed or interfered with by reason of the delay in reviewing the working drawings, the delay will be considered a right of way delay in conformance with the provisions in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

PAVEMENT CONCRETE MIX PROPORTIONS

The Contractor shall determine the mix proportions for pavement concrete. Section 40-1.015, "Cement Content," of the Standard Specifications shall not apply. The laboratory used to develop the mix proportions shall meet the requirements of ASTM Designation: C 1077, and shall have current AASHTO accreditation for test methods AASHTO Designation: T 97 or ASTM Designation: C 78, and AASHTO Designation: T 126 or ASTM Designation: C 192.

The minimum cementitious materials content or the maximum water to cementitious materials ratio shall be determined in conformance with the requirements in California Test 559. Trial mixtures shall be made no more than 24 months before field qualification. The minimum cementitious materials content or the maximum water to cementitious materials ratio shall be that determined from the trial mixtures curve to produce a minimum modulus of rupture of 3.9 MPa at 28 days age and 4.5 MPa at 42 days age. To account for variances in materials, production of concrete, and modulus of rupture testing, the Contractor shall include as part of the proposed mix proportions an increase to the cementitious material content or a decrease to the water to cementitious materials ratio, determined from trial mixtures, to ensure that portland cement concrete produced during paving operations conforms to the requirements in "Modulus of Rupture," in this section.

At least 14 days prior to field qualification, the Contractor shall submit the proposed pavement concrete mix proportions with laboratory test reports. Laboratory test reports shall include modulus of rupture determined for each trial mixture at ages of 10, 21, 28 and 42 days in conformance with the applicable portions of California Test 559.

Field Qualification

Field qualification of proposed mix proportions will be required prior to placement of pavement concrete. The Contractor shall perform field qualification and submit certified test data to the Engineer. Field qualification data shall be based upon the proposed use of materials, mix proportions, mixing equipment, procedures and size of batch.

Proposed concrete mix proportions will be field qualified when the test results of five beams from a single batch of concrete indicate the average modulus of rupture is at least 3.9 MPa with no single beam lower than 3.8 MPa at an age of the Contractor's choice but not later than 28 days. Beams shall be tested for modulus of rupture at a minimum of 10, 21, and 28 days of age. Test specimens shall be made and tested in conformance with the requirements in California Test 523.

The certified field qualification test data reports shall include the following:

A. Date of mixing,
B. Mixing equipment and procedures used,
C. Volume of batch in cubic meters and the mass or volume,
D. Type and source of ingredients used,
E. Penetration and slump of the concrete,
F. The air content of the concrete, and
G. The age at time of testing and strength of concrete specimens tested.

Field qualification test data reports shall be signed by a certified representative in charge of the laboratory that performed the tests.

If the Contractor changes a source of supply or proportions, the Contractor shall submit a new proposed mix design and furnish samples from the new source, or sources, at least 60 days prior to their intended use. The new mix proportions shall be trial batched and field qualified, unless, the Engineer determines the change is not substantive. No extension of contract time will

be allowed for the time required to perform the sampling, testing, preparing and qualifying new mix proportions for new aggregate sources proposed by the Contractor.

MODULUS OF RUPTURE

The Engineer will test portland cement concrete pavement for modulus of rupture in conformance with the requirements in California Test 523. Acceptance will be on a lot basis. Each lot shall not to exceed 750 m^3 of concrete pavement. The Engineer will determine sample locations. A minimum of six beam specimens shall be made from each sample. Beam specimens will be tested for modulus of rupture at 10, 21, and 28 days. The modulus of rupture for each lot will be calculated by averaging the results of two beams representing that lot tested at 28 days of age. The difference in modulus of rupture between each individual beam result shall not exceed 0.44-MPa.

The Contractor shall perform sampling and testing of beam specimens to determine if concrete pavement has achieved a modulus of rupture of 2.4 MPa when requesting early use of concrete pavement in conformance with the provisions in Section 90-8.03, "Protecting Concrete Pavement," of the Standard Specifications. Beam specimens shall be made and tested in conformance with the requirements in California Test 523.

INSTALLING TIE BARS

Tie bars shall be installed at longitudinal contact joints and longitudinal weakened plane joints as shown on the plans. Consecutive width of new portland cement concrete pavement tied together with tie bars shall not exceed 15 m. Tie bars shall not be used at a joint where portland cement concrete and asphalt concrete pavements abut.

Tie bars shall be installed at longitudinal joints by one of the following methods:

A. Drilling and bonding tie bars with two-component, epoxy-resin that conforms to this section. Drilled holes shall be cleaned in conformance with the epoxy manufacturer's instructions and shall be dry at the time of placing the epoxy and tie bars. Tie bars will be rotated 180º while being inserted into the epoxy filled holes. Immediately after inserting the tie bars into the epoxy, the tie bars shall be supported as necessary to prevent movement during curing and shall remain undisturbed until the epoxy has cured as specified by the manufacturer instructions. Tie bars that are improperly placed or bonded, as determined by the Engineer, will be rejected. If rejected, new holes shall be drilled and new tie bars shall be placed and securely bonded to the concrete. Rejected tie bars shall be cut flush with the joint face. Exposed ends of tie bars shall be epoxy coated. The center of the new holes shall be offset 75 mm horizontally from the center of the rejected hole to maintain the minimum clearance to the dowel bar. Work necessary to correct improperly bonded tie bars shall be performed at the Contractor's expense.
B. Inserting tie bars into the plastic slipformed concrete before finishing the concrete. Inserted tie bars shall have full contact between the bar and the concrete. When tie bars are inserted through the pavement surface, the concrete over the tie bars shall be reworked and refinished so that there is no evidence on the surface of the completed pavement that there has been an insertion performed. Loose tie bars shall be replaced by drilling and bonding as described in A above, at the Contractor's expense.
C. Using threaded dowel splice couplers fabricated from deformed bar reinforcement material, free of external welding or machining. Threaded dowel splice couplers shall be accompanied by a Certificate of Compliance in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications, and shall be

accompanied with installation instructions. Installation of threaded dowel splice couplers shall conform to the requirements of the manufacturer's recommendations.

D. Using tie bar assemblies or chairs that conforms with the requirements of these special provisions.

DOWEL PLACEMENT

Dowels shall be spaced as shown on the plans, except dowels placed adjacent to a longitudinal joint or edge of pavement in the concrete pavement shall be placed 150 mm from that joint or edge of pavement. Dowels shall be centered on the transverse joint within a tolerance of ±50 mm in the longitudinal direction directly over the contact joint or sawcut for the transverse weakened plane joints, as shown on the plans. Prior to placement of dowels, the Contractor shall submit to the Engineer a written procedure to identify the transverse weakened plane joint locations relative to the middle of the dowels and the procedure for consolidating concrete around the dowels.

Dowels shall be placed by using load transfer assemblies (dowel baskets) or by mechanical insertion. Dowels shall be oriented parallel with the pavement lane centerline and surface of the pavement at mid-pavement depth. Dowel alignment, in both horizontal and vertical planes, shall be within 9 mm per 460 mm of dowel length. Dowel transverse placement shall be within 25 mm of the location shown on the plans. Dowels shall be placed a distance below the pavement surface that is at least:

$$DB = \frac{d}{3} + 12$$

Where:

DB = distance in mm, measured from pavement surface to top of dowel
d = pavement thickness in mm

Dowels may be placed a maximum of 15 mm below the depth shown on the plans.

When dowels are placed by mechanical insertion, the concrete over the dowels shall be reworked and refinished so that there is no evidence on the surface of the completed pavement that there has been any insertion performed.When load transfer assemblies (dowel baskets) are used, they shall be securely anchored firmly to the base to hold the dowels at the specified depth and alignment during concrete placement without displacement. A minimum of 8 alternating, equally spaced, concrete fasteners with clips shall be used to anchor each 3.6 m assembly (4 per lower runner wire). At least 10 concrete fasteners shall be used for assembly sections greater than 3.6 m and less than or equal to 4.9 m. Temporary spacer wires connecting load transfer assemblies shall be cut or removed after the assemblies are anchored into position prior to concrete placement. Paving shall be suspended when approved assemblies are not in place at least 60 m in advance of the concrete placement operation. The Engineer may waive this requirement upon written request by the Contractor, in areas, where access is restricted, or other construction limitations are encountered.

Approval of the initial placement of load transfer assemblies shall not constitute acceptance of the final position of the dowels.

CORE DRILLING FOR DOWEL PLACEMENT ALIGNMENT ASSURANCE TESTING

Coring, to confirm dowel bar placement, alignment, and concrete consolidation, shall be provided by the Contractor throughout the project, at locations determined by the Engineer. Each day's paving shall be cored within 2 days by performing one test for every 1670 m2 of doweled pavement or fraction thereof. One test shall consist of drilling two cores, one on each end of a dowel bar to expose both ends and allow measurement for proper alignment. If the cores indicate that dowels are not within the allowable tolerances or if air voids exist surrounding the dowels, additional cores will be required to determine the limits and severity of unacceptable work.

The holes shall be cored by methods that will not damage the concrete adjacent to the holes. Immediately after coring, the concrete cores shall be submitted to the Engineer for inspection, and the cores shall be identified by the Contractor with a location description.

After removal of cores, core hole voids in concrete pavement shall be cleaned and filled with hydraulic cement grout (non-shrink). After placement of hydraulic cement grout, the material while still plastic shall be finished and textured to match the adjacent pavement surface. The backfill material shall be the same level as the pavement surface.

Water for core drilling operations shall be from a local domestic water supply, and shall contain not more than 1000 parts per million of chlorides as CL, nor more than 1300 parts per million of sulfates as SO4, nor shall it contain impurities in a sufficient amount to cause discoloration of the concrete or produce etching of the surface.

Water from core drilling operations shall not be permitted to fall on public traffic, to flow across shoulders or lanes occupied by public traffic, or to flow into gutters or other drainage facilities.

Dowel bar alignment shall be within the specified tolerances. If dowels are found to be installed improperly, the paving operations shall not continue until the Contractor has demonstrated to the Engineer that the problem which caused the improper dowel bar positioning has been corrected.

Dowels in rejected joints shall be replaced by the Contractor by saw cutting on each side of the rejected joint a minimum of 0.9-m, lifting out concrete to be removed, installing new dowels at the new transverse joints, installing dowels and preformed sponge rubber expansion joint filler along the longitudinal joints, placing concrete, and installing new joints. Preformed sponge rubber expansion joint filler shall conform to the requirements in ASTM Designation: D 1752. New dowel holes shall be drilled, not more than 3 mm greater than the dowel bar diameter, by the use of an automatic dowel-drilling rig for the dowels to be installed at the contact joints. Dowels shall be placed, as shown on the plans, for the 2 new transverse contact joints. Original exposed tie bars, located within the slab replacement area, shall be cut flush with the lane or pavement edge and dowels shall be installed to replace the tie bars at an offset of 75 mm, horizontally from the tie bar location. Holes for dowels to be placed along the longitudinal joint shall be drilled, not more than 3 mm greater than the dowel bar diameter, by the use of an automatic dowel-drilling rig for the dowels to be installed at the contact joints.

When requested by the Contractor and approved by the Engineer, dowels which are more than ±50 mm but less than ±75 mm from being centered directly over the sawcut for the transverse weakened plane joint, may remain in place, and the Contractor shall pay to the State the amount of $32.30 per square meter for the quantity of concrete pavement panels represented by the cores indicating incorrect dowel bar alignment or improper concrete consolidation around dowels. The quantity of concrete pavement area used to determine the amount payment to the State will be calculated using the panel dimensions for panels adjacent to and inclusive of the joints with incorrect dowel bar alignment or improper concrete consolidation around dowels.

The Department will reduce compensation from moneys due, or that may become due to the Contractor under the contract. This reduced compensation shall be in addition to other adjustments for pavement thickness deficiency in conformance with the provisions in Section 40-1.135, "Pavement Thickness," of the Standard Specifications and in addition to other adjustments for deficient Cleanness Value and coarse aggregate grading; and for deficient Sand Equivalent and fine aggregate grading in conformance with the provisions in Section 90-2.02, "Aggregate," of the Standard Specifications.

PREFORMED COMPRESSION JOINT SEAL INSTALLATION

The compression seal alternative joint detail for transverse and longitudinal joints, as shown on the plans, shall apply only to weakened plane joints. Weakened plane joints shall be constructed by the sawing method. Should grinding or grooving be required over or adjacent to any joint after the compression seal has been placed, the joint materials shall be removed and disposed of, and replaced at the Contractor's expense. Compression seals shall be recessed below the final finished surface as shown on the plans.

At the Contractor's option, transverse weakened plane joints shall be either Type DSC or Type SSC as shown on the plans. Longitudinal weakened plane joints shall be Type SSC as shown on the plans.

Seven days after the concrete pavement placement and not more than 4 hours before placing preformed compression joint seals,the joint walls shall be cleaned by the dry sand blast method and other means as necessary to remove from the joint objectionable material such as soil, asphalt, curing compound, paint and rust. After cleaning the joint, traces of sand, dust and loose material shall be removed from and near the joint for a distance along the pavement surfaces of at least 50 mm on each side of the joint by the use of a vacuum device. Surface moisture shall be removed at the joints by means of compressed air or moderate hot compressed air or other means approved by the Engineer. Drying procedures that leave a residue or film on the joint wall shall not be used. Sandblasting equipment shall have a maximum nozzle diameter size of 6 ± 1 mm and a minimum pressure of 0.62-MPa.

CONSTRUCTING TRANSVERSE CONTACT JOINTS

A transverse contact (construction) joint shall be constructed, including dowels, at the end of each day's work or where concrete placement is interrupted for more than 30 minutes, to coincide with the next weakened plane joint location.

If sufficient concrete has not been mixed to form a slab to match the next weakened plane joint, when an interruption occurs, the excess concrete shall be removed and disposed of back to the last preceding joint. The cost of removing and disposing of excess concrete shall be at the Contractor's expense. Excess material shall become the property of the Contractor and shall be disposed of in conformance with the provisions in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

A metal or wooden bulkhead (header) shall be used to form the joint. The bulkhead shall be designed to accommodate the installation of dowels.

PROFILE INDEX

The pavement surface shall be profiled, by the Contractor not more than 10 days following concrete placement, in the presence of the Engineer, using a California Profilograph or equivalent in conformance with the requirements in California Test 526, except a blanking band of zero (null) shall be used to determine the Profile Index. Two profiles shall be made within each traffic lane, one meter from and parallel with each lane line.

Profiled pavement shall conform to the following Profile Index requirements:

A. Pavement on tangent alignment and pavement on horizontal curves having a centerline radius of curve 600 m or more shall have a Profile Index of 64 mm or less for each 0.1-km.
B. Pavement on horizontal curves having a centerline radius of curve 300 m or more but less than 600 m and pavement within the superelevation transition of those curves shall have a Profile Index of 128 mm or less for each 0.1-km.

Concrete shoulders shall be profiled. Two profiles shall be made within the shoulder, one meter from and parallel with each edge of the shoulder. Concrete shoulders profiled shall conform to the Profile Index requirements in this section.

Individual high points in excess of 7.5 mm, as determined by measurements of the profilogram in conformance with the requirements in California Test 526, except using a blanking band of zero (null), shall be reduced by grinding in conformance with the requirements in Section 40-1.10, "Final Finishing," of the Standard Specifications until the high points as indicated by reruns of the profilograph do not exceed 7.5 mm.

Pavement grinding shall not be performed before 10 days have elapsed after concrete placement, nor before the concrete has developed a modulus of rupture of at least 3.8 MPa.

MEASUREMENT AND PAYMENT

Sealing transverse weakened plane joints in portland cement concrete pavement will be measured by the meter. When a test strip conforms to the specifications for concrete pavement and remains a part of the project paving surface, the sealed pavement joints will be measured and paid for as seal pavement joint.

The contract price paid per meter for seal pavement joint shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in sealing pavement joints complete in place, including sawing, cleaning and preparing the joints in the concrete pavement, furnishing and installing compression seals, repairing and patching spalled or raveled sawed joints, and replacing or repairing rejected joints, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Concrete pavement will be measured by the cubic meter in conformance with the provisions in Section 40-1.13, "Measurement," of the Standard Specifications. No deduction will be made for the volume of epoxy-coated dowels, epoxy-coated tie bars and, when used, tie bar assemblies or chairs with fasteners and dowel assemblies with fasteners, in the concrete pavement. When a test strip conforms to the specifications for concrete pavement and remains a part of the project paving surface, the concrete will be measured and paid for as concrete pavement.

The contract price paid per cubic meter for concrete pavement shall include full compensation for furnishing all labor, materials (including cementitious material in the amount determined by the Contractor), tools, equipment, and incidentals, and for doing all the work involved in constructing the portland cement concrete pavement complete in place, including furnishing and placing epoxy-coated dowels, epoxy-coated tie bars and, when used, any tie bar assemblies or chairs and dowel assemblies with fasteners, submittal to the Engineer all test data for determination of mix proportions of concrete for concrete pavement and for providing the facility, Contractor personnel and all the work involved in arranging and holding the prepaving conference, for constructing and repairing all joints; for performing all profile checks for Profile Index and furnishing final profilograms to the Engineer; for grooving and grinding required for final finishing; and for removing, and replacing pavement for deficient thickness, as shown on

the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Full compensation for drilling holes and bonding tie bars with epoxy resin shall be considered as included in the contract price paid per cubic meter for concrete pavement and no additional compensation will be allowed therefor.

Full compensation for coring test strips for evaluation by the Engineer and for back-filling core holes with hydraulic cement grout when the test strip remains in place as part of the concrete pavement; and for constructing, coring and removing and disposing of test strips that are rejected shall be considered as included in the contract price paid per cubic meter for concrete pavement and no additional compensation will be allowed therefor.

Costs for providing JITT will be determined in conformance with the provisions in Section 9-1.03, "Force Account Payment," of the Standard Specifications, except no markups shall be added, and the Contractor will be paid for one half of the JITT cost. Costs for providing JITT shall include training materials, class site, and the JITT instructor including the JITT instructor's travel, lodging, meals and presentation materials. All costs incurred by the Contractor or Engineer for attending JITT shall be borne by the party incurring the costs.

Full compensation for core drilling for dowel bar alignment and backfilling with hydraulic cement grout shall be considered as included in the contract price per cubic meter for concrete pavement and no additional compensation will be allowed therefor.

If the initial cores show the dowels are out of alignment and the Engineer orders additional dowel coring, full compensation for drilling the additional cores shall be considered as included in the contract price per cubic meter for concrete pavement and no additional compensation will be allowed therefor.

If the initial cores show that the dowels are within alignment tolerances and the Engineer orders more dowel coring than the one test for every 1670 square meters of doweled pavement, the additional cores will be paid for as extra work in conformance with the provisions in Section 4-1.03D, "Extra Work," of the Standard Specifications.

10-1.__ ROCK BOLTS

Rock bolts at existing rock slope of South Portal area , consisting of holes drilled in native material, grouted steel bars, anchorage assemblies, and anchorage enclosure, and testing of installed rock bolts shall conform to the details shown on the plans, the provisions in Section 50, "Prestressing Concrete," of the Standard Specifications, and these special provisions.

Difficult rock bolt installation is anticipated due to the access to rock bolt locations.

In fabricating, handling, shipping, and placing rock bolts, adequate care shall be taken to avoid damage to the sheathing. Damage to the sheathing caused by handling and fabrication prior to rock bolt installation shall be repaired or replaced as determined by the Engineer. Repair procedure for the sheathing shall be included in the working drawings.

MATERIALS

Whenever "member" is referred to in Section 50, "Prestressing Concrete," of the Standard Specifications, it shall be considered to mean rock bolt.

Grout shall conform to the provisions in Section 50-1.09, "Bonding and Grouting," of the Standard Specifications. Fine aggregate may be added to the grout mixture of portland cement and water used outside of the grouted sheathing in drilled holes which are 200 mm or greater in diameter, but only to the extent that the cement content of the grout is not less than 500 kg per cubic meter of grout. Fine aggregate, if used, shall conform to the provisions in Section 90-2, "Materials," and Section 90-3, "Aggregate Gradings," of the Standard Specifications.

The smooth plastic sheathing for rock bolts shall conform to one of the following: polyvinyl chloride (PVC) sheathing, or high density polyethylene (HDPE) sheathing.

Corrugated plastic sheathing shall be PVC or HDPE. The width of corrugations, the distance between corrugations, and the height of corrugations of corrugated plastic sheathing shall be approximately the same.

PVC sheathing may be used for corrugated sheathing and smooth sheathing for bar tendons. PVC sheathing shall conform to ASTM Designation: D 1784, Class 13464-B. Corrugated PVC sheathing shall have a nominal wall thickness of 1.0 mm. HDPE sheathing may be used for corrugated sheathing and smooth sheathing for bar tendons. HDPE sheathing shall have a density between 940 kg/m3 and 960 kg/m3 as measured in accordance with ASTM Designation: D 792, A-2. Corrugated HDPE sheathing shall have a nominal wall thickness of 1.5 mm for sheathing with an outside diameter of 75 mm or greater, and a nominal thickness of 1.0 mm for sheathing with an outside diameter less than 75 mm, with a tolerance of minus 0.25-mm.

The corrugated sheathing, including joints, shall have sufficient strength to prevent damage during construction operations and shall be grout-tight and watertight, chemically stable without embrittlement or softening, and nonreactive with concrete, steel, or corrosion inhibiting grease.

The transition between the corrugated plastic sheathing and the anchorage assembly shall be an approved detail that allows stressing to the design force without evidence of distress in the corrugated plastic sheathing.

Additional requirements for rock bolts are as follows:

A. The corrosion inhibiting grease shall have the physical properties listed in Table 3.2.1 of the Post Tensioning Manual, Fourth Edition, by the Post Tensioning Institute and as modified below. At least 40 days before use, a sample from the lot to be used and test results shall be provided for the corrosion inhibiting grease.

Test	Requirements	ASTM Designation:
Water Soluble Ions: Nitrates	10 ppm max.	D 3867
Corrosion Test: 5% Salt Fog @ 38° C. 125 µm coating on 76 mm x 152 mm Q panel Type S, 1000 hrs min.	Grade 7 or better	B 117, D 610
Compatibility with sheathing: Hardness change & volume change of polymer after exposure to grease 40 days at 66° C.	15% max. 10% max.	D 4289, except use D 792 for density

B. A Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications, shall be furnished to the Engineer certifying that the corrosion inhibiting grease complies with the requirements herein if sample and test results are not provided for the lot used.

CONSTRUCTION

Rock bolts shall be installed in accordance with the manufacturer's recommendations. In case of a conflict between the manufacturer's recommendations and these special provisions, these special provisions shall prevail.

Water and grout from rock bolt construction operations shall not be permitted to fall on public traffic, to flow across shoulders or lanes occupied by public traffic, or to flow into landscaping, gutters, or other drainage facilities. Excessive amounts of water shall not be used in any of the drilling and the rock bolt installation procedures.

Rock bolt steel shall be protected prior to completion of all grouting against rust, corrosion and physical damage in conformance with the provisions in Section 50, "Prestressing Concrete," of the Standard Specifications. In addition, there shall be no evidence of distress in the plastic sheathing or crushing of the cement grout within the pregrouted sheathing.

The rock bolt anchorage assembly shall be protected against rust, corrosion, and physical damage prior to completion of all grouting of enclosure and encasement in concrete.

The rock bolt installation method selected by the Contractor shall be sufficient to achieve the loadings specified herein. Holes for rock bolts shall be drilled in the foundation to a depth sufficient to provide the necessary bond length beyond the minimum unbonded length shown on the plans.

Rock bolt anchorage holes shall be drilled by either the rotary or rotary percussion drilling method. Prior to drilling the rock bolt holes, at the option of the Contractor, the Contractor may prepare and install full length temporary casing to control caving conditions.

The diameter of the drilled hole shall be large enough to provide a minimum of 25 mm grout cover within the bonded length of the tendon. A minimum of three mechanical centralizers shall be used to adequately support the bar in the center of the drilled, bored, or cored hole and shall be spaced at a maximum of 3 m.

Pregrouting shall occur at least 48 hours before placing the bar tendon in the drilled hole.

Prior to installing each rock bolt assembly into the drilled hole, the rock bolt assembly shall be clean and free of oil, grease, or other extraneous substances, and any damage to the sheathing shall be repaired or replaced.

Grout for all stages of rock bolt construction shall be injected at the low end of the void being filled and shall be expelled at the high end until there is no evidence of entrapped air, water, or diluted grout. The grout shall be placed using grout tubes, unless another method is approved by the Engineer. The quantity of the grout and the grout pressures shall be recorded.

Voids in the foundation material may be encountered along the length of the drilled hole which may affect drilling and grouting. Measures such as the use of a "grout sock" may be necessary to avoid the excessive loss of grout into the voids encountered.

After placing initial grout, the rock bolt shall remain undisturbed until the grout has reached a strength sufficient to provide anchorage during testing operations. Anchor head shall be fully embedded in the rock and covered by mortar to match the texture of the rock.

Additional requirements for rock bolts with bar type tendons are as follows:

A. The bar in the unbonded area shall be sheathed with smooth sheathing that extends into the steel tube of the permanent rock bolt anchorage assembly, as shown on the plans. For this portion of smooth sheathing there is no minimum wall thickness and the sheathing shall be either PVC or HDPE.
B. In addition, bar shall be sheathed full-length with corrugated sheathing. The annular space between the bar and the corrugated sheathing shall be pregrouted prior to placing the tendons in the drilled hole. The bar shall be centered in the sheathing.
C. There shall be a seal between the smooth sheathing and the corrugated sheathing at the top and bottom of the length of smooth sheathing.
D. For bar, the initial grout in the drilled hole may be placed before or after insertion of the bar tendon.

E. For drilled holes 150 mm in diameter or less, the initial grout outside of the corrugated sheathing shall extend to within 150 mm of the end of the steel tube of the anchorage assembly. Grout in the unbonded length shall not be placed under pressure. For drilled holes greater than 150 mm in diameter, the initial grout outside of the corrugated sheathing shall be within the limits of the bonded length. After placing the initial grout, the rock bolt shall remain undisturbed until the grout has reached a strength sufficient to provide anchorage during testing operations.

Testing

All rock bolts shall be load tested by a proof test. Proof test shall be performed using the permanent bearing assembly. The magnitude of applied test loads shall be determined with a calibrated pressure gauge or a load cell. Movements of the end of the rock bolt, relative to an independent fixed reference point, shall be measured and recorded to the nearest 0.025 mm at each load increment during the load tests. The Contractor shall perform the measuring and recording and shall furnish the Engineer copies of the recorded movements.

The proof test shall be conducted by measuring the test load applied to the rock bolt and the rock bolt end movement during incremental loading and unloading of the rock bolt in accordance with the loading schedule. The test load shall be held constant for 10 minutes. During the test load hold, the movement of the end of the bar tendon shall be measured at 1, 2, 3, 4, 5, 6, and 10 minutes. If the total movement between one minute and 10 minutes exceeds one mm, the test load shall be held for an additional 50 minutes. Total movement shall be measured at 15, 20, 25, 30, 45, and 60 minutes. If the test load is held for 60 minutes, a creep curve showing the creep movement between one minute and 60 minutes shall be plotted as a function of the logarithm of time.

LOADING SCHEDULES		
		PROOF TEST
		AL
		0.25T
		0.50T
		0.75T
		1.00T
		1.25T
		1.50T (TEST LOAD)
		AL
T = Design force for the rock bolt shown on the plans		
AL = Alignment load		

For proof tests, each increment of load shall be applied in less than one minute and held for at least one minute but not more than 2 minutes or as specified above. The observation period for the load hold shall start when the pump begins to apply the last increment of load.

The jacking equipment, including the bar movement measuring system, shall be stable during all phases of the rock bolt loading operations.

All rock bolts shall be proof tested. If 1.5 times the design force cannot be obtained, the rock bolt shall be redesigned and replaced. Rock bolts shall not be retested, unless the rock bolt bond length is post-grouted after the unacceptable test.

A proof tested rock bolt is acceptable if:

A. The pattern of movements is similar to that of adjacent performance tested rock bolts; and
B. The creep movement between one and 10 minutes is less than 1.0 mm.

Proof tested rock bolts which fail to meet acceptance criterion B will be acceptable if the maximum load is held for 60 minutes and the creep curve plotted from the movement data indicates a creep rate of less than 2.0 mm for the last log cycle of time.

Lock-off

After successful testing of the rock bolts, the rock bolts shall be tensioned against the structure and locked off at a load equal to 0.10T or AL whichever is greater. The lock-off force is the load on the jacks which is maintained while the anchor head or anchor nuts on the rock bolt are permanently set. Immediately after lock-off, a lift-off test shall be performed to demonstrate that the specified lock-off force was obtained.

Grouting to the level of secondary grouting to the dimensions shown on the plans shall be completed only after successful testing and lock-off has been completed. At least 24 hours after the secondary grout has set, the remaining void in the steel tube and bearing plate shall be filled with grout. Grout shall be injected at the low end and expelled at the high end until there is no evidence of entrapped air or water. A minimum grout head of 600 mm shall be maintained until the grout has set.

The rock bolt anchor head or anchor nuts shall be enclosed with a grouted anchorage enclosure device. After grouting the steel tube, the bearing plate surface shall be cleaned, sealant placed, and the anchorage enclosure bolted in place. After bolting the anchorage enclosure in place the void in the anchorage enclosure shall be filled with grout by injecting grout at the low end of the void and venting at the high end. Any holes in the top of the anchorage enclosure used for grout placement shall be cleaned and sealed with sealant. Sealant shall be a non-sag polysulfide or polyurethane sealing compound conforming to the provisions in Federal Specification TT-S-230, Type II.

MEASUREMENT AND PAYMENT

No payment will be made for rock bolts which do not pass the specified testing requirements.

Rock bolts will be measured and paid for by the unit, and the number for payment will be determined by the requirements of the details shown on the plans.

The contract unit price paid for rock bolt shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing the rock bolts, including special measures taken to contain grout in the drilled hole, temporary casing (if used), testing, and furnishing and installing anchorage assemblies, complete in place, including repair or replacement of sheathing as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.__ CONCRETE STRUCTURES

Portland cement concrete structures shall conform to the provisions in Section 51, "Concrete Structures," of the Standard Specifications and these special provisions.

Unless otherwise specified, concrete surfaces leading to drains shall be sloped at a minimum of 10 mm per meter toward the drain and the adjacent surfaces warped as required to provide adequate drainage flow.

Unless otherwise shown on the plans, all exposed concrete edges and corners shall be chamfered with 20 mm, 45 degree chamfer.

Shotcrete shall not be used as an alternative construction method for reinforced concrete members unless otherwise specified.

When a roughened concrete surface is shown on the plans, the previously constructed concrete surface shall be roughened to a full amplitude of approximately 6 mm by abrasive blasting, water blasting, or mechanical equipment.

AGGREGATE GRADINGS

The aggregate grading of concrete shall conform to the requirements in Section 90-3, "Aggregate Gradings," of the Standard Specifications.

FINAL LINING CONTACT GROUTING

Contact grout pipes shall be polyvinyl chloride (PVC) pipe schedule 40; ASTM D1785, and shall conform to the details shown on the plans. Contact grout pipes shall be provided with inside thread and removable plug, perforated at rubber sleeves. Rubber sleeves at nominal 1.8 m on centers for distribution of grout. The Contractor shall provide supports to the contact grout pipes in the forms during placement of concrete.

Grout mix for contact grouting shall consist of one part portland cement, one part fine aggregate, and admixture as approved by the Engineer. Contact grout shall conform minimum compressive strength of 0.7 MPa at 24 hours and 31 MPa at 28 days when tested according to ASTM C109. Minimum water shall be added to achieve water-cement ratio to be compatible with pumping and placing requirements.

Contact grouting shall be performed through contact grouting pipes with to fill all voids. Maximum pressure for contact grouting shall not exceed 0.2 MPa. Grout shall be pumped until grout manifests at adjacent vent pipe.

Contact grouting shall not be performed until final lining concrete has attained its 28-day strength.

Concrete surface finish shall conform to Section 51-1.18B, "Class 1 Surface Finish," of the Standard Specifications.

FALSEWORK

Falsework shall conform to the provisions in Section 51, "Concrete Structures," of the Standard Specifications and these special provisions.

In addition to the provisions in Section 51-1.06A, "Falsework Design and Drawings," of the Standard Specifications, the time to be provided for the Engineer's review of the working drawings for specific structures, or portions thereof, shall be as follows:

Structure or Portion of Structure	Total Review Time - Weeks
Tunnel Final Lining	16
Portals	16

Welding and Nondestructive Testing

Welding of steel members, except for previously welded splices and except for when fillet welds are used where load demands are less than or equal to 175 N/mm for each 3 mm of fillet weld, shall conform to AWS D1.1 or other recognized welding standard. The welding standard to be utilized shall be specified by the Contractor on the working drawings. Previously welded splices for falsework members are defined as splices made prior to the member being shipped to the project site.

Splices made by field welding of steel beams at the project site shall undergo nondestructive testing (NDT). At the option of the Contractor, either ultrasonic testing (UT) or radiographic testing (RT) shall be used as the method of NDT for each field weld and any repair made to a previously welded splice in a steel beam. Testing shall be performed at locations selected by the Contractor. The length of a splice weld where NDT is to be performed, shall be a cumulative weld length equal to 25 percent of the original splice weld length. The cover pass shall be ground smooth at the locations to be tested. The acceptance criteria shall conform to the requirements of AWS D1.1, Section 6, for cyclically loaded nontubular connections subject to tensile stress. If repairs are required in a portion of the weld, additional NDT shall be performed on the repaired sections. The NDT method chosen shall be used for an entire splice evaluation including any required repairs.

For all field welded splices, the Contractor shall furnish to the Engineer a letter of certification which certifies that all welding and NDT, including visual inspection, are in conformance with the specifications and the welding standard shown on the approved working drawings. This letter of certification shall be signed by an engineer who is registered as a Civil Engineer in the State of California and shall be provided prior to placing any concrete for which the falsework is being erected to support.

For previously welded splices, the Contractor shall determine and perform all necessary testing and inspection required to certify the ability of the falsework members to sustain the stresses required by the falsework design. This welding certification shall be in writing, shall be signed by an engineer who is registered as a Civil Engineer in the State of California, and shall be provided prior to placing any concrete for which the falsework is being erected to support.

The Contractor's engineer who signs the falsework drawings shall also certify in writing that the falsework is constructed in conformance with the approved drawings and the contract specifications prior to placing concrete. This certification shall include performing any testing necessary to verify the ability of the falsework members to sustain the stresses required by the falsework design. The engineer who signs the drawings may designate a representative to perform this certification. Where falsework contains openings for railroads, vehicular traffic, or pedestrians, the designated representative shall be qualified to perform this work, shall have at least three years of combined experience in falsework design or supervising falsework construction, and shall be registered as a Civil Engineer in the State of California. For other falsework, the designated representative shall be qualified to perform this work and shall have at least three years of combined experience in falsework design or supervising falsework construction. The Contractor shall certify the experience of the designated representative in writing and provide supporting documentation demonstrating the required experience if requested by the Engineer.

MEASUREMENT AND PAYMENT

Measurement and payment for concrete in structures shall conform to the provisions in Section 51-1.22, "Measurement," and Section 51-1.23, "Payment," of the Standard Specifications and these special provisions.

The contract price paid per cubic meter for structural concrete, final lining shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing final lining concrete, complete in place, including contact grouting, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per cubic meter for structural concrete, transition barrier slab shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing transition barrier slab, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per cubic meter for structural concrete, final lining abutment shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing final lining abutment concrete, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per cubic meter for structural concrete, final lining invert arch shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing final lining invert arch concrete, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per cubic meter for structural concrete, final lining invert slab shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing final lining invert slab concrete, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Concrete for the following items will be measured and paid for by cubic meter as structural concrete, portal:

A. Ventilation outlet structure
B. Leach water pump station
C. Water storage tank
D. Waste water tank
E. Oil water separator tank

The contract price paid per cubic meter for structural concrete, portal shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing portal concrete, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Full compensation for risers and cover plates for ventilation outlet structure, leach water pump station, water storage tank, waste water tank, and oil water separator tank shall be considered as included in the contract price paid per cubic meter for structural concrete, portal and no additional compensation will be allowed therefor.

The contract price paid per cubic meter for structural concrete, portal invert slab shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing portal invert slab concrete including hold-down slab for water storage tank and equipment pads at north portal equipment chamber, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Support wall and footing at south portal will be measured and paid for as structural concrete, retaining wall.

MASONRY BLOCK WALL

Masonry block wall, consisting of a reinforced hollow unit masonry block stem, shall be constructed in conformance with the provisions in Sections 52, "Reinforcement," and 90, "Portland Cement Concrete," of the Standard Specifications and these special provisions.

Wall masonry unit stems shall be constructed with joints of portland cement mortar. Wall stems shall be constructed with hand laid block. Wall stems shall not be constructed with preassembled panels.

Concrete masonry units shall be hollow, load bearing, conforming to the requirements in ASTM Designation: C 90, medium weight classification, Type II. The mass of each unit shall not exceed 17.2 kg. Standard or open end units may be used. Open end units, if used, shall not reduce the spacing of the bar reinforcement as shown on the plans.

The masonry units shall be nominal size and texture and of uniform color. The color shall match the color and texture of the adjoining concrete, selected from the manufacturer's standards.

When high strength concrete masonry units with f'm=17.24 MPa are shown on the plans, the high strength masonry units shall have a minimum compressive strength of 25.86 MPa based on net area. When high strength concrete masonry units with f'm=13.79 MPa are shown on the plans, the high strength masonry units shall have a minimum compressive strength of 19.31 MPa based on net area. Each high strength concrete masonry unit shall be identified with a groove embedded in an interior corner. The groove shall extend from a mortar surface for a length of about 50 mm and shall have a depth of about 5 mm. When regular strength concrete masonry units with f'm=10.34 MPa are shown on the plans, the regular strength masonry units shall have a minimum compressive strength of 13.1 MPa based on net area.

Expansion joint filler shall conform to the requirements in ASTM Designation: D 1751 or ASTM Designation: D 2000 2AA-805.

Portland cement mortar shall be colored to match the units. Coloring shall be chemically inert, fade resistant mineral oxide or synthetic type.

Portland cement for wall stems shall conform to the provisions in Section 90-2.01, "Portland Cement," of the Standard Specifications.

Hydrated lime shall conform to the requirements in ASTM Designation: C 207, Type S.

Mortar sand shall be commercial quality.

Mortar for laying masonry units shall consist, by volume, of one part portland cement, zero to 0.5 part hydrated lime, and 2.25 to 3 parts mortar sand. Sufficient water shall be added to make a workable mortar. Each batch of mortar shall be accurately measured and thoroughly mixed. Mortar shall be freshly mixed as required. Mortar shall not be retempered more than one hour after mixing.

Prepackaged mortar materials and mortar containing admixtures may be used when approved in writing by the Engineer, provided the mortar shall not contain more than 0.05-percent soluble chlorides when tested in conformance with California Test 422 nor more than 0.25-percent soluble sulfates, as SO4, when tested in conformance with California Test 417.

Before laying masonry units using prepackaged mortar materials or mortar containing admixtures, the Contractor shall submit to the Engineer the proposed sources of the materials together with test data from an independent testing laboratory for mortar tested in conformance with California Test 551. The test data shall be from specimens having a moist cure, except, the sample shall not be immersed in lime water. The average 28-day compressive strength of the mortar shall be not less than 17.2 MPa.

Aggregate for grout used to fill masonry units shall consist of fine aggregate and coarse aggregate conforming to the provisions in Section 90-2.02, "Aggregates," of the Standard Specifications. At least 20 percent of the aggregate shall be coarse aggregate. The Contractor shall determine the grading except that 100 percent of the combined grading shall pass the 12.5-mm sieve.

At the option of the Contractor, grout for filling masonry units may be proportioned either by volume or mass. Grout shall contain only enough water to cause the grout to flow and fill the voids without segregation. The maximum amount of free water shall not exceed 0.7 times the weight of the cement for regular strength masonry. The maximum amount of free water shall not exceed 0.6 times the mass of the cement for high strength masonry.

Grout proportioned by volume for regular strength masonry shall consist of at least one part portland cement and 4.5 parts aggregate. Grout proportioned by volume for high strength masonry shall consist of at least one part portland cement and 3.5 parts aggregate. Aggregate volumes shall be based on a loose, air-dry condition.

Grout proportioned by mass for regular strength masonry shall contain not less than 325 kilograms of portland cement per cubic meter. Grout proportioned by mass for high strength masonry shall contain not less than 400 kilograms of portland cement per cubic meter.

Reinforced concrete masonry unit wall stems shall be constructed with portland cement mortar joints in conformance with the following:

A. Concrete masonry unit construction shall be true and plumb in the lateral direction and shall conform to the grade shown on the plans in the longitudinal direction. Bond beam units or recesses for horizontal reinforcement shall be provided.
B. Mortar joints shall be approximately 10 mm wide. Walls and cross webs forming cells to be filled with grout shall be full bedded in mortar to prevent leakage of grout. All head and bed joints shall be solidly filled with mortar for a distance in from the face of the wall or unit not less than the thickness of the longitudinal face shells. Head joints shall be shoved tight.
C. Mortared joints around cells to be filled shall be placed so as to preserve the unobstructed vertical continuity of the grout filling. Any overhanging mortar or other obstruction or debris shall be removed from the inside of such cells.
D. Reinforcement shall be securely held in position at top and bottom with either wire ties or spacing devices and at intervals not exceeding 192 bar diameters before placing any grout. Wire shall be 16-gage (1.57 mm) or heavier. Wooden, aluminum, or plastic spacing devices shall not be used.
E. Splices in vertical reinforcement shall be made only at the locations shown on the plans.
F. Only those cells containing reinforcement shall be filled solidly with grout. All grout in the cells shall be consolidated at the time of placement by vibrating, and reconsolidated after excess moisture has been absorbed, but before plasticity is lost. Grout shall not be sliced with a trowel.
G. Walls shall be constructed in 1.2-m maximum height lifts. Grouting of each lift shall be completed before beginning masonry unit construction for the next lift. The top course of each lift shall consist of a bond beam.
H. A construction joint shall be constructed at the top of the top course to permit placement of the mortar cap. The mix design for the mortar cap shall be as approved by the Engineer.
I. Construction joints shall be made when the placing of grout, in grout filled cells, is stopped for more than one hour. The construction joint shall be approximately 12 mm below the top of the last course filled with grout.

J. Bond beams shall be continuous. The top of unfilled cells under horizontal bond beams shall be covered with metal or plastic lath.
K. When fresh masonry joins masonry that is partially or totally set, the contact surface shall be cleaned, roughened, and lightly wetted.
L. Surfaces of concrete on which the masonry walls are to be constructed shall be roughened and cleaned, exposing the aggregate, and shall be flushed with water and allowed to dry to a surface dry condition immediately before laying the masonry units.
M. Where cutting of masonry units is necessary, all cuts shall be made with a masonry saw to neat and true lines. Masonry units with cracking or chipping of the finished exposed surfaces will not be acceptable.
N. Masonry shall be protected in the same manner specified for concrete structures in Section 90-8, "Protecting Concrete," of the Standard Specifications and these special provisions.
O. During erection, all cells shall be kept dry in inclement weather by covering partially completed walls. The covering shall be waterproof fabric, plastic or paper sheeting, or other approved material. Wooden boards and planks shall not be used as covering materials. The covering shall extend down each side of masonry walls approximately 0.6-m.
P. Splashes, stains, or spots on the exposed faces of the wall shall be removed.

Masonry block wall will be measured by the square meter in conformance with the dimensions shown on the plans or such other dimensions as may be ordered in writing by the Engineer. No deduction will be made for the area occupied by openings in the masonry block wall.

The contract price paid per square meter for masonry block wall shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing masonry block, complete in place, including openings, as shown on the plans, as specified in the Standard Specifications and these special provisions.

10-1.__ REINFORCEMENT

Reinforcement shall conform to the provisions in Section 52, "Reinforcement," of the Standard Specifications and these special provisions.

The Department's mechanical splices prequalified list can be found at the following internet site:

http://www.dot.ca.gov/hq/esc/approved_products_list/

The provisions of "Welding Quality Control" of these special provisions shall not apply to resistance butt welding.

Reinforcement shown on the plans to be galvanized shall be galvanized in conformance with the provisions in Section 75-1.05,"Galvanizing," of the Standard Specifications.

EPOXY-COATED PREFABRICATED REINFORCEMENT

Bar reinforcement to be epoxy-coated shall conform to the ASTM Designation and grade required or permitted by Section 52-1.02A, "Bar Reinforcement," of the Standard Specifications, for the location or type of structure involved. The coated bar reinforcement shall conform to the requirements in ASTM Designation: A 934/A 934M except as provided herein.

Wire reinforcement to be epoxy-coated shall conform to the ASTM Designation and grade required or permitted by Section 52-1.02D, "Reinforcing Wire and Plain Bars," of the Standard

Specifications, for the location or type of structure involved. The coated wire reinforcement shall conform to the requirements for Class A, Type 2 coating of ASTM Designation: A 884/A 884M except as provided herein.

Appendices X1 and X2, "Guidelines For Job-Site Practices," of ASTM Designation: A 884/A 884M and A 934/A 934M, respectively, shall apply except as provided herein. The term "shall" shall replace the term "should" in these appendices. Section X1.2 of Appendix X1 and Section X2.2 of Appendix X2 shall not apply.

All coatings shall be purple or gray in color.

Except for field welding of butt splices, all welding of reinforcement shall be complete prior to epoxy coating the reinforcement.

Prior to epoxy coating, all resistance butt welds shall have the weld flash removed to produce a smooth profile free of any sharp edges that would prevent proper coating of the bar. The flash shall be removed such that the ultimate tensile strength and elongation properties of the bar are not reduced, and the outside radius of the flash, at any point along the circumference of the bar, is 1) not less than the nominal radius of the bar, nor 2) greater than 5 mm beyond the nominal radius of the bar.

A proposed weld flash removal process shall be submitted to and approved by the Engineer in writing, prior to performing any removal work. The submittal shall demonstrate that the proposed flash removal process produces a smooth profile that can be successfully epoxy-coated in conformance with the requirements specified herein.

Bending of epoxy-coated reinforcement after the coating has been applied will not be allowed.

When any portion of a reinforcing bar or wire requires epoxy coating, the entire bar or wire shall be coated, except, when the bar or wire is spliced outside of the limits of epoxy coating shown on the plans, epoxy coating will not be required on the portion of bar or wire beyond the splice.

Within areas where epoxy-coated reinforcement is required, tie wire and bar chairs or other metallic devices used to secure or support the reinforcement shall be plastic-coated or epoxy-coated to prevent corrosion of the devices or damage to the coated reinforcement.

Prior to coating, the Contractor shall furnish to the Transportation Laboratory a representative 110 g sample from each batch of epoxy coating material to be used. Each sample shall be packaged in an airtight container identified with the manufacturer's name and batch number.

Two 700-mm long samples of coated bar or wire reinforcement from each size and from each load shipped to the jobsite shall be furnished to the Engineer for testing. These samples shall be representative of the material furnished. These samples, as well as any additional random samples taken by the Engineer, may be tested for specification compliance. Additional sampling, and all tests performed by the Engineer, may be performed at any location deemed appropriate by the Engineer. Failure of any sample to meet the requirements of the specifications will be cause for rejection.

If any bar tested for coating thickness or for adhesion of coating fails to meet the requirements for coated bars in Section 9 of ASTM Designation: A 934/A 934M, 2 retests on random samples taken from bars represented by the failed test will be conducted for each failed test. If the results of both retests meet the specified requirements, the coated bars represented by the samples may be certified as meeting the test requirements.

If any wire reinforcement tested for coating thickness or for flexibility fails to meet the requirements for coated wire in Section 8 of ASTM Designation: A 884/A 884M, 2 retests on random samples taken from wire represented by the failed test will be conducted for each failed

test. If the results of both retests meet the specified requirements, the coated wire represented by the samples may be certified as meeting the test requirements.

Epoxy-coated reinforcement shall be covered with an opaque polyethylene sheeting or other suitable protective material to protect the reinforcement from exposure to sunlight, salt spray, and weather. For stacked bundles, the protective covering shall be draped around the perimeter of the stack. The covering shall be adequately secured; however, it should allow for air circulation around the reinforcement to prevent condensation under the covering. Epoxy-coated reinforcement shall not be stored within 300 m of ocean or tidal water for more than 2 months.

All visible damage to coatings caused by shipping, handling, or installation shall be repaired as required for repairing coating damaged prior to shipment conforming to the requirements in ASTM Designation: A 934/A 934M for bar reinforcement or ASTM Designation: A 884/A 884M for wire reinforcement. When the extent of coating damage prior to repair exceeds 2 percent of the bar or wire surface area in any 300-mm length, repair of the bar or wire will not be allowed, and the coated bar or wire will be rejected.

The patching material and process shall be suitable for field application. The patching material shall be prequalified as required for the coating material and shall be either identified on the container as a material compatible with the reinforcement coating, or shall be accompanied by a Certificate of Compliance certifying that the material is compatible with the reinforcement coating. Damaged areas shall be patched in conformance with the patching material manufacturer's recommendations.

Except for lap splices, all splices for epoxy-coated reinforcement shall be coated with a corrosion protection covering that is on the Department's list of approved products. The covering shall be installed in conformance with the manufacturer's recommendations and as directed by the Engineer. The list is available from the Transportation Laboratory.

A Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications, shall be furnished for each shipment of epoxy-coated bar or wire reinforcement certifying that the coated bars or wire conform to the requirements in ASTM Designation: A 934/A 934M for bars or A 884/A 884M for wire and Section 52-1.02B, "Epoxy-coated Reinforcement," of the Standard Specifications. This Certificate of Compliance shall include all the certifications specified in ASTM Designation: A 934/A 934M for bars or ASTM Designation: A 884/A 884M for wire and a statement that the coating material has been prequalified by acceptance testing performed by the Valley Forge Laboratories, Inc., Devon, Pennsylvania.

Any portion of bar or wire reinforcement extending beyond the limits for epoxy-coated reinforcement shown on the plans will be measured and paid for as bar reinforcing steel (final lining).

MEASUREMENT AND PAYMENT

Measurement and payment for reinforcement in structures shall conform to the provisions in Section 52-1.10, "Measurement," and Section 52-1.11, "Payment," of the Standard Specifications and these special provisions.

The contract price paid per kilogram for bar reinforcing steel (final lining) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in final lining, abutment, invert arch, and invert slab, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per kilogram for bar reinforcing steel (transition barrier) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in transition barrier, complete in place, as shown on the plans, as

specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Bar reinforcing steel for the following items will be measured and paid for by kilogram as bar reinforcing steel (portal):

A. Ventilation outlet structure
B. Leach water pump station
C. Water storage tank
D. Waste water tank
E. Oil water separator tank

The contract price paid per kilogram for bar reinforcing steel (portal) shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in portals, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.__ SHOTCRETE (SOIL NAIL WALL)

Shotcrete for soil nail wall at north portal shall conform to the provisions in Section 51, "Concrete Structures," and Section 53, "Shotcrete," of the Standard Specifications and these special provisions.

Shotcrete operations shall completely encase all reinforcement and other obstructions shown on the plans. Exceptional care shall be taken to properly encase the reinforcement and other obstructions with shotcrete.

Portions of shotcrete (soil nail wall) shall be removed after north portal construction is completed. The limits of shotcrete to be removed shall conform to the details shown on the plans.

Attention is directed to the section, "Order of Work," in these special provisions regarding furnishing preconstruction shotcrete test panels.

Except for finish coats, shotcrete shall be applied by the wet-mix process only.

Finish coats, applied by the dry-mix process, may be used only when approved by the Engineer.

Shotcrete shall have a minimum compressive strength of 22.5 MPa at 28 days or as shown on the plans, whichever is greater. No shotcrete work shall be performed prior to verification by the Engineer of the required compressive strength.

Splicing of reinforcing bars No. 22 or larger in shotcrete shall be by butt splicing only.

The Contractor shall be responsible for obtaining and testing all required preconstruction and production test cores. All coring and testing shall be at the Contractor's expense and performed in the presence of the Engineer, unless otherwise directed. The Engineer shall be notified a minimum of 24 hours prior to the Contractor performing any coring or testing operations.

All cores shall be obtained and tested for compressive strength in conformance with the requirements in ASTM Designation: C 42. Cores used for determining compressive strength shall not contain any bar reinforcement or other obstructions. The testing shall be performed at an independent testing facility approved by the Engineer. A copy of the test results shall be furnished to the Engineer within 5 days following completion of testing.

All test panels shall become the property of the Contractor and shall be disposed of in conformance with the provisions in Section 7-1.13, "Disposal of Material Outside the Highway Right of Way," of the Standard Specifications.

PRECONSTRUCTION REQUIREMENTS

Prior to performing shotcrete work, the Contractor shall construct at least 2 preconstruction shotcrete test panels for each mixture being considered unless otherwise specified.

The nozzleperson shall have a minimum of 3000 hours experience as a nozzleperson on projects with a similar application.

At least 10 working days prior to constructing any shotcrete test panels, the Contractor shall submit to the Engineer for approval, a Quality Control Plan (QCP) for the proposed method of shotcrete placement. The plan shall include the following:

A. The number and qualifications of nozzlepersons available to place shotcrete, the number of nozzlepersons on-site at any time during the shotcrete placement, description of their work schedule, and the procedures for avoiding fatigue of any nozzleperson.
B. The proposed method of placing shotcrete, including, but not limited to, application rates, details of any proposed construction joints and their locations, and methods for achieving the required thickness and surface finish.
C. The procedure for curing shotcrete surfaces.
D. The description of a debris containment system, to be used during the cleaning of bar reinforcing steel and concrete and placing of shotcrete, as required to provide for public safety.

The Engineer shall have 10 working days to review and approve the QCP submittal after a complete plan has been received. No construction of shotcrete test panels shall be performed until the QCP is approved by the Engineer. Should the Engineer fail to complete the review within this time allowance, and if, in the opinion of the Engineer, the Contractor's controlling operation is delayed or interfered with by reason of the delay in approving the QCP, the delay will be considered a right of way delay in conformance with the provisions in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

Preconstruction shotcrete test panels shall be constructed by the nozzlepersons and application crew scheduled to do the work, using equipment, materials, mixing proportions, ambient temperatures and procedures proposed for the work. The preconstruction shotcrete test panels shall conform to the following:

A. One shotcrete test panel, of the size determined by the Contractor, shall be unreinforced and shall have 3 cores taken from it and tested for compressive strength. The compressive strength shall be the average strength of the 3 cores, except that, if any core should show evidence of improper coring, the core shall be discarded and the compressive strength shall be the average strength of the remaining cores. The test panel shall be identified and submitted to the Engineer with the test results including a description of the mixture, proportions, and ambient temperature.
B. One shotcrete test panel shall have the same (1) thickness, (2) bar size and amount of bar reinforcement or other obstructions and (3) positioning of bar reinforcement or obstructions as the most heavily reinforced section of shotcrete to be placed. The test panel shall be square with the length of the sides equal to at least 3 times the thickness of the most heavily reinforced section of shotcrete to be placed, but not less than 750 mm. After a minimum 7 days of cure, the test panel shall be broken by the Contractor, in the presence of the Engineer, into pieces no larger than 250 mm in greatest dimension. The surfaces of the broken pieces shall be dense and free of laminations and sand pockets, and shall verify that the bar reinforcement or other obstructions are completely encased.
C. Both test panels shall be cured under conditions similar to the actual work.
D. At the option of the Contractor, cores to be used for determining the compressive strength may be taken from the reinforced test panel described above in lieu of making a separate unreinforced test panel as described above. The compressive strength shall be the

average strength of the 3 cores, except that, if any core should show evidence of improper coring or contains bar reinforcement or other obstructions, the core shall be discarded and the compressive strength shall be the average strength of the remaining cores. If cores are taken from the reinforced test panel, the panel shall not be broken into pieces, as described above, until it has cured for a minimum of 14 days.

PLACING

An air blowpipe shall be used during shotcrete placement to remove rebound, overspray and other debris from the areas to receive shotcrete.

Construction joints shall be tapered, and shall conform to the provisions in Sections 51-1.13, "Bonding," of the Standard Specifications.

All overspray and rebound shall be removed prior to final set and before placement of shotcrete on adjacent surfaces.

Rebound or any other material which has already exited the nozzle shall not be reused.

Shotcrete shall be cured in conformance with the provisions of Section 90-7.03, "Curing Structures," of the Standard Specifications.

When a finish coat is to be used, all loose, uneven or excess material, glaze, and rebound shall be removed by brooming, scraping, or other means and the surface left scarified. Any surface deposits which take a final set shall be removed by abrasive blasting. Prior to placing the finish coat, the receiving surface shall be washed down with an air-water blast.

Shotcrete extending into the space shown on the plans for cast-in-place concrete shall be removed.

TESTING AND ACCEPTANCE

At least 3 production shotcrete test cores shall be taken from each 30 square meters or portion thereof of shotcrete placed each day. The cores shall be 76 mm in diameter. The location where cores are to be taken will be designated by the Engineer. Test cores shall be identified by the Contractor and a description of the core location and mixture, including proportions, shall be submitted to the Engineer with the test cores, immediately after coring. Cored holes shall be filled with mortar in conformance with the provisions in Section 51-1.135, "Mortar," of the Standard Specifications.

Upon receipt of the cores, the Engineer will perform a visual examination to determine acceptance, as described below. Within 48 hours after receipt, the Engineer will return the cores to the Contractor for compressive strength testing.

The compressive strength test shall be performed using the shotcrete production test cores described above. The compressive strength shall be the average strength of the 3 cores, except that, if any core should show evidence of improper coring, the core shall be discarded and the compressive strength shall be the average strength of the remaining cores.

The basis of acceptance for production shotcrete test cores shall be (1) that the core is dense and free of laminations and sand pockets, and shows that the reinforcement or other obstructions are completely encased and (2) the same as specified for test cylinders in the fourth and fifth paragraphs of Section 90-9.01, "General," of the Standard Specifications.

If any production test core shows signs of defective shotcrete as described in (1) above, the shotcrete represented by such test core will be rejected, unless the Contractor, at the Contractor's expense, obtains and submits evidence acceptable to the Engineer that the strength and quality of the shotcrete placed in the work are acceptable.

The surface finish of the shotcrete shall conform to the provisions of Section 51-1.18, "Surface Finishes," of the Standard Specifications.

MEASUREMENT AND PAYMENT

Full compensation for the Quality Control Plan, constructing and breaking test panels, furnishing and testing cores and patching cored holes shall be considered as included in the contract price paid per cubic meter for shotcrete (soil nail wall) and no additional compensation will be allowed therefor.

Full compensation for portions of shotcrete (soil nail wall) removal as shown on the plans shall be considered as included in the contract price paid per cubic meter for shotcrete (soil nail wall) and no separate payment will be made therefor.

10-1.__ WATERPROOFING

Waterproofing for cut-and-cover structures shall conform to the provisions in Section 54, "Waterproofing," of the Standard Specifications and these special provisions.

Waterproofing membrane shall be polyvinyl chloride (PVC) flexible sheets with non-woven fiberglass reinforcing conforming to the following requirements:

Parameters	ASTM Test Method	Typical Physical Properties
Overall thickness, mm	D-751	2.00
Tensile strength, MPa, min.	D-638	11 MPa
Elongation at break, min., %	D-638	300 MD, 280 CMD
Seam strength, min. % of tensile strength*	D-638	90%
Retention of properties after heat aging	D-3045	---
Tensile strength, min. % of original	D-638	95%
Elongation, min. % of original	D-638	95%
Tear resistance (N/m)	D-1004	14.6
Low temperature bend (-40°C)	D-2136	Pass
Linear dimensional change, maximum, %	D-1204	0.0
Weight change after immersion in water, maximum, %	D-570	2.0
Puncture resistance	D-FEDERAL TEST METHOD 2065	50.16

* Failure occurs through membrane rupture, not seam failure.

All fasteners shall be of the same type as the metal being secured. In general, all fasteners, anchors, nails, straps, shall be of stainless steel. Fasteners shall be compatible with materials in contact with fasteners and shall be approved by waterproofing membrane manufacturer. All fasteners and anchors shall have a minimum embedment of 32 mm and shall be approved for such use by the fastener manufacturer. Fasteners for attachment of metal to wood blocking shall be annular ring nails. Fasteners for attachment of metal to masonry shall be expansion type fasteners. All fasteners shall meet Factory Mutual Standard 4470 for corrosion resistance.

Protection board, leveling layers, flashing materials, drainage layers, securement strips, adhesive and sealants, and other accessories shall be compatible with the membrane waterproofing system as recommended by the membrane manufacturer.

Full compensation for protection board shall be considered as included in the contract price paid per square meter for cut and cover waterproofing and no separate payment will be made therefor.

10-1.__ REINFORCED CONCRETE PIPE

Reinforced concrete pipe shall conform to the provisions in Section 65, "Reinforced Concrete Pipe," of the Standard Specifications and these special provisions.

Where embankment will not be placed over the top of the pipe, a relative compaction of not less than 85 percent shall be required below the pipe spring line for pipe installed using

Method 1 backfill in trench, as shown on Standard Plan A62D. Where the pipe is to be placed under the traveled way, a relative compaction of not less than 90 percent shall be required unless the minimum distance between the top of the pipe and the pavement surface is the greater of 1.2 m or one half of the outside diameter of the pipe.

Except as otherwise designated by classification on the plans or in the specifications, joints for culvert and drainage pipes shall conform to the plans or specifications for standard joints.

When reinforced concrete pipe is installed in conformance with the details shown on Revised Standard Plan A62DA, the fifth paragraph of Section 19-3.04, "Water Control and Foundation Treatment," of the Standard Specifications shall not apply.

When solid rock or other unyielding material is encountered at the planned elevation of the bottom of the bedding, the material below the bottom of the bedding shall be removed to a depth of 1/50 of the height of the embankment over the top of the culvert, but not less than 150 mm nor more than 300 mm. The resulting trench below the bottom of the bedding shall be backfilled with structure backfill material in conformance with the provisions in Section 19-3.06, "Structure Backfill," of the Standard Specifications.

The excavation and backfill below the planned elevation of the bottom of the bedding will be paid for as extra work as provided in Section 4-1.03D, "Extra Work," of the Standard Specifications.

The Outer Bedding shown on Revised Standard Plan A62DA shall not be compacted prior to placement of the pipe.

10-1.__ REINFORCED CONCRETE DRAIN

Tunnel road drain shall be reinforced concrete drain in conformance with the details as shown on the plans, Section 65, "Reinforced Concrete Pipe," of the Standard Specifications, and the requirements specified in these special provisions.

Concrete bed shall conform to the Section 90-10, "Minor Concrete," of the Standard Specifications.

Reinforced concrete drain interceptor covers shall conform to "Miscellaneous Metal" of these special provisions.

PAYMENT

The contract unit price paid for road drainage slotted drain of the types listed in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in furnishing and installing reinforced concrete drain, complete in place, including concrete bed, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract unit price paid for road drainage interceptor of the types listed in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in furnishing and installing reinforced concrete drain interceptor, complete in place, including concrete bed and covers, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.__ UNDERDRAIN

Plastic pipe underdrains tunnel drainage, base drainage, cross passage and equipment chamber drainage, drainage at south end of south equipment chamber, and perforated plastic pipe

underdrains at North Portals shall conform to the provisions in Section 68-1, "Underdrains," of the Standard Specifications and these special provisions.

Plastic pipe underdrains at tunnels shall be half perforated in conformance with the details as shown on the plans.

Permeable drain rock shall be class 1 permeable material in conformance with the Section 68-1.025, "Permeable Material," of the Standard Specifications.

Concrete bed shall conform to the Section 90-10, "Minor Concrete," of the Standard Specifications.

Perforated plastic pipe underdrains at North Portals shall be inspected after installation and slope construction is completed. The Contractor shall inspect the perforated plastic pipe using a pipe inspection digital video camera. The video camera shall be high resolution, low light sensitivity, and equipped with built-in light. The Contractor shall run the video camera along the full length of the pipe to ensure the pipe is open and intact without crushed or narrowed. After the video camera inspection is completed, the Contractor shall submit the Engineer digital video disks (DVDs) containing all unedited videos during the inspection.

Full compensation for concrete bed shall be considered as included in the contract price paid per meter for perforated plastic pipe underdrain of the sizes listed in the Engineer's Estimate and no separate payment will be made therefore.

Full compensation for digital video camera inspection shall be considered as included in the contract price paid per meter for perforated plastic pipe underdrain of the sizes listed in the Engineer's Estimate and no separate payment will be made therefore.

10-1.__ MISCELLANEOUS FACILITIES

Plastic pipe cleanout manhole and drainage inlet shall conform to the provisions in Section 70, "Miscellaneous Facilities," of the Standard Specifications.

10-1.__ SLOPE PROTECTION

Slope protection shall be placed or constructed in conformance with the provisions in Section 72, "Slope Protection," of the Standard Specifications and these special provisions.

Minor concrete (ditch lining) shall conform to Section 72-4, "Concrete Slop Protection, Gutter Lining, Ditch Lining, and Channel Lining," of the Standard Specifications.

10-1.1__ GABIONS

Gabions shall be constructed as shown on the plans and in conformance with these special provisions.

Gabions shall consist of wire mesh, cubical-celled or mattress-styled baskets that are filled on the project site with hard, durable rock.

Standard gabion sizes and the overall plan and profile dimensions of the gabion structures shall be as shown on the plans. Each standard gabion size shall be divided into one meter long cells by diaphragm panels. The width, height or length of the standard gabions shall not vary more than 5 percent from the dimensions specified in these special provisions or as shown on the plans.

Empty gabion baskets shall be assembled individually and joined successively. Individual gabion mesh panels (base, front, ends, back, diaphragms, and lid) and successive gabions shall be assembled so that the strength and flexibility along the joints is comparable to a single panel.

MATERIALS

All materials for the gabions and gabion assembly shall conform to the provisions in these special provisions. Each shipment of gabion baskets to the project site shall be accompanied by a Certificate of Compliance conforming to the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

Mesh

At the Contractor's option, either twisted mesh or welded mesh shall be used, in conformance with Table 1 and Table 2 herein. For each standard gabion size, the same mesh style shall be used for the base, front, ends, back, diaphragms, and lid panels. Individual wires of either the twisted-mesh style or the welded-mesh style shall conform to the definitions and requirements in ASTM Designation: A641/A641 M.

Mattress-style gabion baskets that are 0.3–m and 0.5–m high shall be manufactured from either 11-gage (3.05 mm) welded mesh or twisted mesh. Cubical-celled gabion baskets that are one meter high by one meter wide shall be fabricated from 11-gage (3.05 mm) twisted mesh or welded mesh gages between 11–gage (3.05 mm) and 9–gage (3.76 mm), inclusive.

Table 1

CUBICAL-CELLED FACILITIES	
USA WIRE GAGE	MESH STYLE
11	Twisted Mesh
11 Min to 9 Max	Welded Mesh

Table 2

MATTRESS-STYLE FACILITIES	
USA WIRE GAGE	MESH STYLE
11	Twisted Mesh
11	Welded Mesh

GABION MESH MATERIAL PROPERTIES

Characteristic	Test Designation	Requirement
Minimum tensile strength	ASTM A370	410 MPa
Wire Size	USA Steel Wire Gage	11
Wire Diameter	ASTM A641/A641 M	3.05 mm
(Minimum)	ASTM A641/A641 M	2.95 mm
Galvanizing, Zinc	ASTM A641/A641 M, Class 3 and ASTM A90 / A90M	240 g/m^2
Wire Size	USA Steel Wire Gage	9
Wire Diameter	ASTM A641/A641 M	3.76 mm
(Minimum)	ASTM A641/A641 M	3.66 mm
Galvanizing, Zinc	ASTM A641/A641 M, Class 3 and ASTM A90 / A90M	270 g/m^2

Twisted-mesh wires shall form a uniform hexagonal pattern and shall be formed with a nonraveling twist. The area of the hexagonal opening shall not exceed the dimensions shown on the plans. Twisted-mesh gabion panels shall be manufactured from 11-gage (3.05 mm) wires with 9-gage (3.76 mm) selvage wires.

Welded-mesh wires shall form a grid pattern as shown on the plans. Welds shall be made by resistance welding. Welds and panels shall conform to the requirements in ASTM Designation: A185, except weld shears shall be 2.7 kN for 11-gage (3.05 mm) wires and 3.6 kN for 9-gage (3.76 mm) wires. Resistance welding after coating the wire with zinc will be acceptable if there are no large splashes, flakes or flashes of zinc at the weld.

Joints

Standard tie wire and standard spiral binder shall conform to the definitions and requirements in ASTM Designation: A641/A641 M and shall conform to the following provisions:

Minimum Tensile Strength	ASTM A370	410 MPa
Tie Wire		
Wire Size (Minimum)	USA Steel Wire Gage	13.5
Wire Diameter	ASTM A641/A641 M	2.19 mm
(Minimum)	ASTM A641/A641 M	2.09 mm
Zinc Coating	ASTM A641/A641 M, Class 3 and ASTM A90 / A90M	220 g/m^2
Spirals		
Wire Size (Maximum)	USA Steel Wire Gage	9
Wire Diameter	ASTM A641/A641 M	3.76 mm
(Minimum)	ASTM A641/A641 M	3.66 mm
Zinc Coating	ASTM A641/A641 M, Class 3 and ASTM A90 / A90M	270 g/m^2

Spiral binders shall have a 75 mm to 85 mm separation between continuous, successive loops.

Alternative fasteners shall have the configurations, wire diameters, and other dimensions shown on the plans. Alternative fasteners shall conform to the definitions and requirements in ASTM Designation: A764 for "Metallic Coated Carbon Steel Wire, Coated at Size and Drawn to Size for Mechanical Springs." Interlocking fasteners shall conform to Tensile Requirement Class I, Finish 2 and shall have a Class 3 zinc coating, Overlapping fasteners shall conform to Tensile Requirement Class II, Finish 1 and shall have a Class 3 zinc coating.

Internal Connecting Wire

Internal connecting wires shall be 13.5-gage (2.19 mm) minimum. Each wire shall conform to the minimum requirements for standard tie wire in these special provisions and shall be installed in conformance with the provisions in these special provisions and as shown on the plans. Alternatively, at the Contractor's option, preformed stiffeners may be substituted for internal connecting wires. Preformed stiffener wire shall meet the requirements specified for standard tie wire and shall be installed in conformance with these special provisions and the manufacturer's recommendations.

Rock

Rock for filling gabions, which are greater than or equal to 0.5-m in height, shall vary in size and shall conform to the following:

Screen Size (mm)	Percentage Passing
305	100
102	0-5

Rock for filling gabions, which are equal to 0.3-m in height, shall vary in size and shall conform to the following:

Screen Size (mm)	Percent age Passing
203	100
102	0-5

Rock shall conform to the material provisions for rock slope protection in Section 72-2.02, "Materials," of the Standard Specifications.

The minimum unit mass of a rock-filled gabion shall be 1750 kg/m^3. Verification of the 1750 kg/m^3 shall be performed when ordered by the Engineer. Verification shall be performed on the smallest standard gabion size to be used on the project. The rock supplied for the project shall be used for verification. Filling shall be done using the same method intended for actual construction. The mass of a rock-filled gabion shall be determined using available certified scales. The volume for calculating the unit mass shall be determined on the theoretical volume of the standard gabion which is rock-filled and weighed.

GRADING, EXCAVATION AND BACKFILL

Areas where gabions are to be placed shall be constructed to the lines and grades shown on the plans and as determined by the Engineer. Excavation or backfill for achieving the required grades shall conform to the provisions for structure excavation and backfill in Section 19, "Earthwork," of the Standard Specifications.

ROCK SLOPE PROTECTION FABRIC PLACEMENT

Rock slope protection fabric shall be placed in conformance with the provisions in Section 72-2.025, “Rock Slope Protection Fabric” of the Standard Specifications. Rock slope protection fabric shall be placed on the subgrade, backslope, and sides of excavations. If earth fill is to be placed over the gabions, rock slope protection fabric shall be placed on top of the gabions, before placing the earth fill.

CONSTRUCTION

Gabions shall be assembled individually as empty units. Each gabion shall be manufactured with the necessary panels, properly spaced and secured, so that the panels can be rotated into position at the construction site with no additional tying of the rotation joint. The panels and diaphragms shall be rotated into position and joined along the vertical edges.

For twisted mesh, the joint shall be constructed using alternating double and single half hitches (locked loops) of 13.5-gage (2.19 mm) standard tie wire at 100-mm nominal spacing. Joints shall not be constructed with simple spiraling (looping without locking) of the standard tie wires.

When standard tie wire is used as a joint connector for welded mesh, the joint shall be constructed using alternating double and single half hitches (locked loops) in every mesh opening along the joint. When 9-gage (3.76 mm) spiral binders are used, the spiral shall be placed so that the spiral binder passes through each mesh opening along the joint. Both ends of all 9-gage (3.76 mm) spiral binders shall be crimped to secure the spiral in place.

Temporary fasteners may be used to hold panels wherever gabion-to-gabion joints will be constructed. Temporary fasteners may remain in place.

At the Contractor’s option, interlocking fasteners or overlapping fasteners may be used for assembly of either the twisted-mesh or welded-mesh gabions. A fastener shall be placed in each mesh opening along the joint (a minimum of 10 fasteners per meter).

ASSEMBLY OF SUCCESSIVE GABION BASKETS (GABION-TO-GABION JOINTS)

Gabion baskets shall be set in place. Individually constructed gabion baskets shall then be joined successively to the next gabion baskets with 13.5-gage (2.19 mm) tie wire or 9-gage (3.76 mm) standard spiral binder before filling the basket with rock. The 13.5-gage (2.19 mm)

standard tie wire or 9-gage (3.76 mm) standard spiral binder shall secure, in one pass, all selvage or end wires of the panels of all adjacent baskets along the joint.

When forming successive gabion-to-gabion joints with alternative fasteners, there shall be one alternative fastener in each mesh opening. The alternative fastener shall contain and secure all the wires along the joint.

Gabion baskets shall be joined along the front, back, and ends, including the tops and bottoms of the adjacent gabions.

ASSEMBLY OF MULTIPLE LAYERED GABIONS

Multi-layered gabion configurations shall be stepped and staggered as shown on the plans or as designated by the Engineer.

When constructing multi-layered gabion configurations, each layer of gabions shall be joined to the underlying layer along the front, back, and ends.

ASSEMBLY OF SHEAR KEY GABIONS

Shear key gabions, or counterforts, shall be spaced as shown on the plans. Shear key gabions shall be tied to adjacent gabions in the manner specified for "Assembly of Successive Gabion Baskets (Gabion-to-Gabion Joints)" of these special provisions.

ASSEMBLY OF TRANSITIONAL GABIONS

To match the geometry of the planned gabion configuration, or to meet specific conditions, panels shall be folded, cut and fastened as shown on the plans or as directed by the Engineer.

FILLING WITH ROCK

Before filling each gabion basket with rock, all kinks and folds in the wire fabric shall be straightened and all successive gabions shall be properly aligned.

Rock shall be placed in the baskets to provide proper alignment, avoid bulges in the wire mesh, and provide a minimum of voids. All exposed rock surfaces shall have a smooth and neat appearance. Sharp rock edges shall not project through the wire mesh.

Internal connecting wires or preformed stiffeners shall be used to produce a flat, smooth external surface, when constructing with 0.5-m or one meter high gabions. If the Engineer determines that there is excessive bulging or dimpling of the outside panels, the unit shall be reconstructed at the Contractor’s expense.

When filling one meter high gabions, rock shall be placed in 3 nominal 0.33-m layers to allow placement of the 13.5-gage (2.19 mm) internal connecting wires. The wires shall be fastened as shown on the plans. Alternatively, preformed stiffeners may be installed at the one-third points in conformance with the recommendations of the manufacturer, to produce a smooth external surface.

When filling 0.5-m high gabions, 2 nominal 0.25-m layers of rock shall be placed to allow placement of a set of internal connecting wires or preformed stiffeners. The configuration of wires shall be similar to those used on the one meter high gabions, except there shall be only one set of internal connecting wires instead of the 2 sets of internal connecting wires or preformed stiffeners.

The last layer of rock shall slightly overfill the gabion baskets so that the lid will rest on rock when the lid is closed.

CLOSURE OF LIDS

Lids shall be tied along the front, ends, and diaphragms in conformance with the provisions in "Assembly of Successive Gabion Baskets (Gabion-to-Gabion Joints)" of these special provisions.

MEASUREMENT

Gabions will be measured by the cubic meter as determined from the dimensions shown on the plans or the dimensions directed by the Engineer and gabions placed in excess of these dimensions will not be paid for.

PAYMENT

The contract price paid per cubic meter for gabion shall include full compensation for furnishing all labor, materials (including gabion baskets and rock), tools, equipment, and incidentals, and for doing all the work involved in constructing gabions, complete, in place, including excavation and backfill, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.__ MISCELLANEOUS METAL

Miscellaneous metal shall conform to the provisions for miscellaneous bridge metal in Section 75, "Miscellaneous Metal," of the Standard Specifications and these special provisions.

Attention is directed to "Welding" of these special provisions.

Miscellaneous metal shall consist of the miscellaneous bridge metal items listed in Section 75-1.03, "Miscellaneous Bridge Metal," of the Standard Specifications, and the following:

A. Manhole frames and covers, frames and grates, ladder rungs, guard posts and access door assemblies.
B. Butt plates, foot plates at heading and bench, and invert, stirrup channels.
C. Anchorages at equipment chambers and cross passages.
D. Cover plates at leach water pump station.
E. Ladders at service niches.
G. Handrail and mounting bracket at center equipment chamber.

10-1.__ TUBULAR BICYCLE RAILING

Tubular bicycle railing shall conform to the provisions in Section 83-1, "Railings," of the Standard Specifications.

10-1.__ TUBULAR BICYCLE RAILING

Tubular bicycle railing shall conform to the provisions in Section 83-1, "Railings," of the Standard Specifications.

10-1.__ CONCRETE BARRIER

Concrete barriers shall conform to the provisions in Section 83-2, "Barriers," of the Standard Specifications.

ARCHITECTURAL

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SECTION 12. ARCHITECTURAL WORK

SECTION 12-1. GENERAL REQUIREMENTS

12-1.01 SCOPE

Architectural work described herein and as shown on the plans shall conform to the requirements of these special provisions and Sections 1 through 9 of the Standard Specifications. Sections 10 through 95 of the Standard Specifications shall not apply to the work in this Section 12 except when specific reference is made thereto.

The architectural work to be done consists, in general, of:

A. Miscellaneous metal including steel pipe railings at interior stairs
B. Metal grating ceiling panels and stair nosings
C. Sealants as required
D. Stainless steel doors and frames and finish hardware
E. Overhead coiling doors
F. Specialties including louvers, signs, fire extinguishers and fire extinguishers cabinets

and such other items or details, not mentioned above, that are required by the plans, Standard Specifications, or these special provisions shall be performed, placed, constructed or installed.

12-1.02 ABBREVIATIONS

Section 1-1.02, "Abbreviations," of the Standard Specifications is amended by adding the following:

AAMA	American Architectural Manufacturers' Association
ACI	American Concrete Institute
AGA	American Gas Association
AITC	American Institute of Timber Construction
AMCA	Air Movement and Control Association
APA	American Plywood Association
ARI	American Refrigeration Institute
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
CBC	California Building Code (2001 Edition)
CEC	California Electrical Code (2001 Edition)
CMC	California Mechanical Code (2001 Edition)
CPC	California Plumbing Code (2001 Edition)
CS	Commercial Standards (US Department of Commerce)
ESO	Electrical Safety Orders
FGMA	Flat Glass Marketing Association
FM	Factory Mutual
FS	Federal Specification
ICBO	International Conference of Building Officials
NAAMM	National Association of Architectural Metal Manufacturers
NBFU	National Board Fire Underwriters
NEC	National Electrical Code
NFPA	National Fire Protection Association or National Forests Products Association
PEI	Porcelain Enamel Institute
PS	Product Standard (US Department of Commerce)
RIS	Redwood Inspection Service
SCPI	Structural Clay Products Institute
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
SSPC	Steel Structures Paint Council
TCA	Tile Council of America
TPI	Truss Plate Institute
UBC	Uniform Building Code (1997 Edition)
WCLIB	West Coast Lumber Inspection Bureau (stamped WCLB)
WCLB	Grade stamp for WCLIB
WIC	Woodwork Institute of California
WWPA	Western Wood Products' Association

12-1.__ GUARANTEE

The Contractor hereby unconditionally guarantees that the architectural work will be done in accordance with the requirements of the contract, and further guarantees the architectural work of the contract to be and remain free of defects in workmanship and materials for a period of one year from the date of acceptance of the contract, unless a longer guarantee period is required elsewhere in these special provisions. The Contractor hereby agrees to repair or replace any and all architectural work, together with any other adjacent work which may be displaced in so doing, that may prove to be not in accordance with the requirements of the contract or that may be defective in its workmanship or material within the guarantee period specified, without any expense whatsoever to the Department, ordinary wear and tear and unusual abuse or neglect excepted.

The performance bond for contract price of the architectural work, shall remain in full force and effect during the guarantee period.

The Contractor further agrees, that within 10 calendar days after being notified in writing by the Department of any architectural work not in accordance with the requirements of the contract or any defects in the architectural work, he shall commence and prosecute with due diligence all work necessary to fulfill the terms of this guarantee, and shall complete the work within a reasonable period of time, and, in the event he fails to comply, he does hereby authorize the

Department to proceed to have such work done at the Contractor's expense and he shall honor and pay the cost and charges therefor upon demand. The Department shall be entitled to all costs and expenses, including reasonable attorney's fees, necessarily incurred upon the Contractor's refusal to honor and pay the above costs and charges.

12-1.__ AREAS FOR CONTRACTOR'S USE

No area is available within the contract limits for the exclusive use of the Contractor. The Contractor shall arrange with the Engineer for areas to store equipment and materials within the work area.

12-1.__ COOPERATION

Attention is directed to Sections 7-1.14, "Cooperation," and 8-1.10, "Utility and Non-Highway Facilities," of the Standard Specifications and these special provisions.

Work by State forces will be in progress within the contract limits during the working period for this contract.

The Contractor shall plan his work to minimize interference with State forces and the public. Interruptions to any services for the purpose of making or breaking a connection shall be made only after consultation with and for such time periods as directed by the Engineer.

12-1.__ SUBMITTALS

Working drawings, material lists, descriptive data, samples and other submittals specified in these special provisions shall be submitted for approval in accordance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications and these special provisions.

Unless otherwise permitted in writing by the Engineer, all submittals required by these special provisions shall be submitted within 35 days after the contract has been approved.

Attention is directed to the provisions in Section 5-1.01, "Authority of Engineer," of the Standard Specifications. The Engineer may request submittals for materials or products where submittals have not been specified in these special provisions, or may request that additional information be included in specified submittals, as necessary to determine the quality or acceptability of such materials or products.

Attention is directed to Section 6-1.05, "Trade Names and Alternatives," of the Standard Specifications. The second indented paragraph of the first paragraph of said Section 6-1.05 is amended to read:

> Whenever the specifications permit the substitution of a similar or equivalent material or article, no test or action relating to the approval of such substituted material will be made until the request for substitution is made in writing by the Contractor accompanied by complete data as to the equality of the material or article proposed. Such request shall be made within 35 days after the date the contract has been approved and in ample time to permit approval without delaying the work, but need not be made in less than 35 days after award of the contract.

Work requiring the submittal of working drawings, material lists, descriptive data, samples, or other submittals shall not begin prior to approval of said submittal by the Engineer. Twenty working days shall be allowed for approval or return for correction of each submittal or resubmittal. Should the Engineer fail to complete his review within the time specified and if, in the opinion of the Engineer, the Contractor's controlling operation is delayed or interfered with by reason of the delay in review, an extension of time commensurate with the delay in

completion of the work thus caused will be granted as provided in Section 8-1.07, "Liquidated Damages," of the Standard Specifications.

Submittals shall be delivered to the locations indicated in these special provisions. If a specific location is not indicated, the submittal shall be delivered to the Division of Structure Design, Documents Unit, Fourth Floor, Mail Station 9-4/4I, 1801 30th Street, Sacramento, California 95816, telephone (916) 227-8252, or the submittals shall be mailed to the Division of Structure Design, Documents Unit, Mail Station 9-4/4I, P. O. Box 942874, Sacramento, California 94274-0001.

Each submission of drawings, material lists and descriptive data shall consist of at least 5 copies. Two copies will be returned to the Contractor either approved for use or returned for correction and resubmittal.

Each separate item submitted shall bear a descriptive title, the name of the project, district, county, and contract number. Plans and detailed drawings shall be not larger than 559 mm x 914 mm.

The material list shall be complete as to name of manufacturer, catalog number, size, capacity, finish, all pertinent ratings, and identification symbols used on the plans and in the special provisions for each unit.

Parts lists and service instructions packaged with or accompanying the equipment installed in the work shall be delivered to the Engineer at the jobsite. Required operating and maintenance instructions shall be submitted in triplicate.

Manufacturer's warranties for products installed in the work shall be delivered to the Engineer at the jobsite.

Unapproved samples and samples not incorporated in the work shall be removed from State property, when directed by the Engineer.

12-1.__ PROGRESS SCHEDULE

A progress schedule shall be submitted in duplicate for the architectural work in accordance with the requirements in Section 8-1.04, "Progress Schedule," of the Standard Specifications.

12-1.__ SCHEDULE OF VALUES

The Contractor shall prepare and submit to the Engineer for approval 2 copies of a Schedule of Values within 15 working days of approval of the contract covering each lump sum item for architectural work. Fifteen working days shall be allowed for approval or return for correction of each submittal or resubmittal. Should the Engineer fail to complete his review within the time specified and if, in the opinion of the Engineer, the Contractor's controlling operation is delayed or interfered with by reason of the delay in review, an extension of time commensurate with the delay in completion of the work thus caused will be granted as provided in Section 8-1.07, "Liquidated Damages," of the Standard Specifications.

The Schedule of Values must be accurately divided into sections representing the cost of each separate building or structure. All work that is not part of a separate building or structure, such as excavation, grading, curbs, gutters, sidewalks, paving, sewer and storm drainage and utility distribution lines are to be included under a specific section as General Work and not included in the building or structure cost. Indirect costs and general condition items are to be listed as a separate line item of work. The sections representing each building or structure must be identified as to the building or structure they represent and be broken down to show the corresponding value of each craft, trade or other significant portion of the work. A sub-total for each section shall be provided.

The Schedule of Values shall be approved by the Engineer before any partial payment estimate is prepared.

The sum of the items listed in the Schedule of Values shall equal the contract lump sum price for architectural work. Overhead and profit shall not be listed. Bond premium and other such items will not be paid for under the various architectural work items and shall be included in the mobilization bid item for the entire project.

12-1.__ INSPECTION

All items covered or all stages of work that are not to remain observable must be inspected and approved before progress of work conceals portions to be inspected. The Contractor shall notify the Engineer not less than 72 hours in advance of when such inspection is needed.

12-1.__ OBSTRUCTIONS

Attention is directed to Sections 7-1.11, "Preservation of Property," 7-1.12, "Responsibility for Damage," 7-1.16, "Contractor's Responsibility for the Work and Materials," and 8-1.10, "Utility and Non-Highway Facilities," of the Standard Specifications.

The Contractor shall notify the Engineer and the appropriate regional notification center for operators of subsurface installations at least 5 working days prior to performing any excavation or other work close to any underground pipeline, conduit, duct, wire or other structure. Regional notification centers include but are not limited to the following:

Underground Service Alert
Northern California (USA)
Telephone: 1(800)642-2444

Underground Service Alert
Southern California (USA)
Telephone: 1(800)422-4133

South Shore Utility
Coordinating Council (DIGS)
Telephone: 1(800)541-3447

Western Utilities
Underground Alert, Inc.
Telephone: 1(800)424-3447

12-1.__ PRESERVATION OF PROPERTY

Attention is directed to Sections 7-1.11, "Preservation of Property," 7-1.12, "Responsibility for Damage," 7-1.16, "Contractor's Responsibility for the Work and Materials," and 8-1.10, "Utility and Non-Highway Facilities," of the Standard Specifications.

Operations shall be conducted in such a manner that existing facilities, surfacing, installations, and utilities which are to remain in place will not be damaged. Temporary surfacing, facilities, utilities and installations shall also be protected until they are no longer required. The Contractor, at his expense shall furnish and install piling, sheet piling, cribbing, bulkheads, shores, or whatever means may be necessary to adequately support material carrying such facilities, or to support the facilities themselves and shall maintain such support until they are no longer needed.

12-1.__ UTILITY CONNECTION

The Contractor shall make all arrangements, and obtain all permits and licenses required for the extension of and connection to each utility service applicable to this project, shall furnish all labor and materials necessary for such extensions which are not performed or provided by the utility, and shall furnish and install any intermediate equipment required by the serving utilities.

Upon written request by the Contractor, the State will pay all utility permits, licenses, connection charges, and excess length charges directly to the utility. Such request shall be submitted not less than 45 days before service connections are required.

The costs incurred by the Contractor for the extensions of utilities beyond the limits shown on the plans, and in furnishing and installing any intermediate equipment required by the serving utilities, will be paid for as extra work as provided in Section 4-1.03D of the Standard Specifications.

Full compensation for any costs incurred by the Contractor to obtain the permits and licenses shall be considered as included in the contract lump sum price paid for architectural work and no additional compensation will be allowed therefor.

12-1.__ TEMPORARY UTILITIES

The Contractor may obtain electrical power and water from existing State electrical power and water outlets within the contract limits free of charge for contract operations where such utilities exist, provided that such utility services are in service and are not required by the State for other purposes and subject to the provisions in the section "Cooperation" of these special provisions.

The Contractor shall make his own arrangements to obtain any additional electrical power and water or other utilities required for his operations and shall make and maintain the necessary service connections at his own expense.

When existing utility systems are being modified, periods of shutdown will be determined by the Engineer.

The Contractor shall provide adequate temporary lighting to perform the work and allow the Engineer to inspect the project as each portion is completed.

The Contractor shall provide and pay for telephone service he may require. State telephone facilities shall not be used.

12-1.__ MEASUREMENT AND PAYMENT

The contract lump sum price paid for architectural work shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing the architectural work, complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Full compensation for any incidental materials and labor, not shown on the plans or specified, which are necessary to complete the buildings and appurtenances shall be considered as included in the contract lump sum price paid for architectural work and no additional compensation will be allowed therefor.

12-1.__ PROJECT RECORD DRAWINGS

The Contractor shall prepare and maintain one set of project record drawings, using an unaltered set of original project plans, to clearly show all as-constructed information for the project. As a minimum, the information to be shown shall include 1) any plan clarifications or

change orders, 2) locations of any underground utilities, or 3) the location, size, type, and manufacturer of all major products or components selected by the Contractor for use in the work.

All markings shall be placed on the project record drawings using red ink or red pencil. Original figures shall not be eradicated nor written over and superseded material shall be neatly lined out. Additional drawings shall be submitted if the required information cannot be clearly shown on the original set of project plans. The additional drawings shall be not less than 279 mm x 432 mm in size and shall have the contract number on each sheet. The Contractor shall sign and date each sheet of the project record drawings to verify that all as-constructed information shown on the drawings is correct.

The Contractor shall periodically review the set of project record drawings with the Engineer during the progress of the work to assure that all changes and other required information are being recorded.

Before completion of the work, the Contractor shall request a review of the project record drawings to determine the completeness and adequacy of them. If the project record drawings are unacceptable, the Contractor shall inspect, measure, and survey the project as necessary to record the required additional information.

The set of completed project record drawings shall be delivered to the Engineer prior to acceptance of the contract.

SECTION 12-2. (BLANK)

SECTION 12-3. (BLANK)

SECTION 12-4. (BLANK)

SECTION 12-5. METALS

12-5.01 ARCHITECTURAL MISCELLANEOUS METAL

PART 1.- GENERAL

Scope.--This work shall consist of fabricating, furnishing and installing architectural miscellaneous metal in accordance with the details shown on the plans and these special provisions.

Architectural miscellaneous metal shall consist of the following:

A. Steel Pipe Railings at interior stairs
B. Metal (Steel) Grating Ceiling Panels

including all anchors, fastenings, hardware, accessories and other supplementary parts necessary to complete the work.

REFERENCES.--

Codes and standards.--Welding of steel shall be in accordance with American Welding Society (AWS) D 1.1, "Structural Welding Code-Steel" and D 1.3, "Structural Welding Code-Sheet Steel."

SUBMITTALS.--

Product data.--Submit manufacturer's specifications, anchor details and installation instructions for products used in miscellaneous metal fabrications.

Working drawings.--Working drawings of fabricated items shall be submitted for approval.

QUALITY ASSURANCE.--

Shop assembly.--Preassemble items in shop to the greatest extent possible to minimize field splicing and assembly. Disassemble units only as necessary for shipping and handling limitations. Clearly mark all units for reassembly and installation.

Inspection and tests.--Materials and fabrication procedures shall be subject to inspection and tests by the Engineer, in mill, shop and field. Such tests will not relieve the Contractor of responsibility of providing materials and fabrication procedures in compliance with specified requirements.

PART 2.- PRODUCTS

MATERIALS.--

Steel bars, plates and hot-rolled shapes.--

Steel bars, plates and hot-rolled shapes shall conform to ASTM Designation: A 36/A 36M.

Galvanized sheet steel.--

Galvanized sheet steel shall conform to ASTM Designation: A 446 M having minimum yield strength of 228 MPa or current designation. Galvanizing shall be Z180.

Steel grating for ceilings. --

Steel grating shall be standard pressure locked conforming to ASTM Designation: A 167 type 304 stainless steel. Bearing bar size shall be 19 mm by 3 mm spaced 52 mm inches on center with cross bar spaced at 52 mm on center. Surface shall be plain and finish shall be stainless steel. Loose support plates and hanger brackets shall be stainless steel. Gratings shall be removable.

Pipe.--

Pipe shall be commercial quality standard steel pipe.

Steel tubing.--

Steel tubing shall conform to ASTM Designation: A 500, Grade B, or A 501.

Bolts, studs, threaded rods, nuts and washers.--

Bolts, studs, threaded rods, and nuts for general application shall conform to ASTM Designation: A 307.

Washers shall be commercial quality.

Fittings.--

Brackets, bolt, threaded studs, nuts, washers, and other fittings for railings and handrailings shall be commercial quality pipe and fittings.

Expansion anchors.--

Expansion anchors shall be ICBO approved for the purpose intended, integral stud type anchor or internally threaded type with independent stud, hex nut and washer.

Powder driven anchors.--

Powder driven anchors shall be plated, spring steel alloy drive pin or threaded stud type anchors for use in concrete or steel. Spring steel shall conform to ASTM Designation: A 227M, Class 1. The diameter, length and type of shank and the number and type of washer shall be as recommended by the manufacturer for the types and thickness of material being anchored or fastened.

Resin capsule anchors.--

Stud anchors for resin capsule anchors shall conform to ASTM Designation: A 307 threaded steel rod with hex nut and washer and sealed glass capsule or cartridge containing an adhesive composed of unsaturated polyester resin and benzol peroxide coated quartz sand. Resin capsule shall be Hilti; Molly; or equal.

Mortar.--

Mortar shall consist of one part cement, measured by volume, to 2 parts clean sand and only enough water to permit placing and packing.

FABRICATION.--

Workmanship and finish.--Workmanship and finish shall be equal to the best general practice in modern shops.

Miscellaneous metal shall be clean and free from loose mill scale, flake rust and rust pitting, and shall be well formed and finished to shape and size with sharp lines and angles. Bends from shearing or punching shall be straightened.

The thickness of metal and details of assembly and support shall give ample strength and stiffness.

Built-up parts shall be true to line and without sharp bends, twists and kinks. Exposed ends and edges of metal shall be milled or ground smooth, with corners slightly rounded.

Joints exposed to the weather shall be made up to exclude water.

Galvanizing.--Items indicated on the plans to be galvanized shall be hot-dip galvanized after fabrication. The weight of galvanized coating shall be at least 460 grams per square meter of surface area, except drainage grates shall have at least 610 grams per square meter of surface area.

Loose bearing and leveling plates.--Loose bearing and leveling plates shall be furnished for steel items bearing on masonry or concrete construction, made flat, free from warps or twists, and of required thickness and bearing area. Plates shall be drilled to receive anchor bolts. Galvanize after fabrication.

Steel pipe railings and handrailings.--Pipe handrailing shall consist of handrailing elements supported by metal brackets (wall type) or handrailing elements supported by tubular steel posts (post type).

Ends of railing pipe shall be closed, except for a 3 mm diameter weep hole at the low point.

All corners on railings shall be rounded. Simple and compound curves shall be formed by bending pipe in jigs to produce uniform curvature; maintain cylindrical cross-section of pipe throughout the bend without buckling, twisting or otherwise deforming exposed surfaces of the pipe.

Wall brackets, end closures, flanges, miscellaneous fitting and anchors shall be provided for interconnections of pipe and attachment of railings and handrails to other work. Inserts and other anchorage devices shall be furnished for connecting railings and handrails to concrete or masonry.

Steel railing shall be galvanized after fabrication. After galvanizing, all elements of the railing shall be free of fins, abrasions, rough or sharp edges, and other surface defects and shall not be kinked, twisted or bent.

PART 3.- EXECUTION

GENERAL.--

Anchorages.--Anchorage devices and fasteners shall be provided for securing miscellaneous metal in-place construction; including threaded fasteners for concrete and masonry inserts, toggle bolts, through bolts, lag bolts, wood screws and other connectors.

Cutting, drilling and fitting shall be performed as required for installation of miscellaneous metal fabrications. Work is to set accurately in location, alignment and elevation, plumb, level, true and free of rack, measured from established lines and levels.

Loose leveling and bearing plates.--Plates shall be set on wedges or other adjustable devices. Anchor bolts shall be wrench tightened after the plates have been positioned and plumbed. Mortar shall be packed solidly between bearing surfaces and plates to ensure that no voids remain.

Steel pipe railings and handrailings.--Railings shall be adjusted prior to anchoring to ensure matching alignment at abutting joints. Secure posts and railing ends to building construction as shown on the plans.

Resin capsule anchors shall not to be used for anchoring railings and handrailings.

Powder driven anchors.--Powder driven anchors shall be installed with low velocity powder actuated equipment in accordance with the manufacturer's instructions and State and Federal OSHA regulations.

Resin capsule anchors.--Resin capsule anchors shall be installed in accordance with the manufacturer's instructions.

DAMAGED SURFACES.--

General.--Galvanized surfaces that are abraded or damaged at any time after the application of the zinc coating shall be repaired by thoroughly wire brushing the damaged areas and removing all loose and cracked coating, after which the clean areas shall be painted with 2 applications of unthinned zinc-rich primer (organic vehicle type). Aerosol cans shall not be used.

12-5.02 STAIR NOSING

PART 1.- GENERAL

SUMMARY.--

Scope.--This work shall consist of furnishing and installing stair nosings in accordance with the details shown on the plans and these special provisions.

SUBMITTALS.--

Product data.--Manufacturer's descriptive data and installation instructions shall be submitted for approval.

PART 2.- PRODUCTS

MANUFACTURERS.--

Acceptable manufacturers.--Subject to these special provisions, acceptable manufacturer's shall be American Safety Tread Co., Inc., Model No. FA-311D, Safety yellow color; Armstrong Products Inc., Model No. S62, Red color; Wooster Products Inc., Model No. WP4C, Safety yellow color; or equal.

MATERIALS.--

Stair nosing.-

Stair nosing shall be factory fabricated units made of heavy duty, heat treated 6063-T5 extruded aluminum base with anchors and an abrasive filler.

Stair nosing shall meet OSHA requirements for anti-slip safety on stairs.

The anti-slip filler shall be firmly adhered to the base, and shall be composed of aluminum oxide and an epoxy binder. The color shall extend uniformly throughout out the filler. The filler shall contain not less than 60 percent aluminum oxide.

The base anchor system shall stabilize the nosing, prevent rocking and loosening, and shall permanently lock the nosing into place.

PART 3.- EXECUTION

INSTALLATION.--

General.--The stair nosing shall be securely installed to prevent rocking or other movement during placing of concrete.

SECTION 12-6. (BLANK)

SECTION 12-7. THERMAL AND MOISTURE PROTECTION

12-7.01 SEALANTS AND CAULKING

PART 1.- GENERAL

SUMMARY.--

Scope.--This work shall consist of furnishing and applying sealants and caulking which are required for this project, but not specified elsewhere, in accordance with the details shown on the plans and these special provisions.

QUALITY ASSURANCE.--

Certificates of Compliance.--Certificates of compliance shall be furnished for the sealants and caulking in accordance with the requirements specified in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.

SUBMITTALS.--

Product data.--Manufacturer's descriptive data and installation instructions for all sealants shall be submitted for approval. Include a schedule listing each category and location of joints to be sealed and the proposed sealant or caulk.

Samples.--Color samples of all sealants shall be submitted for approval. Unless otherwise shown on the plans, colors will be selected by the Engineer from the manufacturer's standard colors.

PART 2.- PRODUCTS

MATERIALS.--

General.--All sealants, primers and accessories shall be non-staining to adjacent exposed surfaces. Products having similar applications and usage shall be of the same type and same manufacturer. Gun consistency compound shall be used unless otherwise required by the job conditions.

Acrylic sealant.--

Acrylic sealant shall be one compound, solvent release acrylic sealant.

Butyl sealant.--

Butyl sealant shall be one component, skinning type.

Silicone sealant.--

Silicone sealant shall be one component, low modulus building sealant. Sealant shall be tack-free in one hour, shall not sag or flow, shall be ozone resistant and capable of 100 percent extension without failure.

Joint sealant.--

Joint sealant shall be a two-part, non sag polysulfide base, synthetic rubber sealant formulated from liquid polysulfide polymer.

Backer rod.--

Backer rod shall be round, open or closed cell polyurethane. Backer rod shall be sized such that it must be compressed between 25 and 75 percent of its uncompressed diameter during installation in the joint.

Neoprene.--

Neoprene shall conform to the requirements of ASTM Designation: C 542.

PART 3.- EXECUTION

APPLICATION.--

General.--Unless otherwise shown on the plans, sealants shall be applied in accordance with the manufacturer's instructions.

Silicone sealants shall not be used in locations where painting is required.

Butyl sealants shall not be used in exterior applications, and acrylic sealants shall not be used in interior applications.

Sealants shall be applied in a continuous operation for the full length of the joint. Immediately following the application of the sealant, the sealant shall be tooled smooth using a tool similar to that used to produce concave masonry joints. Following tooling, the sealant shall remain undisturbed for not less than 48 hours.

SECTION 12-8. DOORS AND WINDOWS

12-8.01 STAINLESS STEEL DOORS AND FRAMES

PART 1.- GENERAL

Scope.--This work shall consist of fabricating, furnishing and installing stainless steel hollow metal products, including doors and frames, in accordance with the details shown on the plans and these special provisions.

Products provided under this section consist of stainless steel hollow metal doors, swing type, and frames as shown on the plans.

REFERENCES.--

Codes and standards.--The publications listed in this section form a part of this specification to the extent referenced:

ANSI A250.4, Test Procedure and Acceptance Criteria for Physical Endurance for Steel Doors and Hardware Reinforcings.
ANSI/NFPA 80, Standard for Fire Doors and Windows.
ANSI/NFPA 252, Standard Methods of Fire Tests of Door Assemblies.
ANSI/UL 10B, Fire Tests of Door Assemblies.
ASTM A 666, Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar.
NAAMM HMMA 802, Manufacturing of Hollow Metal Doors and Frames.
NAAMM HMMA 820, Hollow Metal Frames.
NAAMM HMMA 850, Fire-Rated Hollow Metal Doors and Frames.
UBC 7-2, Fire Tests of Door Assemblies.
UL 10C, Positive Pressure Fire Tests of Door Assemblies.

TESTING AND PERFORMANCE--

Performance test for steel doors and hardware reinforcings:

The test specimen shall be a 914 mm x 2134 mm nominal size 44 mm door. The test specimen shall be representative of the material to be provided.
The specimen shall be tested in accordance with the ANSI A250-4 procedure and shall meet the acceptance criteria for the Level A doors.

Labeled fire-rated doors and door frames:

Doors and frames shall be provided for those openings requiring fire protection ratings as determined and scheduled in the contract documents. Such doors and frames shall be constructed as tested in accordance with ANSI/NFPA 252, ANSI/UL 10C and UBC 7-2 and listed or classified for labeling by a recognized testing agency having a factory inspection service. Labeled fire doors and frames shall be installed in accordance with the terms of their listings, and in accordance with NFPA 80.

QUALITY ASSURANCE.--

Manufacturer's Qualifications:

Manufacturer shall provide evidence of having personnel and plant equipment capable of fabricating stainless steel door and frame assemblies of the types specified.
Manufacturer shall provide evidence of having a quality control system in place.

Quality Criteria:

All door and frame assemblies shall meet the testing and performance requirements of these special provisions.
Fabrication methods and product quality shall meet ANSI/NAAMM HMMA 866-01.

SUBMITTALS.--

Working drawings.--Working drawings of fabricated items shall be submitted for approval, including:

Show dimensioned door and frame elevations and sections.
Show listing of opening descriptions including locations, thickness, and anchors.
Show location and details of openings.

Samples.--A 305 mm x 305 mm corner section of the door, with hinge preparation showing top and internal construction, shall be submitted for approval.

WARRANTY.--

Stainless steel hollow metal work shall be warranted from defects in workmanship and quality for a period of one year from date of acceptance of contract.

PART 2.- PRODUCTS

STAINLESS STEEL HOLLOW METAL DOORS.--

Materials

Door face sheets shall be manufactured from Type 304 stainless steel conforming to ASTM A 666. It shall be free of buckles, waves or other defects.
Components shall be Type 304 stainless steel.
Both exterior and interior doors: face sheets shall be 1.0 mm minimum thickness.

Construction

Doors shall be of types, sizes and construction in accordance with the contract documents and shall meet the performance requirements of these special provisions.
Door edge constructions:

Continuously welded seam: door face sheets shall be joined at their vertical edges by a continuous weld extending the full height of the door with no visible seams on their faces or vertical edges. Edges shall be polished to match door face sheets in accordance with "Finish" of these special provisions.
Provide stainless steel astragals on active leaf on all pairs of doors.

Door thickness shall be 44 mm nominal. Doors shall be neat in appearance and free from warpage or buckle. Edge bends shall be true and straight and of minimum radius for the thickness of metal used.
Core Constructions:

Laminated steel stiffened: the door shall be stiffened by continuous vertically formed steel sections which, upon assembly, shall span the full thickness of the interior space between door faces. These stiffeners shall be 0.6 mm minimum thickness, spaced so that the vertical interior webs shall be no more than 152 mm apart and securely fastened to both face sheets by adhesive. Spaces between stiffeners shall be filled with fiberglass or mineral rock wool batt-type material. Stiffeners shall be Type 304 stainless steel.

Exterior doors shall be closed flush at the top edge. Where required for attachment for weatherstripping, a flush steel closure channel shall also be provided at the bottom edge. Openings shall be provided in the bottom closure channel of exterior doors to permit the escape of entrapped moisture.
Edge profiles shall be provided on both vertical edges of doors as follows:

Single acting doors: beveled 3 mm in 50.8 mm profile.
Double acting doors: rounded on 54 mm radius.

Hardware reinforcements:

Doors shall be mortised, reinforced, drilled and tapped at the factory for templated mortised hardware only, in accordance with the final approved hardware schedule and templates provided by the hardware supplier. Where surface mounted hardware, anchor hinges, thrust pivots, pivot reinforced hinges, or non-templated mortised hardware apply, doors shall be reinforced, with drilling and tapping done by others in the field. Hardware reinforcements shall be Type 304 stainless steel.
Minimum thickness for hardware reinforcements shall be as follows:

Hardware Reinforcement	Minimum Thickness
Full mortise hinges and pivots	4.2 mm
Reinforcements for lock fronts	2.3 mm or 1.3 mm unitized reinforcement with extruded tapped holes that provide equivalent number of threads as 2.3 mm.
Concealed holders or surface mounted closers	2.3 mm
Internal reinforcements for other surface applied hardware	1.7 mm

STAINLESS STEEL HOLLOW METAL FRAMES.--

Materials

Frame sections shall be manufactured from Type 304 stainless steel conforming to ASTM A 666. It shall be free of buckles, waves or other defects.
Components shall be Type 304 stainless steel.
Interior and exterior openings: for door openings steel shall be 1.7 mm minimum thickness.

Construction

Door frames shall be welded all of the sizes and types shown on approved submittal drawings. All frames shall be constructed in accordance with these special provisions and meet the performance requirements in these special provisions. Frames shall be constructed in accordance with NAAMM HMMA 820 with regard to joint designs and welding techniques.

Finished work shall be neat in appearance, square, and free of defects, warps and buckles.

Stainless steel members shall be straight and of uniform profile throughout their lengths.

Jamb, header, and mullion profiles shall be in accordance with the frame schedule and as shown on the approved submittal drawings.

Corner joints shall have all contact edges closed tight with faces mitered and stops either butted or mitered.

Flush face joints at mullions shall be continuously welded and smoothly finished.

Minimum depth of stops shall be 15.8 mm. Cut-off stops, where shown, shall be capped at heights as shown on approved submittal drawings.

Hardware reinforcements:

Frames shall be mortised, reinforced, drilled and tapped at the factory for templated mortised hardware only, in accordance with the final approved hardware schedule and templates provided by the hardware supplier. Where surface mounted hardware, anchor hinges, thrust pivots, pivot reinforced hinges, or non-templated mortised hardware apply, frames shall be reinforced, with drilling and tapping done by others in the field. Hardware reinforcing shall be Type 304 stainless steel.

Minimum thickness of hardware reinforcing plates shall be as follows:

Hardware Reinforcement	Minimum Thickness
Hinge and pivot reinforcements	4.2 mm x 31.7 mm x 254 mm length
Strike reinforcements	2.3 mm or 1.3 mm unitized reinforcement with extruded tapped holes that provide equivalent number of threads as 2.3 mm.
Closer reinforcements	2.3 mm
Flush bolt reinforcements	2.3 mm
Reinforcements for surface applied hardware	2.3 mm
Reinforcements for hold open arms	2.3 mm
Reinforcements for surface panic devices	2.3 mm

Jamb anchors: frame anchors shall be Type 304 stainless steel, expansion bolt type. Frames for installation in existing masonry or concrete walls shall be prepared for expansion bolt type anchors. The preparation shall consist of a countersunk hole for a 9.5 mm diameter bolt and a spacer from the unexposed surface of the frame to the wall. The spacer shall be welded to the frame and spaced a maximum of 152 mm from the top and bottom of the door opening, with intermediate spacing at a maximum of 660 mm on center.

When the frame head is to be grouted and the door opening width exceeds 1219 mm in width, it shall be reinforced. A steel channel or angle shall be welded into the head at the

factory. Such stiffeners shall be not less than 2.3 mm in thickness and not longer than the opening width, and shall not be used as lintels or load bearing members.
Plaster guards not less than 0.4 mm thick shall be attached at all hardware mortises on frames to be set in masonry or concrete openings.
Welded frames shall be provided with a temporary steel spreader welded or mechanically attached to the feet of the jambs to serve as bracing during shipping and handling and which shall not be used for installation.

CLEARANCES AND TOLERANCES.--

Edge clearances for swinging doors shall not exceed the following:

Between doors and frames at head and jambs: 4.7 mm.
Between edges of pairs of doors: 4.7 mm.
At door sills where a threshold is used: 9.5 mm from bottom of door to top of threshold.
At door sills where no threshold is used: 19.0 mm above floor.
Between door bottom and nominal surface of floor coverings at fire rated openings as provided in ANSI/NFPA 80: 12.7 mm.

Manufacturing tolerances shall be maintained within the following limits:

Frames for single door or pair of doors:

Measurement	Tolerance
Width measured between rabbets at the head: nominal opening width	+1.5 mm, –0.8 mm
Height (total length of jamb rabbet): nominal opening height	+1.2 mm
Face	+0.8 mm
Stop	+0.8 mm
Rabbet	+0.8 mm
Depth	+0.8 mm
Throat	+1.5 mm Frames overlapping walls to have throat dimension 3.1 mm greater than dimensioned wall thickness to accommodate irregularities in wall construction

Doors:

Measurement	Tolerance
Width	+1.2 mm
Height	+1.2 mm
Thickness	+1.5 mm

Hardware:

Measurement	Tolerance
Cutout dimension: template dimensions	+0.38 mm, –0 mm
Location	+1.2 mm
Thickness	+0.8 mm

Bow/Flatness:

Measurement	Tolerance
Bow/Flatness	+1.5 mm

HARDWARE LOCATIONS.--

The location of the hardware on doors and frames shall be as listed below. All dimensions except the hinge locations are referenced from the floor:

Hinges:

Top: 127 mm from frame head to top of hinge.
Bottom: 254 mm from floor to bottom of hinge.
Intermediate: centered between top and bottom hinges.

Unit and integral type locks and latches: 965 mm to centerline of knob.
Deadlocks: 1168 mm to centerline of cylinder.
Panic hardware: 965 mm to centerline of cross bar or as shown on hardware template.

FINISH.--

After fabrication, all tool marks and surface imperfections shall be finished to make face sheets, vertical edges and weld joints free from irregularities. All exposed surfaces of doors and frames shall then be finished in accordance with NAAMM HMMA 802 Manufacturing of Hollow Metal Doors and Frames "Finishes for Stainless Steel," Finish No. 4, described as: a general purpose bright polished finish obtained by finishing with a 120-150 mesh abrasive, following initial grinding with coarser abrasives. All grained finishes applied to faces of doors shall be vertical. All grained finishes applied to frame jambs shall be vertical. Finishes applied to the frame header shall be horizontal.

PART 3.- EXECUTION

SITE STORAGE AND PROTECTION OF STAINLESS STEEL MATERIALS.--

The contractor shall not remove wraps or covers from stainless steel doors and frames until time of installation. The contractor shall see that stainless steel doors and frames are unloaded, stored and handled in a manner that will prevent damage to the finish.

The contractor shall see that materials are properly stored on planks or dunnage in a dry location. Doors shall be stored in a vertical position and spaced by blocking. Materials shall be covered to protect them from damage and shall be stored in such a manner as to permit air to circulate between each door or frame.

INSTALLATION.--

The Contractor shall perform the following:

Prior to installation, frames shall be checked and corrected for size, swing, squareness, alignment, twist and plumbness. Permissible installation tolerances shall not exceed the following:

Squareness: +1.5 mm measured on a line, 90 degrees from one jamb, at the upper corner of the frame at the other jamb.
Alignment: +1.5 mm measured on the jambs on a horizontal line parallel to the plane of the wall.
Twist: +1.5 mm measured at face corners of jambs on parallel lines perpendicular to the plane of the wall.
Plumbness: +1.5 mm measured on the jamb at the floor.

Plaster guards and junction boxes are intended to protect hardware mortises and tapped mounting holes from masonry grout of 101 mm maximum slump consistency which is hand troweled in place. If a lighter consistency grout (greater than 101 mm) slump when tested in accordance with ASTM C 143M is to be used, special precautions shall be taken in the field by the Contractor to protect the aforementioned.
Proper door clearances shall be maintained in accordance with "Clearances and Tolerances" of these special provisions, except for special conditions otherwise noted. Hinge shims, furnished by Contractor, are permitted to maintain clearances.
Hardware shall be applied in accordance with hardware manufacturer's templates and instructions.
Stainless steel surfaces shall be kept free of grout, tar or other bonding materials or sealers. Grout, tar, or other bonding materials or sealers shall be promptly cleaned off frames and doors.
Finished surfaces which have been scratched or otherwise marred during installation (including field welding) or cleaning shall promptly be finished smooth and refinished to match the original polish or finish.
Labeled fire doors and frames shall be installed in accordance with the terms of their listings, and in accordance with NFPA 80.

12-8.02 OVERHEAD COILING DOORS

PART 1.- GENERAL

Scope.--This work shall consist of fabricating, furnishing and installing overhead coiling fire-rated service doors in accordance with the details shown on the plans and these special provisions.

PERFORMANCE REQUIREMENTS--

Structural performance: provide overhead coiling doors capable of withstanding the effects of gravity loads and the following loads and stresses without evidencing permanent deformation of door components:

Wind load: uniform pressure (velocity pressure) of 1440 Pa, acting inward and outward.

Operation-cycle requirements: provide overhead coiling door components and operators capable of operating for not less than 20,000 cycles.

QUALITY ASSURANCE.--

Installer qualifications: manufacturer's authorized representative who is trained and approved for both installation and maintenance of units required for this project.
Fire-test-response characteristics: provide assemblies complying with NFPA 80 that are identical to door and frame assemblies tested for fire-test-response characteristics per UL 10b and NFPA 252, and that are listed and labeled for fire ratings indicated by UL, FMG, ITS, or another testing and inspecting agency acceptable to authorities having jurisdiction.
Electrical components, devices, and accessories: listed and labeled as defined in NFPA 70, Article 100.

SUBMITTALS.--

Product Data.--Manufacturer's technical data shall be submitted for each type and size of overhead coiling door and accessories.
Working drawings.--Working drawings of fabricated items shall be submitted for approval, including plans, elevations, sections, details, and attachment to other work and wiring diagrams.
Samples.--A sample of each exposed finish shall be submitted for approval.
Oversize Construction Certification.--For door assemblies required to be fire-rated and exceeding size limitations of labeled assemblies.

DELIVERY, STORAGE AND HANDLING.--

Package coiling doors to prevent damage in transit or during handling. Store at site to avoid misalignment or distortion.
Protect against damage from weather or other causes.

COORDINATION.--

Coordinate location of electrical service and tie-in to alarm and detecting system. Coordinate location of door electrical motor controls.

PART 2.- PRODUCTS

DOOR CURTAIN MATERIALS AND CONSTRUCTION.--

Door curtains: interlocking slats in a continuous length for width of door of thickness and mechanical properties recommended by door manufacturer for performance, size, and type of door:

Steel door curtain slats: stainless steel sheet; complying with ASTM A 666M, A304 No. 4 coating designation.
Slat type: flat profile.

Endlocks and windlocks: malleable-iron casings, secured to curtain slats to comply with wind load.
Bottom bar: 2 stainless steel angles, each not less than 38 by 38 by 3 mm thick to suit type of curtain slats.

Astragal: replaceable, adjustable, continuous, compressible gasket of flexible vinyl, rubber, or neoprene; as a cushion bumper for interior door.

Fire door curtain jamb guides: stainless steel angles or channels and angles, with sufficient depth and strength to retain curtain, to allow curtain to operate smoothly, and to withstand loading. Slot bolt holes for guide adjustment. Provide removable stops on guides to prevent overtravel of curtain, and a continuous bar for holding windlocks.
Hood: form to act as weatherseal and entirely enclose coiled curtain and operating mechanism at opening head. Contour to fit end brackets. Roll and reinforce top and bottom edges for stiffness. Provide closed ends for surface-mounted hoods, and provide fascia for any portion of between-jamb mounting projecting beyond wall face. Provide intermediate support brackets as required to prevent sagging.

Steel door hoods: minimum 0.7-mm thick, stainless steel sheet that matches slat steel.
Include automatic drop baffle to guard against passage of smoke or flame.
Shape: Round.
Exterior-Mounted Door: Fabricate hood with sealant-joint bead profile for applying joint sealant.

Integral frame, hood, and fascia: welded assemblies of stainless steel, minimum 0.065 mm thick sheet that matches door steel.
Smoke seals: UL-listed and -tested smoke-seal perimeter gaskets.
Weatherseals: replaceable, adjustable, continuous, compressible weather-stripping gaskets fitted to bottom and top of exterior doors, unless otherwise indicated. At door head, use 3 mm thick, replaceable, continuous sheet secured to inside of hood.

Motor-operated doors: combination bottom weatherseal and sensor edge.
Jamb Seals: Replaceable, adjustable, continuous, flexible, 3-mm- thick seals of flexible vinyl, rubber, or neoprene at door jambs for a weathertight installation.

Push/pull handles: galvanized steel lifting handles on each side of door.

Provide pull-down straps or pole hooks for doors more than 2130 mm high.

Power-operated doors: safety interlock switch to disengage power supply when door is locked.

Automatic-closing device: inoperative during normal door operations; with viscous-speed governor unit complying with requirements of NFPA 80 and with an easily tested and reset release mechanism, and designed to be activated by the following:

Replaceable fusible links with temperature rise and melting point of 74°C; interconnected and mounted on both sides of door opening.
Manufacturer's standard UL-labeled smoke and heat detector and door-holder-release devices.
Building fire alarm and detection system and door-holder-release devices.

Counterbalancing mechanism: adjustable-tension, steel helical torsion spring mounted around a steel shaft and contained in a spring barrel connected to door curtain with barrel rings. Use grease-sealed bearings or self-lubricating graphite bearings for rotating members.

Mounting brackets: cast iron or cold-rolled steel plate.

Electric door operator: manufacturer's standard type, size, and capacity for door and operation-cycle requirements specified, with electric motor and factory-prewired motor controls, starter, gear-reduction unit, solenoid-operated brake, clutch, remote-control stations, control devices, integral gearing for locking door, and accessories. Comply with NFPA 70. The basis of design motor operated fire doors and fire counter shall be controlled by

Disconnect device: hand-operated for automatically engaging chain and sprocket operator and releasing brake for emergency manual operation while disconnecting motor without affecting timing of limit switch. Mount to be accessible from floor level. Include interlock device to automatically prevent motor from operating when emergency operator is engaged.
Door-operator type: wall-, hood-, or bracket-mounted unit with electric motor, worm-gear running-in-oil drive, and chain and sprocket secondary drive.
Fire doors with motor operators shall be controlled by motor operator with electronic testing capability. This motor operator shall allow testing of fire doors without ever mechanically resetting the release mechanism. The motor and controls shall be UL approved for fire doors. The control panel shall be wired directly into the building 24 V(dc) fire alarm system.
Upon activation of the fire alarm system, the motor operator shall power close the door. If there is an obstruction in the opening, the door shall automatically open and close again. The sensor edge shall continue to cycle the door up and down until the obstruction is removed and the door can fully close or the door has cycled three times, in which case the door shall stop at the obstruction. If at any time the obstruction is removed, with the continuation of the alarm signal, the door will continue to the fully closed position. To reset the door, push the up control station. The door shall return to the fully open position.
If power to the motor operator is interrupted, the automatic closing device shall close the door. The motor operator shall not be disconnected from the door.
To reset the fire door, resume power to the motor operator, clear the alarm system and push up control station. The fire door shall never need to be mechanically reset and

testing can be performed by any individual by activating the alarm system or by interrupting power to the motor operator.

Electric motors: high-starting torque, reversible, continuous-duty, Class A insulated, electric motors complying with NEMA MG 1; with overload protection; sized to start, accelerate, and operate door in either direction from any position, at not less than 0.2 m/s and not more than 0.3 m/s, without exceeding nameplate ratings or service factor. Coordinate wiring requirements and electrical characteristics of motors with building electrical system. Motor size shall be that recommended by the manufacturer to operate the door size scheduled:

Open drip proof-type motor with belt drive and roller chain sprocket reducer, and controller with NEMA ICS 6, Type 1 enclosure.

Control Equipment: NEMA ICS 1, NEMA ICS 2, and NEMA ICS 6, with NFPA 70 Class 2 control circuit, maximum 24 V, ac or dc, with remote, three-button control station:

Units, full-guarded, surface-mounted, standard-duty, weatherproof type, NEMA ICS 6, Type 4 enclosure, key operated.
Obstruction detection device: external and internal automatic safety sensors capable of protecting full width of door opening. Activation of sensor immediately stops and reverses downward door travel.
Photoelectric sensor: manufacturer's standard system designed to detect an obstruction in door opening without contact between door and obstruction.
Sensor edge: provide each motorized door with an automatic safety sensor edge, located within astragal or weather stripping mounted to bottom bar. Contact with sensor immediately stops and reverses downward door travel. Connect to control circuit using manufacturer's standard take-up reel or self-coiling cable. Provide pneumatically actuated automatic bottom bar.
Provide electric operators with ADA-compliant audible alarm and visual indicator lights.

FINISHES.--

Stainless steel 304 with No. 4 finish with finish grain running parallel with profile grade.

PART 3.- EXECUTION

INSTALLATION.--

General: install coiling doors and operating equipment complete with necessary hardware, jamb and head molding strips, anchors, inserts, hangers, and equipment supports. Install fire-rated doors to comply with NFPA 80.
Lubricate bearings and sliding parts; adjust doors to operate easily, free of warp, twist, or distortion, and with weathertight fit around entire perimeter.
Test doors to demonstrate normal operation and emergency operation at fire doors and fire counter doors.

12-8.03 FINISH HARDWARE

PART 1.- GENERAL

SUMMARY.--

This work shall consist of furnishing and installing hardware items for doors in accordance with the details shown on the plans and these special provisions.

Astragals for pairs of doors shall be as specified under "Stainless Steel Doors and Frames" in Section 12-8 "Doors and Windows," of these special provisions.

Hardware assemblies shall comply with the fire ratings for doors indicated on the plans and specified in these special provisions.

SUBMITTALS.—

Manufacturer's technical information and catalog cuts for each item of door hardware and a door hardware schedule shall be submitted for approval prior to installation. The Engineer will require 3 weeks to review the submittal after a complete set has been received, as determined by the Engineer.

Manufacturer's catalog cuts shall include catalog numbers, material, grade, type, size, function, design, quality and finish of hardware.

The door hardware schedule shall indicate the location and size of door opening, the door and frame material, and the size, style, finish and quantity of the hardware components required.

FINISHES.—

Hardware shall be provided with a BHMA 630 finish satin stainless steel. Provide items not manufactured in stainless steel in BHMA finish (satin chrome plated) over brass or bronze.

KEYING INSTRUCTIONS.—

New facilities shall have a building master key system established.

Locks shall have cylinders with figure eight interchangeable cores with six pin barrels. Permanent cores and keys shall be delivered to the Engineer for final installation at completion of project.

The Contractor shall also provide 10 figure eight interchangeable cores for use during construction which shall remain the property of the State.

Key bows shall be stamped "State of California" and "Do Not Duplicate."

PART 2.- PRODUCTS.--

GENERAL.—

Door hardware equal in material, grade, type, size, function, design, quality and manufacture to that specified herein may be submitted for approval.

Butt hinges.--

Butt hinges shall be stainless steel, 1 1/2-pair per door unless otherwise specified or shown on the plans. Full mortise, 5 knuckle, ball bearing hinges with nonremovable pins shall be provided. Hinge size shall be 114 mm x 114 mm unless otherwise noted.

Heavy weight hinges shall be:

Hager	BB 1199
McKinney	T4B 3386
Stanley	FBB 199
or equal.	

Door closers.--

Parallel arms for closers shall be installed at outswing exterior doors. Closers shall have sprayed finish to match other hardware on door.

Door closers shall be:

LCN	4040
Norton	85001
Dorma	7800
or equal.	

Panic devices.--

Rim type panic devices shall be installed at single doors and on pairs of doors, unless indicated otherwise. Removable mullion and type 21 door coordinator and carry-open bar shall be provided on pairs of doors. Astragal on active leaf on pairs of doors to be provided with stainless steel doors. Dogging devices shall be omitted. On function 08, lever shall always be unlocked and key device shall be omitted.

Panic devices with outside key operation function 05 shall be:

Corbin	ED 5200 A
Monarch	(F) 18-R-T
Von Duprin	98-TP-F
or equal.	

Panic devices with outside lever handle operation function 08 shall be:

Corbin	ED 5200 A
Monarch	(F) 18-R-L\K2
Von Duprin	98-BE-F
or equal.	

Panic devices with exit only operation function 01 shall be:

Corbin	ED 5200 A
Monarch	(F) 18-R-BA
Von Duprin	98-EQ-F
or equal.	

Kickplates.--

Kickplates shall be 254 mm in height x 51 mm less than door width x 1.52 mm (16-gage).

Kickplates shall be:

Builders Brass	37
Quality	48
Trimco	6000
or equal.	

Wall mounted door stop and holder.--

Wall mounted door stop and holder shall be:

Builders Brass	W140, W141X
Quality	36, 136
Trimco	1202, 1207
or equal.	

Wall bumpers.--

Wall bumpers base diameter shall be 64 mm with a 25 mm projection.

Bumpers shall be:

Builders Brass	WC9
Quality	302
Trimco	1272-1/4-CCS
or equal.	

Automatic door bottom.--

Automatic door bottom shall be heavy duty, full mortise.

Bottom shall be:

Pemko	420 AKPL
Zero	355A
or equal.	

Thresholds, rain drips, door sweeps and door shoes.--

Thresholds, shall conform to the sizes and configurations shown on plans. Thresholds at door openings shall not exceed 13 mm in height.

Threshold, rain drip, door sweep and door shoe manufacturers shall be Pemko, Reese, Zero, or equal.

Threshold bedding sealant.--

Threshold bedding sealant shall conform to Federal Specification: SS-C-153.

Weatherstrip and draft stop.--

Weatherstrip and draft stop assemblies shall be UL listed and shall be provided where shown on the plans or as specified in these special provisions.

Weatherstrip and draft stop manufacturers shall be Pemko, Reese, Zero, or equal.

Door signs and name plates.--

Door signs and name plates shall be as specified under "Signs" in Section 12-10, "Specialties," of these special provisions.

PART 3.- EXECUTION

STAINLESS STEEL DOORS AND FRAMES.—Stainless steel doors and frames shall be set square and plumb and be properly prepared before the installation of hardware.

INSTALLATION.--Hardware items shall be accurately fitted, securely applied, and adjusted and lubricated in accordance with the manufacturer's instructions. Installation shall provide proper operation without bind or excessive play. Hardware installation shall comply with NFPA 80.

Hardware shall be located on the doors as noted under "Stainless Steel Doors and Frames" in Section 12-8 "Doors and Windows," of these special provisions.

Thresholds shall be set in a continuous bed of sealant material.

Door controls shall be set so that the effort required to operate doors with closers shall not exceed 22.3 N maximum for exterior doors and 22.3 N maximum for interior doors. The effort required to operate fire doors may be increased above the values shown for exterior and interior doors but shall not exceed 66.7 N maximum.

Door stops located on concrete surfaces shall be fastened rigidly and securely in place with expansion anchoring devices. Door stops mounted elsewhere shall be securely attached with wood screws or expansion devices as required.

Backing shall be provided in wall framing at wall bumper locations.

Hardware, except hinges, shall be removed from surfaces to be painted before painting.

Upon completion of installation and adjustment, the Contractor shall deliver to the Engineer all dogging keys, closer valve keys, lock spanner wrenches, and other factory furnished installation aids, instructions and maintenance guides.

DOOR HARDWARE GROUPS AND SCHEDULE.--Hardware groups specified herein shall correspond to those shown on the plans:

GROUP 1 (Each Cross Passage Door)

Two each 1-1/2-pair butt hinges
Two each panic device with exit only operation
Two each Weatherstripping
Two each Automatic Door Bottom
Two each Threshold
Two each Wall Bumper
Two each Door Closer
Two each Door Kickplate on exit device side

GROUP 2 (Equipment Chamber Access Entry & Interior Pump Room)

Two each 1-1/2-pair butt hinges
One each panic device with outside key operation on active leaf

One each Threshold.
One each Weatherstripping
One Removable Mullion
One set concealed flush bolts on inactive leaf
Two each Door Stop and Holder
Two each Door closer
Two each Door Kickplate on active leaf

GROUP 3 (Equipment access North, Center& South Equipment Chambers)

Two each 2-pair butt hinges
One each panic device with outside key operation on active leaf
One each panic device with exit only operation on inactive leaf
One Removable Mullion
One each Door Coordinator
Two each Automatic Door Bottom
One each Threshold.
Two each Weatherstripping
Two each Door Stop and Holder
Two each Door closer

GROUP 4 (Center Cross Passage Door)

One each 1-1/2-pair butt hinges
One each panic device with exit only operation
One each Automatic Door Bottom
One each Threshold.
One each Weatherstripping
One each Wall Bumper
One each Door closer
Two each Door Kickplate

GROUP 5 (Access South Equipment Chamber)

One each 1-1/2-pair butt hinges
One each panic device with outside key operation
One each Automatic Door Bottom
One each Threshold.
One each Weatherstripping
One each Wall Bumper
One each Door closer
Two each Door Kickplate

SECTION 12-9. FINISHES

12-9.01 ARCHITECTURAL SURFACE (TEXTURED CONCRETE)

Architectural texture for concrete surfaces shall conform to the details shown on the plans and the provisions in Section 51, "Concrete Structures," of the Standard Specifications and these special provisions.

Architectural textures listed below are required at concrete surfaces shown on the plans:

A. Formed relief texture

The architectural texture shall simulate a formed relief constructed to the dimensions and shapes shown on the plans. Corners at the intersection of plane surfaces shall be sharp and crisp without easing or rounding. A Class 1 surface finish shall be applied to the architectural texture.

The Contractor shall submit the working drawings for formed relief texture in conformance with the provisions in Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications. The working drawings shall include form liner panel layout drawings that identify each texture type, individual panel type and details. Delineation of proposed area to be hand textured and details of hand textured area shall be provided.

CONCRETE SURFACE TEXTURE A

The rock sample for Concrete Texture "A" is an Igneous Rock whose composition is granite. The age of the rock is Upper Jurassic to Lower Cretaceous (about 100 to 150 million years old). The sample is located in the vicinity of the cut on Route 1 at the south portal. The rock also occurs at rock outcrops on the cliff face and along the east side of the highway above the south portal area.

The texture reference sample is located on the east side of highway 1 just at the south portal area at about station point SB 118+45. It is approximately at the roadway shoulder elevation but is above the existing depression at the portal. It is characterized as monolithic with a mottled weathered surface texture.

The rock sample color is light grey. The typical color shall match the large outcrops on the east side of the south portal area. It is above the trail on the mountain at approximately elevation 126. The color shall match the light green of the new spring growth of lichen with specs of black/green and areas of darker grey.

The concrete texture at the pedestals at the bottom of the south portal structures shall be color 2 and shall match the dark buff color of the weathered material above the bottom of the mountain washed by the ocean. This is on the north end of Gray Whale Cove State Park beach.

CONCRETE SURFACE TEXTURE B

The rock sample for Concrete Texture "B" is a Cretaceous Sedimentary Rock. Cretaceous sandstone and shale crop out at the north end of the alignment. The rock outcrops just north of the North Portal above the trail. The shale is similar to the Paleocene shale such that they can not be easily differentiated.

The sandstone is massively bedded, and typically strong to very strong where slightly weathered to fresh. The material is closely jointed in outcrop.

The texture reference sample is located on the north side of north portal area at about station point SB 130+70. It is approximately 2 m above the trail elevation. It is characterized as varying width layers of shale and sandstone that are block-like.

The rock sample is multi-colored with hues of buff, yellow and gray.

Concrete surface texture (Type B) shall be scallop shape as shown on the plans.

CONCRETE SURFACE TEXTURE C

The rock sample for Concrete Texture "C" is a Paleocene Sedimentary Rock. In outcrops along the highway near the north end of the roadway above the ocean before it turns inland are Paleocene rocks that include shale and sandstone. These rocks are folded into east-west trending synclines and anticlines, which range from broad open structures with gently dipping limbs to tight folds with steeply dipping to locally overturned bedding.

In outcrop the shale is typically weak to medium strong, and closely jointed. Bedding is typically thin, generally in the 60 mm to 15 cm range. Thin (2 to 7 cm) interbeds of sandstone are common. Thickness of shale intervals ranged from less than half a meter to 30 m. In outcrop, sandstone is typically fine to medium grained with local coarse grains; arkosic with some lithic fragments; weak to medium strong where highly to moderately weathered, and strong to very strong where slightly weathered to fresh; and moderately to widely jointed. In outcrop and in the borings, sandstone intervals range from less than half a meter to 30 m thick. Shale is commonly interbedded with the sandstone.

The texture reference sample is located on the east side of highway 1 at about station point SB 130+80. It is approximately 1.2 m above the roadway elevation. It is characterized as varying width layers of shale and sandstone. The layer widths shall vary from 4-24cm. The rock is easily subject to displacement. Rock surface height variation will range from 5-75 mm.

The rock sample is multi-colored with hues of buff, orange, green and black.

CONCRETE SURFACE TEXTURE D

The rock sample for Concrete Texture "D" is an Igneous Rock ranging in composition from granodiorite and quartz diorite. To simplify discussions in this report these rocks are referred to as granitic. The age of the rocks is Upper Jurassic to Lower Cretaceous (about 100 to 150 million years old). The rock mass contains local vein quartz, which increases in abundance to the southeast. In the vicinity of the cut on Route 1 near the south portal, the rocks are deeply weathered. At the ground surface, the granitic rock is typically extremely weathered.

The texture reference sample is located on the east side of highway 1 just north of the south portal area at about station point SB 118+60. It is approximately 2 m above the roadway shoulder elevation. It is characterized as granular and weathered in nature. The rock is easily subject to displacement.

The rock sample is multi-colored with hues of buff and orange with specs of white.

CONCRETE SURFACE TEXTURE E

The rock sample for Concrete Texture "E" is the same as Concrete Texture "C" except that the thickness of the layers is more uniform. The layer thickness is approximately 6-8 cm.

The texture reference sample is located on the east side of highway 1 at about station point SB 131+20. It is approximately 1.2 m above the roadway elevation. It is characterized as varying width layers of shale and sandstone. The layer widths shall vary from 4-8 cm. The rock is easily subject to displacement. Rock surface height variation may be greater than 75 mm.

The rock sample is multi-colored with hues of buff, orange, green and black.

REFEREE SAMPLE

The architectural texture shall match the texture, color and pattern of the referee sample. The referee sample consists of actual rock formations at the project site. The Contractor's form liner molds shall be taken from the referee sample locations. The referee samples are available for inspection by bidders either at scheduled site visits or as arranged in advance with the Office of

Structures Design, Specifications Section, Second Floor, 1801 30th Street, Sacramento, California.

Attention is directed to "Prepare and Paint Concrete" of these special provisions.

TEST PANEL

Test panels at least 1.25 m x 1.25 m in size shall be successfully completed at a location approved by the Engineer before beginning work on the mockups of architectural concrete textures. The test panel shall be constructed and finished with the materials, tools, equipment and methods to be used in constructing the architectural concrete texture. One test panel shall be required for each texture. A separate test panel shall be provided for any finishes that are to be hand textured. The test panel for concrete texture B shall be in the scallop geometric configuration and shall include as a minimum the height of one scallop. The texture of the test panels shall be approved by the Engineer before the mockups are produced. If ordered by the Engineer, additional test panels shall be constructed and finished until the specified finish, texture and color are obtained, as determined by the Engineer.

The concrete barrier includes Concrete Surface Texture D. The test panel for the concrete barrier textures is included as work of this section.

Attention is directed to "Concrete Barrier" of these special provisions.

The test panel approved by the Engineer shall be used as the standard of comparison in determining acceptability of architectural texture for concrete surfaces.

MOCK-UPS FOR PAINTING AND REPAIR OF DEFECT APPROVAL

Mockup panels of architectural concrete textures shall be successfully completed at a location approved by the Engineer. Full size mock-ups of architectural concrete textures shall be submitted for approval. Area of architectural concrete textures to be provided in mock-up shall be shown on the plans. The mock-up shall be constructed and finished with the materials, tools, equipment and methods to be used in constructing the architectural concrete texture in the actual three dimensional configuration of the construction. The mock-up shall include all the form liner edge conditions to be encountered in the final construction. This shall include the interface edge between the form finish transverse and longitudinal form liner panel edges and the form finish and the hand textured concrete texture edges. There shall be no visible edge variation. The architectural concrete textures shall be painted to match the colors of the reference samples. If ordered by the Engineer, additional mock-ups shall be constructed and finished until the specified finish, texture and color are obtained, as determined by the Engineer.

Attention is directed to "Prepare and Paint Concrete" of these special provisions.

The concrete safety shape includes Concrete Surface Texture D. The mock-up for the concrete barrier textures is included as work of this section.

Attention is directed to "Concrete Barrier" of these special provisions.

The mockup shall include proposed sample repairs of defects. The extent of proposed defects to be repaired in the final construction shall be included on the mock-up. The mock-up shall show two similar defects. One shall be repaired and the other left un-repaired for comparison. The Engineer shall approve the extent of defects that can be repaired in lieu of replacement based on the sample repairs methods approved on the mock-up. The mockup approved by the Engineer shall be used as the standard of comparison in determining those defects that are allowed to be repaired and the acceptability of the repair method.

The mock-up approved by the Engineer shall be used as the standard of comparison in determining acceptability of architectural texture for concrete surfaces.

FORM LINERS

Form liners shall be used for textured concrete surfaces and shall be installed in conformance with the manufacturer's recommendations, unless other methods of forming textured concrete surfaces are approved by the Engineer. Form liners shall be manufactured from an elastomeric material or a semi-elastomeric polyurethane material by a manufacturer of commercially available concrete form liners. No substitution of other types of formliner material will be allowed. Form liners shall leave crisp, sharp definition of the architectural concrete texture surface. Recurring textural configurations exhibited by repeating, recognizable shadow patterns shall not be accepted. The minimum area of non-repeating pattern shall be 3.66 meters by 9.15 meters. This shall be prevented by the use of a multiple number of form liner panels in each concrete texture type. The number of different form liner patterns in each concrete texture type shall be determined by the form liner manufacturer. Textured concrete surfaces with such recurring textural configurations shall be reworked to remove such patterns as approved by the Engineer or the concrete shall be replaced.

Form liners shall have the following properties:

Description	ASTM Designation:	Range
Elastomeric material		
Shore A hardness	D 2240	20 to 65
Tensile strength (MPa)	D 412	0.9 to 6.2
Semi-elastomeric polyurethane		
Shore D hardness	D 2240	55 to 65
Tensile strength (MPa)	D 2370	18 minimum

Cuts and tears in form liners shall be sealed and repaired in conformance with the manufacturer's recommendations. Form liners that are delaminated from the form shall not be used. Form liners with deformations to the manufactured surface caused by improper storage practices or any other reason shall not be used.

Form liners shall extend the full length of texturing with transverse joints at 2.5 m minimum spacing. Small pieces of form liners shall not be used. Patterning of architectural concrete textures shall appear natural and non-repeating. Seam lines caused by two or more molds coming together will not be apparent when viewing the final installation. Patterns shall be aligned straight and true. Patterns shall match at edges of adjoining form liner panels. Adjoining edges of form liner panels shall be butted together without distortion, open cracks or offsets at the joints. Edges of form liner panels shall be cleaned before each use to remove any concrete in the joint.

Adhesives shall be compatible with the form liner material and with concrete. Adhesives shall be approved by the liner manufacturer. Adhesives shall not cause swelling of the liner material.

RELEASING FORM LINERS

Products and application procedures for form release agents shall be approved by the form liner manufacturer. Release agents shall not cause swelling of the liner material or delamination from the forms. Release agents shall not stain the concrete or react with the liner material. For reliefs with a directional pattern the application method shall include the scrubbing method using a natural bristle scrub brush in the direction of the pattern. The release agent shall coat the liner with a thin film. Following application of form release agent, the liner surfaces shall be cleaned of excess amounts of agent using compressed air. Buildup of form release agent caused by the reuse of a liner shall be removed at least every 5 uses.

Form liners shall release without leaving particles or pieces of liner material on the concrete and without pulling or breaking concrete from the textured surface. The concrete surfaces exposed by removing forms shall be protected from damage.

HAND TEXTURING

Where concrete surface texture can not be achieved by a formed finish on either concrete texture A or C as shown on the plans, the Contractor shall sculpt the concrete surface to match the formed texture. The area of the concrete textures where hand texturing is allowed is located from the concrete surface texture type B or D scallop form edge to the exterior surface edge of the tunnel structure including areas on the exterior not able to be formed. The formed concrete surface texture finish shall be used to the maximum extent possible in these areas. The hand textured areas shall be painted to match the reference samples.

Attention is directed to "Prepare and Paint Concrete" of these special provisions.

CURING

Concrete surfaces with architectural texture shall be cured only by the forms-in-place or water methods. Seals and curing compounds shall not be used.

MEASUREMENT AND PAYMENT

Concrete texture will be measured and paid for by the square meter.

The contract price paid per square meter for concrete texture of the types listed in the Engineer's Estimate shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals and for doing all the work involved in concrete texture, complete in place, including test panels, mock-ups, and painting of concrete surfaces, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

12-9.03 PREPARE AND PAINT CONCRETE SURFACES

This work shall consist of preparing and painting concrete surfaces, where shown on the plans, and in conformance with these special provisions.

Materials

The paint shall be a light-stable, alkali-resistant, acrylic latex or acrylic latex copolymer emulsion, commercially manufactured for use as an exterior concrete coating. The paint shall

conform to the provisions in Section 91-4.05, "Paint: Acrylic Emulsion, Exterior White and Light and Medium Tints," of the Standard Specifications.

The paint for the architectural surface (textured concrete) shall be semi-transparent, acrylic emulsion, low viscosity, using inorganic pigments, titanium dioxide, quartz for toning pigments, providing resistance to mildew and commercially manufactured for use on exterior concrete. A two coat anti-graffiti coating material consisting of a permanent base coat and sacrificial top coat listed by the manufacturer as graffiti resistant shall be applied. The permanent base coat shall be a co-polymer material that dries clear, non-yellowing with low luster sheen, and V.O.C. compliant. The sacrificial top coating shall be a water base emulsion, clear, non-yellowing with low luster sheen, and V.O.C. compliant.

The Contractor shall submit to the Engineer, not less than one week prior to initial application of the concrete coating, a copy of the manufacturer's recommendations and written application instructions.

Architectural Surface (Textured Concrete) Referee Sample

The architectural texture shall match the texture, color and pattern of the referee sample as specified in "Architectural Surface (Textured Concrete)" of these special provisions. The referee sample consists of actual rock formations at the project site. It is the intent that the painted mock-up panel shall resemble in appearance the texture, pattern, surface relief, strata line detail, and color of the reference samples. Final coloration shall accurately simulate the appearance of the reference sample including the multiple colors, shades, flecking, and veining of real stone. It shall also demonstrate the colors that may be apparent from aging, such as staining from oxidation, rusting and/or organic staining from soil and/or vegetation. The referee samples are available for inspection by bidders either at scheduled site visits or as arranged in advance with the Office of Structures Design, Specifications Section, Second Floor, 1801 30th Street, Sacramento, California

Architectural Surface (Textured Concrete) Paint Applicator Qualifications

Experience in painting of architectural surface textured concrete is highly desirable and will be an important factor in determining the Contractor's qualifications to perform the architectural treatment. The Contractor shall furnish evidence of at least 10 years experience to the Engineer, including, but not limited to, project references, dates, names, phone numbers, and color photos. Painting personnel responsible for painting of the mock-up shall be the same personnel used to paint the architectural surface textured concrete throughout the duration of the project.

Test Panel

A test panel at least 1.25 m x 1.25 m in size shall be successfully completed at a location approved by the Engineer before beginning work on architectural texture or painting concrete. The test panel shall be constructed, finished, and painted with the materials, tools, equipment, personnel, and methods to be used in constructing the architectural texture, finishing, and painting the concrete surfaces. The test panel shall include both formed and hand sculpted samples of the architectural textures. If ordered by the Engineer, additional test panels shall be constructed and finished until the specified finish, texture, and color are obtained, as determined by the Engineer.

The test panel for painting of interior room concrete walls shall be installed on a wall in the south equipment chamber.

Architectural Surface (Textured Concrete) Mock-up

The mock-ups with the approved architectural surface textured concrete substrates to receive a paint finish are included in the section "Architectural Surface (Textured Concrete)" of these special provisions under mock-ups. The painting for architectural surface textured concrete on the mock-ups shall be provided as work of this section.

The test panel approved by the Engineer shall be used as the standard for comparison in determining acceptability of architectural texture and painting for concrete surfaces.

The Contractor shall submit to the Engineer, not less than one week prior to initial application of the concrete coating to the test panel, a copy of the manufacturer's recommendations and written application instructions.

Surface Preparation

New concrete surfaces to be painted shall be cured in conformance with the provisions in Section 90-7.03, "Curing Structures," of the Standard Specifications.

Concrete surfaces to be painted shall be prepared in conformance with the requirements of SSPC-SP 13, "Surface Preparation of Concrete," of the Structural Steel Painting Council. After concrete surface preparation is complete, the Contractor shall clean all concrete surfaces to be painted by water rinsing as defined in Section 59-1.03, "Application," of the Standard Specifications.

Painting Concrete

The coating shall be applied per the manufacturer's recommendations and in conformance with the requirements of SSPC-SP 11,"Guide for Coating Concrete," of the Structural Steel Painting Council.

Any damaged areas shall be repaired in the same manner as the original surface preparation and paint application.

Architectural Surface (Textured Concrete) Painting

Paint shall be applied in multiple coats to accurately simulate the appearance of the reference sample including the multiple colors, shades, flecking, and veining of the reference sample. The paint is to be applied as a stain using brush, roller or spray. Exterior areas subject to rain and fog shall be protected. Final paint coat shall fully cure before application of two coat anti-graffiti coating. Apply base coat permanent and top coat sacrificial anti-graffiti coating.

Measurement and Payment

Concrete surfaces to be prepared and painted will be measured by the square meter. Measurement will be determined along the surface of the actual areas painted.

The contract price paid per square meter for prepare and paint concrete surfaces shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in preparing of and applying paint to concrete surfaces, complete in place, including construction of test panels and repairing damaged areas, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-1.__ PREPARE AND STAIN CONCRETE

This work shall consist of preparing and staining concrete surfaces, where shown on the plans, and in conformance with these special provisions.

MATERIALS

Concrete stain shall be a water based solution of metallic salts that penetrate and react with concrete to produce insoluble, abrasion-resistant color deposits. The stain shall contain dilute acid to etch concrete surfaces so that the staining ingredients can penetrate the concrete.

Concrete stain shall be formulated and applied so that the final color of the stained concrete shall conform the following:

A. Concrete Smooth Stained Color 1 located at the concrete behind the metal panels and at the tunnel crown between the top of the metal panels on each side of the tunnel shall be black.
B. Concrete Smooth Stained and Concrete Texture D Color 2 located at the Safety Shape shall match the blended color of Concrete Surface Texture D. The blended color shall be a single color that matches the multi colored paint of Concrete Surface Texture D.
C. Concrete Smooth Stained Color 2 located at the concrete walls in the vestibules on the tunnel side of the cross passages shall match the blended color of Concrete Surface Texture D. The blended color shall be a single color that matches the multi colored paint of Concrete Surface Texture D.

TEST PANEL

A test panel at least 1.25 m x 1.25 m in size shall be completed and approved at a location approved by the Engineer before beginning work on staining concrete. The test panel shall be constructed, finished, and stained with the materials, tools, equipment, personnel, and methods to be used in constructing, finishing, and staining the concrete surfaces. Additional test panels may be ordered by the Engineer until the specified finish, texture, and color are obtained, as determined by the Engineer.

The test panel approved by the Engineer shall be used as the standard of comparison in determining acceptability of staining for concrete surfaces.

The Contractor shall submit a copy of the manufacturer's recommendations and written application instructions to the Engineer not less than one week prior to applying concrete stain to test panels.

DEBRIS CONTAINMENT AND COLLECTION PROGRAM

Prior to commencing concrete staining operations, the Contractor shall submit to the Engineer a debris containment and collection program for the water and debris resulting from preparing, staining, and rinsing concrete surfaces. The Engineer will notify the Contractor of the approval or rejection of the debris containment and collection program within 2 weeks of the Contractor's complete submittal. No concrete staining work shall be performed until the Engineer has reviewed and approved the debris containment and collection program.

The containment system shall contain all water and debris resulting from preparing, staining, and rinsing stained concrete surfaces. All water and debris collected shall be sampled. Samples shall be taken to an authorized hazardous waste testing laboratory for testing to determine proper disposal procedures. A copy of the test results shall be given to the Engineer.

In the event the Engineer fails to provide approval within the time allowed, and if, in the opinion of the Engineer, completion of the work is delayed or interfered with by reason of the Engineer's delay in providing approval, the Contractor will be compensated for resulting losses, and an extension of time will be granted in the same manner as provided for in Section 8-1.09, "Right of Way Delays," of the Standard Specifications.

Disposal of water and debris collected by the containment system shall be performed in conformance with applicable Federal, State, and Local hazardous waste laws, including:

A. Health and Safety Code, Division 20, Chapter 6.5.
B. California Code of Regulations, Title 22, Division 4.5
C. California Code of Regulations, Title 8.

SURFACE PREPARATION

New concrete surfaces to be stained shall be cured in conformance with the provisions in Section 90-7.03, "Curing Structures," of the Standard Specifications and these special provisions.

Concrete surfaces to be stained shall be prepared in conformance with the requirements of SSPC-SP 13, "Surface Preparation of Concrete," of the SSPC: The Society for Protective Coatings.

Immediately prior to concrete staining operations the Contractor shall clean concrete surfaces to be stained by water rinsing as defined in Section 59-1.03, "Application," of the Standard Specifications.

Joints between concrete surfaces to be stained and metal surfaces that are galvanized or painted shall be sealed with a single component polysulfide sealant. The polysulfide sealant shall conform to the requirements in Federal Specification TT-S-230, Type II. The color of the polysulfide sealant shall match the color of the adjoining stained concrete.

CONCRETE STAINING

Prior to commencing work, concrete surfaces to be stained shall be tested for acceptance of stain per the manufacturer's recommendations. Any areas that resist accepting stain shall be cleaned as approved by the Engineer.

Concrete stain shall be applied in conformance with the manufacturer's recommendations and the provisions for paint application in Section 59-1.02,"Weather Conditions," of the Standard Specifications, except that stain shall not be applied when the atmospheric or concrete surface temperature is at or below 10°C or above 35°C. The stain shall be applied uniformly, working to avoid excessive rundown. The stain shall be worked into the concrete surface in circular motions with a nylon-bristled brush. Drips, puddles, or other irregularities shall be worked into the concrete.

After the last coat of stain has dried, all stained surfaces shall be rinsed with clean water and wet scrubbed with a stiff bristled nylon brush until the rinse water runs clear.

Adjacent surfaces shall be protected from concrete staining operations. Damage to adjacent surfaces resulting from concrete staining operations shall be repaired at the Contractor's expense.

MEASUREMENT AND PAYMENT

Prepare and stain concrete will be measured by the square meter. Measurement will be determined along the surface of the actual area stained.

The contract price paid per square meter for prepare and stain concrete shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in preparing of and applying stain to concrete surfaces, complete in place, including construction of test panels, protection of adjacent surfaces, furnishing and placing the polysulfide joint sealant, repairing damaged areas, and the adequate collection, containment, testing, and disposal of rinse water and debris, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

12-9.04 METAL PANEL

This work shall consist of fabricating, furnishing, storing as required, and installing steel metal panels with a porcelain enameled finish or a stainless steel finish and stainless steel panel support framing in conformance with the details shown on the plans and the requirements of these special provisions. The work shall include designing the stainless steel metal panel support framing for support of steel metal panels and other elements provided in other sections as specified herein.

PERFORMANCE REQUIREMENTS

Structural Performance of steel support framing for metal panels: Metal panel manufacturer shall provide steel framing capable of withstanding design loads within limits and under conditions indicated in the following:

A. Design Loads: Comply with requirements of the California Building Code (CBC).
B. Dead Loads: Weights of materials and construction.
C. Live Loads: 0
D. Wind Loads: 75 mph wind exposure C.
E. Seismic Zone: 4.

Deflection Limits for steel support framing: Design nonload bearing framing systems to withstand design loads without horizontal deflections greater than 1/360 of metal panel height.

Design steel support framing system to provide for movement of framing members without damage or overstressing, connection failure, undue strain on fasteners and anchors, or other detrimental effects when subject to a maximum ambient temperature change of 67 degrees C.

Design steel support framing system to maintain clearances at openings and to allow for construction tolerances.

Porcelain metal panels

Specular gloss test: Porcelain metal panel finish shall meet the requirements of ASTM C346-87(2004)e1, Standard Test Method for 45-deg Specular Gloss of Ceramic Materials. Test shall show gloss value on a sample in each of four quadrants at a gloss range of 40 to 50 at 45degrees. The test range maximum variation shall not be greater than 1.

Abrasion resistance test: Porcelain metal panel finish shall meet the requirements of ASTM C448-99(1999), Standard Test Methods for Abrasion Resistance of Porcelain Enamels. Using the weight and abrader type specified in the Taber Abrasion Manual for porcelain enameled surfaces test a minimum of 2 samples for weight loss and gloss retention. Sample shall exceed minimum requirements for resistance to surface abrasion of porcelain enamels having 45 degree specular gloss of more than 30 gloss units.

Reflectance: Porcelain metal panel finish shall meet the requirements of ASTM E347-98, Standard Test Method for Reflectivity and Coeffiicent of Scatter of White Porcelain Materials.

Salt spray resistance: Porcelain metal panel finish shall meet the requirements of ASTM B117-03, Standard Practice for Operating Salt Spray (Fog) Apparatus. Test shall show that for complete coverage for seven days that the finish shall not be affected.

Acid resistance: Porcelain metal panel finish shall meet the requirements of ASTM C282-99, Standard Test Method for Acid Resistance of Porcelain Enamels (Citric Acid Spot Test). Test shall show that for acid resistance class AA there is no visible stain and specimen passes dry rub.

Alkali resistance: Porcelain metal panel finish shall meet the requirements of ASTM C614-74(1999), Standard Test Method for Alkali Resistance of Porcelain Enamels. Test shall show sample porcelain enamel coating shall have a weight loss of less than 11.5 mg/inch squared.

Thermal expansion: Porcelain metal panel finish shall meet the requirements of ASTM C539-84(2000), Standard Test Method for Linear Expansion of Porcelain Enamel and Glaze Frits and Ceramic Whiteware Materials by the Interferometric Method. Test shall show the linear coefficient of expansion is between a range of 8 to 14 x 10 -6 cm/cm-degree C. The temperature range shall be adjusted to -10 degree C to 110 degree C.

Chemical resistance test: Porcelain metal panel finish shall meet the requirements of Spot Test NSF-30. Test shall show that when exposed to the reagents listed in NSF 30, Table I, the porcelain enamel surface shall show no visible effect on the finish other than a slight change of gloss, discoloration and/or a temporary slight softening of the porcelain enamel finish with no loss of adhesion and film protection.

Table I

Spot Test NSF30

Acid	Solvents
H_2SO_4 - 33% Solution	Acetone
H_2SO_4 - 77% Solution	Formaldehyde
H_2SO_4 - 96% Solution	Methanol
HCL – 20% Solution	Ethylacetate
HCL – 30% Solution	Toluene
HCL – 70% Solution	Ethyl Ether
HOA_c (glac) – 100% Solution	Ethyl Alcohol
H_3PO_4 - 86% Solution	Chloroform
HCOOH – 88% Solution	Phenol
Bases and Salts	**Stains**
$KMNO_4$ - 2% Solution	Eoisin (5% aqueous)
$AgNO_3$ - 10% Solution	Eoisin B (5% aqueous)
NaOH - 10% Solution	Gentain Violet
NaOH - 40% Solution	Wright's Stain
NaOH - Pellets	
NaOC1 - 5% Solution	
HH_4OH - 30% Solution	

Weather Resistance: Porcelain metal panel finish shall meet the requirements of NBS Building Science Series Report (BSS-50) 15 Year Exposure Test 1956. Test shall show a color change of $\leq$ 2 NBS units and a color retention $\geq$ 74%.

Exposure: Porcelain metal panel finish shall meet the requirements of NBS Building Science Series Report (BSS-38) 30 Year Exposure Test 1956. Test shall show a color change of $\leq$ 2.5 NBS units and a color retention $\geq$ 59%.

QUALITY ASSURANCE

Metal panel manufacturer shall have a minimum of 10 years experience in the manufacturing of porcelain enamel on steel panel system for use in architectural cladding.

Manufacturer shall have in-house pretreatment, color matching, milling and finishing capability for porcelain enamel. Manufacturer shall be a current member of the Porcelain Enamel Institute (PEI).

Inspection of metal panels shall be made by manufacturer prior to crating. Finished metal panels shall be inspected for blemishes, chips and for flatness Any metal panel not meeting the requirements of the specification shall be rejected. Inspection shall be recorded on inspection form provided by manufacturer. The form shall note the inspector, crate identification and other

relevant tracking information. Copy of inspection report shall be affixed to crate with a separate copy provided to Contractor.

Installer shall be authorized or certified by the panel manufacturer.

Installer Qualifications: Installer having minimum 5 years documented experience similar in material, design, and extent to that indicated.

Professional Engineer Qualifications: Professional Engineer, legally qualified and licensed to practice in the State of California, and experienced in providing engineering services of the kind indicated. Engineering services are defined as those performed for installations of steel framing that are similar to those indicated in material, design, and extent. Design Engineer required to seal and sign calculations and Shop Drawings.

Testing Agency Qualifications: An independent testing agency, acceptable to authorities having jurisdiction, qualified according to ASTM E 329 to conduct testing indicated as documented according to ASTM E 548.

Sealants shall conform to the requirements specified under "Sealants" in Section 12-7, "Thermal and Moisture Protection," of these special provisions.

Support framing for access door for fire hose connection and integral custom cabinet module for fire/telephone cabinet specified under "Fire Extinguishers and Cabinets" in Section 12-10 "Specialties," of these special provisions shall be installed as part of this section.

Support framing for stainless steel metal grating for ceilings specified under in "Building Miscellaneous Metal," in Section 12-5 "Steel" of the special provisions shall be installed as part of this section.

Support framing for stainless steel louver specified under in "Louvers," in Section 12-10 "Specialties" of the special provisions shall be installed as part of this section.

Metal panel manufacturer shall furnish warranty against discoloring, chalking, blistering or peeling of the porcelain panels. Warranty shall be for a period of 10 years.

SUBMITTALS

Manufacturer's certification.--Written certification shall be submitted that the manufacturer has 10 years of experience in the manufacture of porcelain enameled panels for architectural use.

Mill test reports signed by manufacturers certifying specified products comply with requirements. Indicate structural strength, destructive and nondestructive test and analysis. Chemical and physical properties shall be noted for structural steel. Mechanical properties and chemical analysis shall be noted for bolts, nuts, and washers.

Material Test Reports: From qualified testing agency indicating and interpreting test results for compliance of requirements based on comprehensive testing of current materials. Provide tests reports for all test listed under Quality Assurance.

Samples of metal panels with porcelain enamel finish showing specified colors, texture and gloss shall be submitted for approval. Three sets of 5 samples of 300 mm x 300 mm minimum size of each type and color finish shall be furnished, samples shall be of materials and gage as specified. Samples shall be provided that match the gloss specified with reflectance values of 40, 42.5, 45, 47.5 and 50. If ordered by the Engineer, additional sample panels shall be constructed and finished until the specified finish, texture and color are obtained, as determined by the Engineer. After approval by Engineer a full size mock-up of a section of the panel system shall be provided. Manufacture of the mock--up shall not begin until the color sample has been approved by the Engineer.

Full size mock-up of metal panels with porcelain enamel finish shall be submitted for approval. Area of metal panel to be provided in mock-up is indicated in the project plans as "Metal Panel Mock-up". Mock-up shall include all framing, metal panels, closure trim and fasteners required for the final installation. The mockup metal panel shall be constructed and

finished with the materials, tools, equipment and methods to be used in constructing the metal panel system. The test metal panel shall include all detailed elements that are part of the metal panel system. If ordered by the Engineer, additional mockups shall be constructed and finished until the details shown in the drawings and materials specified are obtained, as determined by the Engineer. Manufacture of the metal panels shall not begin until the mock-up has been approved by the Engineer. Approved portions of the mock-up may be used as a portion of the Spare Material requirement.

The mockup approved by the Engineer shall be used as the standard of comparison in determining acceptability of the metal panels.

The mockup shall include proposed sample repairs of panel defects. The extent of defects to be repaired shall be included on the mock-up panel. The mock-up shall show two similar defects. One shall be repaired and the other left un-repaired for comparison. The Engineer shall approve the extent of defects that can be repaired in lieu of replacing panels based on the sample repairs on the mock-up. The mockup approved by the Engineer shall be used as the standard of comparison in determining those defects that are allowed to be repaired and the acceptability of the repair method.

The Contractor shall provide design calculations confirming that metal panel system meets the design criteria. The structural design calculations shall be stamped and signed by the supervising engineer.

Working drawings shall show all materials required; shall indicate sections, layout of panels on all building surfaces, including all associated components and penetrations through panels, dimensions of units, jointing, anchoring attachments, and other necessary details; identify units with setting numbers as required for the installation. All items provided by others attached to the metal panel system shall be shown on the working drawings. Metal framing support for fire hose cabinet and integral custom cabinet module for fire and telephone, stainless steel metal grating for ceilings and stainless steel louver shall be indicated.

PRODUCT DELIVERY, STORAGE AND HANDLING

Metal panels shall be stored on end in a dry, well ventilated place to prevent condensation.

Metal panels or other components shall not come in contact with mud, uncured concrete or other strong chemicals which might cause staining of panels.

Panels and panel components shall be suitably wrapped or otherwise protected to prevent damage to finish.

PRODUCTS

Porcelain enameled panels

Porcelain enameled metal panels shall be fabricated from 11 guage (2.5-2.65 mm) vitreous enameling iron (VIT), a special purpose enameling steel that conforms with ASTM A 424 Standard Specification for Steel, Sheet, for Porcelain Enameling. Steel shall be Type I with a carbon content not more than 0.008 percent.

Porcelain enamel coating materials shall provide a Class AA acid resistant finish. Panels shall be flat finish with no embossed texture design. The finish shall have a matte gloss within a 40 to 50 percent reflective range.

Metal panels shall be coated with porcelain enamel frit as described in Processing and in compliance with the Porcelain Enamel Institute's standard specifications.

Porcelain enamel materials shall be shall be manufactured in compliance with the Porcelain Enamel Institute's standard specifications. Frit shall be ground in a mill. Frit shall be checked for proper fineness and color. Necessary adjustments shall be made in the mill prior to unloading. Separate mills must be used for grinding frits for ground coat, white cover-coat, and colors. Prior to spraying, the porcelain enamel slip must be checked for proper specific gravity and set.

Stainless steel panels

All metal panels identified to be stainless steel shall be Type 304 with a No. 4 satin finish with the finish grain running parallel to the profile grade. Stainless steel panels shall be fabricated from 16 guage material conforming to ASTM A 666. It shall be free of buckles, waves or other defects. Panels shall be formed to the shapes indicated on the drawings.

Referee Sample

The architectural finish of the porcelain enameled metal panels shall match the texture, color and pattern of the referee samples are available for inspection by bidders at the Office of Structures Design, Specifications Section, Second Floor, 1801 30th Street, Sacramento, California.

Accessory items

Accessory items shall be as provided by the metal panel manufacturer.

All non exposed steel support framing and alignment support framing, pins and clips shall be stainless steel Type 304 No. 2B finish or equal. All exposed closures, trim and panels identified to be stainless steel shall be Type 304 with a No. 4 satin finish with the finish grain running parallel to the profile grade. All panels shall have an exposed stainless steel bottom and top closure.

Aluminum vertical closure

All panels shall have a vertical closure joint cap. Vertical closures shall be of extruded aluminum alloy 6061TS in same finish as the porcelain panel. Vertical closures shall be coated with porcelain enamel frit as described in Processing and in compliance with the Porcelain Enamel Institute's standard specifications.

Silicone sealant and backer rod

Silicone sealant and backer rod shall be as recommended by the metal panel manufacturer. Sealant shall have a 20 year warranty.

Spare Materials

Metal panel of types and numbers listed shall be furnished and stored for future installation: The spare panels are for the future use of the agency. The manufacturer shall provide spare panels for their own use where panels are required to be replaced due to defects.

Metal Panel Type	Panel Finish	No. of Spare Panels	Panel Gauge
1	Porcelain Enamel	100	11
2	Porcelain Enamel	8	11
3	Porcelain Enamel	4	11
4	Porcelain Enamel	1	11
5	Porcelain Enamel	1	11
6	Stainless Steel	1	16
7	Stainless Steel	1	16
8	Porcelain Enamel	8	11
9	Porcelain Enamel	4	11
10	Stainless Steel	4	16
11	Stainless Steel	4	16
12	Stainless Steel	2	16
Vertical Closure	Porcelain Enamel	100 full height pieces	16
Top & Bottom Closure	Stainless Steel	100 lineal meters	16

Spare materials shall be clearly marked and transported to and stored at the storage facility as designated by the Engineer. The Contractor shall notify the Engineer at least two months prior to delivery of the spare materials.

PROCESSING

Porcelain enameled metal panels

Metal panels shall be coated with porcelain enamel coating. Coating is a vitreous, inorganic coating spray applied to metal panel and bonded to metal by fusion in a furnace. Metal panels shall have porcelain enamel coating applied as follows:

Metal panels shall be fabricated to the size and shape shown on the approved working drawings. Joint lines shall occur as shown. Metal panels shall be cut to size and ground smooth. Drill all necessary holes as required by building components and mounting of panels, and perform all cuts prior to the application of any porcelain enamel finish. Metal panels shall be thoroughly cleaned, degreased, acid etched, and neutralized prior to application of the porcelain enamel coating.

Porcelain enamel coating system shall be applied to all required areas on panel by spray application. At least two separately fired coatings shall be applied to all areas of each unit, including backs and edges. Each panel shall be covered with separate ground coat enamel with a minimum dry thickness of 3.5 mils and a separate cover coat with a minimum dry thickness of 4 mils. The total thickness per coat shall not exceed 20 mils. At least two separately fired coatings shall be applied to all areas of each unit, including backs and edges, by methods recognized as good commercial practice.

Between each coating of enamel, fuse coat to the metal at approximately 1500°F. Continuous line furnace for fusing coating shall be used to minimize color variation from panel to panel.

The porcelain enamel on all exposed surfaces shall be free of blemishes, stains, and scratches in the coating that may impair the serviceability or detract from the general appearance of the panel when viewed from a distance of 1.5 meters per PEI specification S1001.D(3).

Aluminum vertical closure

All exposed aluminum extrusions shall have a porcelain enamel coating applied per the provisions of PEI standard no. PEI-801, 802 and 803.

INSTALLATION

Stainless steel support framing shall be installed per approved working drawings.

Stainless steel alignment pins and attachment clips shall be provided and secured to panels after finishing. Additional pins and clips shall be shipped loose with the panels in case of damage during shipping.

Metal panel systems shall be installed in accordance with the approved working drawings.

Metal panel surfaces in contact with cementitious materials and other dissimilar materials shall be coated with bituminous paint or installed with nonmetallic shims. Such protective coating shall be allowed to dry prior to installation.

Metal panel system shall be permanently fastened to structural supporting framing members, properly aligned and leveled. Panels are aligned at a constant offset to plumb. The offset angle is equal to the roadway slope. The intent of this is to provide square panels with continuously aligned trim at the top and bottom. Maximum offset from true alignment between adjacent members butting or in line shall be 1.5 mm. Panel system shall be designed so that attachment allows panels to expand and contract freely during thermal expansion and contraction.

Fasteners and all laps shall be spaced symmetrically.

Install metal trim shall be installed in a manner to avoid straining of metal, joints, or fasteners. Carry all laps in a continuous straight horizontal line and carry all vertical joints plumb and true to line.

Chipped or damaged metal panels or components to the metal panel system and trim shall be replaced at expense of the Contractor.

Metal panel system shall be complete with all fasteners, seals, closures and closure strips, fabricated corners, and fascia, edge strips and associated accessories in connection with the metal panel system.

Installation shall be rigid.

Concealed fasteners shall be used in all locations unless otherwise indicated on the approved working drawings. Exposed fasteners are permitted in the vertical closures. All supports and fasteners shall be protected against corrosion and effect of moisture.

Porcelain Panel Repair: Small chips, imperfections, blemishes or other minor defects shall be touched up to the approval of the Engineer. Defects shall be repaired with color matched synthetic enamel and two part epoxy where ground coat is breached. The extent of defects to be repaired shall be included on the mock-up panel. The mock-up shall show two similar defects. One shall be repaired and the other left un-repaired for comparison. The Engineer shall approve the extent of defects that can be repaired in lieu of replacing panels based on the sample repairs on the mock-up.

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Final cleaning: Upon completion of the work clean all smears, sealant, dirt and grime from the face of the metal panels using cleaning materials recommended by the manufacturer.

MEASUREMENT AND PAYMENT

Furnish and install metal panel will be measured and paid for by square meter in conformance with the dimensions shown on the plans.

The contract price paid per square meter for furnish and install metal panel shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing the metal panels, including referee samples and support framings, installing in final position, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

The contract price paid per square meter for furnish and store metal panel shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in constructing the metal panels, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

SECTION 12-10. SPECIALTIES

12-10.01 LOUVERS

GENERAL.--This work consists of furnishing and installing louvers in accordance with the details shown on the plans and these special provisions.

SUBMITTALS.--Manufacturer's descriptive data and installation instructions shall be submitted for approval.

QUALITY ASSURANCE.--Codes and standards. Performance ratings of louver shall bear the Air Movement and Control Association (AMCA) seal certifying the performance ratings specified.

PRODUCTS.--

Louvers.--

Louvers shall be fixed, formed metal, horizontal drainable blade louvers. Louvers shall be factory fabricated and fully assembled. Frame corner shall be mitered. Louver frame type shall be exterior flange with a 104 mm deep blade. Frame and blade material shall be stainless steel conforming to ASTM A666, type 304 with No. 4 finish in a thickness required to comply with structural performance requirements but not less than 1.3 mm, with finish grain running perpendicular to length of blade. Louver shall have no interior mullions. Provide 16 x 16 stainless steel insect screen.
Performance requirements: free area shall be 0.153 m^2 for 0.61 m wide x 0.61 m high louver. Point of beginning water penetration shall be not less than 4.1 m/s. Air performance shall be not more than 25 Pa.

EXECUTION.--

INSTALLATION.--Louvers shall be installed in accordance with the manufacturer's instructions. The completed louver installation shall be weather tight in the metal panel system.

12-10.02 SIGNS

PART 1.- GENERAL

SUMMARY.--

Scope.--This work shall consist of furnishing and installing panel signs in accordance with the details shown on the plans and these special provisions.

SUBMITTALS.--

Product data.--Manufacturer's descriptive data for sign materials, colors and graphics, and for fastening hardware and material shall be submitted for approval.

PART 2.- PRODUCTS

Aluminum signs (directional signage).--

Sign Numbers 1 through 11: Painted unframed aluminum single sheet panel signs for directional information shall be aluminum sheet complying with ASTM B 209 alloy 5005-H15, aluminum thickness shall be 2.0 mm, panel shall have baked enamel finish of manufacturer's standard semigloss paint with UV inhibitors. Panel edge condition shall be square cut and corners rounded with a 26 mm radius. Provide 26 mm wide vertical backing on each side of sign to not trap water behind sign. Letters shall be upper case Helvetica, 75 mm minimum in height and black in color unless otherwise noted. The sign text "EXIT" shall be upper case Helvetica, 104 mm in height and red in color.

Sign Number 12: Painted unframed hinged aluminum single sheet panel signs for emergency services location information shall be aluminum sheet complying with ASTM B 209 alloy 5005-H15, aluminum thickness shall be 3.0 mm panel shall have baked enamel finish of manufacturer's standard semigloss paint with UV inhibitors. Panel edge condition shall be square cut and corners rounded with a 26 mm radius. The sign graphics size, color and location shall be as indicated on the drawings. Each sign shall have two double acting steel spring hinges.

Tactile "EXIT" and "EXIT ROUTE" signs

Tactile signs shall be not less than 6 mm hard phenolic plastic laminate. Plastic laminate shall be opaque scratch resistant, non-static, fire retardent, with a non-glare surface. Sign background color shall be blue and shall match porcelain enameled metal panel color. Letter color shall be black. Letters shall be upper case sans serif characters, 51 mm in height, raised 0.80 mm above and integral with sign material, accompanied by Braille. The process for producing the characters shall be sand blast for removing the background material for a monolithic sign. Produce precisely formed characters with square-cut edges free from burrs and cut marks; Braille dots with domed or rounded shape.

Braille shall be Contracted Grade 2 Braille. Dots shall be 2.54 mm on centers in each cell with 5.08 space between cells, measured from the second column of dots in the first cell to the first column of dots in the second cell. Dots shall be raised 0.635 mm above the background.

Fastening hardware and material.--

Door directional signs shall be fastened to stainless steel doors with sealant as recommended by the sign manufacturer.

Signs for emergency services location information mounted on the aluminum vertical closures for the metal panel system shall have two double acting steel spring hinges. The hinges shall permit the sign rotate in either direction and return to original position. Spring tension of hinge shall be adjustable. Hinge shall comply with ANSI K81131.

PART 3.- EXECUTION

Inscription.--Sign messages shall be as follows:

EXIT
TO SOUTHBOUND TUNNEL

EXIT
TO NORTHBOUND TUNNEL

EXIT
TO SOUTHBOUND TUNNEL
DANGER MOVING TRAFFIC

EXIT
TO NORTHBOUND TUNNEL
DANGER MOVING TRAFFIC

USE OTHER DOOR

SOUTH EQUIPMENT CHAMBER
AUTHORIZED ACCESS ONLY

CENTER EQUIPMENT CHAMBER
AUTHORIZED ACCESS ONLY

NORTH EQUIPMENT CHAMBER
AUTHORIZED ACCESS ONLY

FIRE PUMP ROOM
AUTHORIZED ACCESS ONLY

EXIT
TO EXTERIOR
THROUGH FIRE PUMP ROOM

SIGN WITH GRAPHICS SHOWN ON
DRAWINGS

Installation.--Aluminum signs for room identification and restrooms shall be fastened or secured to clean, finished surfaces in accordance with the sign manufacturer's instructions. Signs shall be installed at a location and height as shown on the plans.

Aluminum signs for emergency services location information hinges shall be fastened to the aluminum vertical closure with self tapping stainless steel screws. Sign shall be bolted to the hinges with stainless steel sex bolts.

Fastening hardware and material shall be installed within the sign as shown on the plans.

12-10.03 FIRE EXTINGUISHERS AND CABINETS

PART 1.- GENERAL

SUMMARY.--

Scope.--This work shall consist of furnishing and installing fire extinguishers with cabinets or mounting brackets in accordance with the details shown on the plans and these special provisions. Cabinets shall include access door for fire department hose connection and separate integral custom cabinet module for recessed fire extinguisher with access door, recessed emergency telephone unit and detection sensors.

REFERENCES.--

General.--Fire Extinguishers shall conform to the requirements in California Code of Regulations, Title 19 Division 1, Chapter 3, "Portable Fire Extinguishers" and National Fire Protection Association (NFPA) Standard 10.

SUBMITTALS.--

Product data.--Manufacturer's descriptive data and installation instructions shall be submitted for approval. The Engineer will require 3 weeks to review the submittal after a complete set has been received, as determined by the Engineer.

QUALITY ASSURANCE.--

Codes and standards.--Fire extinguishers shall be Underwriters Laboratories or Factory Mutual Laboratories approved for the type, rating and classification of extinguisher specified.

PART 2.- PRODUCTS

MANUFACTURER'S.--

Acceptable manufacturers,--Subject to contract compliance, manufacturers shall be J. L. Industries; Larsen's Manufacturing; Potter-Roemer; or equal.

COMPONENTS.--

Fire extinguisher.--

Fire extinguisher shall be fully charged, multi-purpose dry chemical type, with charge indicator, hose and nozzle, and attached service record tag. Fire extinguisher shall be of the capacity and type rating shown on the plans.

Mounting bracket.--

Mounting bracket shall be the manufacturer's standard painted, surface mounted type.

Fire extinguisher cabinet.--

Fire extinguisher cabinet shall be factory fabricated, constructed of stainless steel.

Fire extinguisher cabinet shall be surface mountedfully recessed as shown on the plans.

Access door for Fire Department Hose Connection. --

Access door and frame assembly shall be factory fabricated, constructed of stainless steel in an 1.21 mm (18 gauge) door frame, and shall have a 1.21 mm (18 gauge) stainless steel back box without a back. Door and frame style shall be flush solid metal. Frame shall be one-piece combination trim and perimeter door frame overlapping surrounding wall surface with exposed trim face and wall return at outer edge. Door hardware shall include manufacturer's standard door-operating hardware and hinge. Operating hardware shall be projecting door pull and friction latch, of same finish as door. Latch shall hold door closed to a minimum negative wind pressure of 1,0 kPa. Hinge shall be continuous hinge. Stainless steel shall be number 304 with a No. 6 dull satin finish with the finish grain running parallel to the profile grade. All outside corners of frame cabinet shall be mitered. All joints shall be welded, ground smooth and finished to provide a blemish free finish and match the adjoining cabinet wall finish. Grind and polish surfaces to produce uniform finish, free of cross scratches.

Access door and frame assembly shall be fully recessed as shown on the plans.

Integral custom cabinet module. --

Integral custom cabinet module for recessed fire extinguisher with access door, recessed emergency telephone unit and detection sensors shall be factory fabricated, constructed of stainless steel with welded seamless corners. Recess for fire extinguisher shall have a 1.21 mm (18 gauge) stainless steel back box with a flush solid metal door. Door appearance and frame detail shall match adjoining access door for fire department hose connection. Recess for emergency telephone unit and detection sensors shall have all welded corners. Stainless steel shall be number 304 with a No. 4 satin finish with the finish grain running parallel to the profile grade. All outside corners of frame cabinet shall be mitered. All joints shall be welded, ground smooth and finished to provide a blemish free finish and match the adjoining cabinet wall finish. Grind and polish surfaces to produce uniform finish, free of cross scratches.

Access door and frame assembly shall be fully recessed as shown on the plans.

PART 3.- EXECUTION

INSTALLATION.--

General.--Fire extinguishers shall be installed in locations and at mounting heights shown on the plans, or if not shown, at a height of 1220 mm from the finished floor to the top of the fire extinguisher.

Fire extinguisher mounting brackets and cabinets shall be attached to structure, square and plumb, in accordance with the manufacturer's recommendations.

IDENTIFICATION.--

Bracket-mounted fire extinguisher.--Extinguishers shall be identified with red letter decals spelling "FIRE EXTINGUISHER" applied to wall surface. Letter size, style and location shall be selected by the Engineer.

Cabinet-mounted extinguisher.—Fire extinguishers cabinets door shall be identified with letters spelling "FIRE EXTINGUISHER" applied to the cabinet door with a silk screened application process. Letter size shall be 51 mm, style shall be Helvetica, and color shall be red.

Cabinet-mounted integral custom cabinet module.--Fire department hose connection cabinet door shall be identified with letter spelling "FIRE DEPARTMENT HOSE CONNECTION" applied to the cabinet door with a silk screened application process. Letter size shall be 51 mm, style shall be Helvetica, and color shall be red.

SERVICING.--

General.--Fire extinguishers shall be serviced, charged, and tagged not more than 5 days prior to contract acceptance.

SECTION 12-11. (BLANK)
SECTION 12-12. (BLANK)
SECTION 12-13. (BLANK)
SECTION 12-14. (BLANK)
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10-5__ MECHANICAL MATERIALS AND METHODS

GENERAL

SUMMARY

Scope.--This work shall include furnishing and installing components needed for complete installation of systems described in other sections in accordance with the details shown on the plans and these special provisions. The following components are included in these special provisions:

A. Piping materials and installation instructions common to most piping systems.
B. Concrete base construction requirements.
C. Escutcheons.
D. Dielectric fittings.
E. Flexible connectors.
F. Mechanical sleeve seals.
G. Operation and maintenance manual requirements
H. Nonshrink grout for equipment installations.
I. Field-fabricated metal and wood equipment supports.
J. Installation requirements common to equipment specification sections.
K. Cutting and patching.
L. Firestopping sealants and caulks
M. Touchup painting and finishing.

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data of pipe and pipe fittings, joining and materials, dielectric fittings, flexible connectors, mechanical sleeve, piping specialties, grout, firestopping and sealants and grout, piping system (common requirements). In addition, brochures or other information describing the materials, construction methods and the general characteristics of the pipe and pipe fittings, joining and materials, dielectric fittings, flexible connectors, mechanical sleeve, piping specialties, grout, firestopping and sealants and grout, piping system (common requirements) shall be submitted. Samples of color, lettering style, and other graphic representation required for each identification material and device shall also be submitted.

Working Drawings.--The Contractor shall submit working drawings that include compete details, information and equipment selection criteria for mechanical materials and methods as specified in these special provisions:

A. Detail fabrication and installation for metal and wood supports and anchorage for mechanical materials and equipment.
B. Coordination drawings for access panel and door locations.
C. Coordination drawings showing major elements, components, and systems of mechanical equipment and materials in relationship with other systems, installations, and building components. Show space requirements for installation and access. Indicate if sequence and coordination of installations are important to efficient flow of the work. The following shall be included:

1. Planned piping layout, including valve and specialty locations and valve-stem movement.
2. Clearances for installing and maintaining insulation.
3. Clearances for servicing and maintaining equipment, accessories, and specialties, including space for disassembly required for periodic maintenance.
4. Equipment and accessory service connections and support details.
5. Exterior wall and foundation penetrations.
6. Fire-rated wall and floor penetrations.
7. Sizes and location of required concrete pads and bases.
8. Scheduling, sequencing, movement, and positioning of large equipment into building during construction.
9. Floor plans, elevations, and details to indicate penetrations in floors, walls, and ceilings and their relationship to other penetrations and installations.

Operation and Maintenance Manual.--An operation and maintenance (O&M) manual shall be provided that includes every major piece of mechanical equipment having specific operating procedures, or would require maintenance, inspection or adjustment. O&M manuals shall also be provided for each item of equipment in a system as specified in other sections. The Contractor shall furnish 3 copies, bound in hardback binders or an accepted equivalent. The Contractor shall furnish one complete manual 3 months prior to performance of systems or equipment tests for review, and furnish the remaining manuals with installation, start-up and test data and settings, prior to contract completion. The following identification shall be inscribed on the cover: the words "OPERATION AND MAINTENANCE MANUAL," the name and location of the system, equipment, building, name of Contractor, and contract number. The manual shall include the names, addresses, and telephone numbers of each subcontractor installing the system or equipment and the local representatives for the system or equipment. A table of contents shall be included and the manual assembled to conform to the table of contents, with the tab sheets placed before instructions covering the subject. The instructions shall be legible and easily read, with large sheets of drawings folded in. The manual shall include:

A. Internal and interconnecting wiring and control diagrams with data to explain detailed operation and control of the system or equipment.
B. Description of the function of each principal item of equipment including, a control sequence describing normal startup, operation, and shutdown, and emergency procedures.
C. Installation and maintenance instructions.
D. Safety precautions.
E. Diagrams and illustrations.
F. Testing methods.
G. Performance data and settings "as installed."
H. Cleaning and lubrication schedule including type, grade, temperature range, and frequency.
I. List items requiring scheduled maintenance such as V-Belt drives bearings in spreadsheet form with frequency and including instructions for performing the maintenance.
J. List initial settings for vibration and temperature alarms, low temperature and high temperature cut-outs and other similar devices. List acceptable range for these set points.
K. Recommended spare parts list. The list shall indicate sources of supply, recommended spare parts, and name of servicing organization. Furnish pictorial diagrams identifying part numbers.

L. Appendix: list qualified permanent servicing organizations for support of the equipment, including addresses, telephone numbers and certified qualifications.

Posted Operating Instructions.--Operating instructions shall be furnished for systems and equipment listed in the technical sections for use by operation and maintenance personnel. The operating instructions shall include wiring diagrams, control diagrams, and control sequence for each principal system and equipment. Operating instructions shall be printed or engraved, and framed under glass or in approved laminated plastic. Operating instructions shall be attached or posted adjacent to each principal system and equipment including startup, proper adjustment, operating, lubrication, shutdown, safety precautions, procedure in the event of equipment failure, and other items of instruction as recommended by the manufacturer of each system or equipment. Weather-resistant materials or weatherproof enclosures shall be provided for operating instructions exposed to the weather. Operating instructions shall not fade when exposed to sunlight and shall be secured to prevent easy removal or peeling.

Lesson plan and training manuals for the training phases including types of training shall be provided with lists of reference materials and sections of O&M manual to be addressed. The final O&M data shall be approved prior to the scheduling of training.

The Contractor shall provide all equipment, materials and qualified personnel to visually and audibly record all training sessions. The qualifications of the video recording personnel shall be submitted for approval at least 10 days prior to the session. Video recordings shall be produced in DVD-R format. Each system or piece of equipment covered shall be recorded as a single program and correlated with the O&M manuals. An identification label shall be affixed to the DVD and be shown on the first two minutes of recording. The label shall identify the project/contract number, equipment or system discussed, length of recording, and reference O&M manual.

The Contractor shall conduct training sessions on the following equipment items and systems for the minimum duration indicated. Three separate training sessions shall be required, one for each of three working shifts. (i.e. 24 hour operation; day shift, swing shift and night shift). Training times shall be for each shift's regularly scheduled work time. Training materials shall be provided for up to six (6) persons per session (shift), as follows:

Equipment or System	Class Duration per System per Shift
Tunnel Heating and Ventilation Systems	4 Hour
Tunnel Cross Passage Fans	1 Hour
Tunnel Jet Fans	8 Hour
Tunnel Fire Protection System & Water Storage Tank	6 Hour
Leach Water System	6 Hour
Roadway Drainage System	3 Hour

QUALITY ASSURANCE

Identification devices shall conform to the requirements in ASME A13.1 for lettering size, length of color field, colors, and viewing angles.

Equipment of higher electrical characteristics, physical dimensions, capacities, and ratings may be furnished provided such proposed equipment is approved in writing and connecting mechanical and electrical services, circuit breakers, conduit, motors, bases, and equipment spaces shall be increased, and at no additional cost to the State. If minimum energy ratings or efficiencies of equipment shall be specified, equipment shall meet design and commissioning requirements.

Testing.--Where testing is called for in these special provisions, the test shall be performed by a testing firm or an engineer who is registered as a Civil or Mechanical Engineer in the State of California. The Contractor shall furnish all test instruments, materials and labor necessary to perform the following tests. All tests shall be performed in the presence of the Engineer. All instruments shall have been calibrated within a period of two years preceding testing. Calibrations shall be traceable to applicable industry recognized standards.

Delivery Storage and Handling.--Pipes and tubes shall be delivered with factory-applied end caps. End caps shall be maintained through shipping, storage, and handling to prevent pipe end damage and prevent entrance of dirt, debris, and moisture.

Stored pipes and tubes shall be protected from moisture and dirt and elevated above grade. Structural capacity of floors shall not be exceeded, if stored inside. Flanges, fittings, and piping specialties shall be protected from moisture and dirt. Plastic pipes and ducts shall be stored protected from direct sunlight, and supported to prevent sagging and bending.

SEQUENCING AND SCHEDULING

Sequencing and scheduling shall include the following:

A. Coordinate mechanical equipment installation with other building components.
B. Arrange for pipe spaces, chases, slots, and openings in building and tunnel structures during progress of construction to allow for mechanical installations.
C. Coordinate installation of required supporting devices and set sleeves, embedded struts and embedded pipe in cast-in-place concrete and other structural components, as they are constructed.
D. Sequence, coordinate, and integrate installations of mechanical materials and equipment for efficient flow of the work. Coordinate installation of large equipment requiring positioning before closing in building.
E. Coordinate connection of mechanical systems with exterior underground and overhead utilities and services. Comply with requirements of governing regulations, franchised service companies, and controlling agencies.
F. Coordinate requirements for access panels and doors if mechanical items requiring access shall be concealed behind finished surfaces.
G. Coordinate installation of identifying devices after completing covering and painting, if devices are applied to surfaces. Install identifying devices before installing acoustical ceilings and similar concealment.

DEFINITIONS

A. Finished spaces: spaces other than mechanical and electrical equipment rooms, furred spaces, pipe and duct shafts, unheated spaces immediately below roof, spaces above ceilings, unexcavated spaces, crawl spaces, and tunnels.
B. Exposed, interior installations: exposed to view indoors. Examples include finished occupied spaces and mechanical equipment rooms.
C. Exposed, exterior installations: exposed to view outdoors, or subject to outdoor ambient temperatures and weather conditions. Examples include rooftop locations.
D. Concealed, interior installations: concealed from view and protected from physical contact by building occupants. Examples include above ceilings and in duct shafts.

E. Concealed, exterior installations: concealed from view and protected from weather conditions and physical contact by building occupants, but subject to outdoor ambient temperatures. Examples include installations within unheated shelters.
F. ABS: Acrylonitrile-butadiene-styrene plastic.
G. CPVC: Chlorinated polyvinyl chloride plastic.
H. NP: Nylon plastic.
I. PE: Polyethylene plastic.
J. PVC: Polyvinyl chloride plastic.
K. FRP: Fiberglass reinforced plastic.
L. CR: Chlorosulfonated polyethylene synthetic rubber.
M. EPDM: Ethylene propylene diene terpolymer rubber.
N. Fire-pump unit assembly: complete assembly with fire pump, driver, controller, and related accessories.
O. Pressure-maintenance pump: electric-drive pump used to maintain water pressure in fire-suppression piping system.
P. Pressure-maintenance-pump unit assembly: complete assembly with pressure-maintenance pump, driver, controller, and related accessories.

PRODUCTS

Pipe and Pipe Fittings.--Pipe threads shall be ASME B1.20.1 for factory-threaded pipe and pipe fittings.

Joining and Materials.--Joining materials shall conform to the following:

A. Pipe-flange gasket materials: suitable for chemical and thermal conditions of piping system contents, as follows:

1. ASME B16.21, nonmetallic, flat, asbestos-free, 3.2 mm maximum thickness, unless thickness or specific material is indicated.
2. Full-face type: for flat-face, Class 125, cast-iron and cast-bronze flanges.
3. Narrow-face type: for raised-face, Class 250, cast-iron and steel flanges.
4. AWWA C110, rubber, flat face, 3.2 mm thick, unless otherwise indicated; and full-face or ring type, unless otherwise indicated.

B. Flange bolts and nuts: ASME B18.2.1, carbon steel, unless otherwise indicated in these specifications or on the plans.
C. Solder filler metals: ASTM B 32, and as follows:

1. Alloy Sn95 or Alloy Sn94: Approximately 95 percent tin and 5 percent silver, with 0.10 percent lead content.
2. Alloy E: Approximately 95 percent tin and 5 percent copper, with 0.10 percent maximum lead content.
3. Alloy HA: Tin-antimony-silver-copper zinc, with 0.10 percent maximum lead content.
4. Alloy HB: Tin-antimony-silver-copper nickel, with 0.10 percent maximum lead content.
5. Alloy Sb5: 95 percent tin and 5 percent antimony, with 0.20 percent maximum lead content.

D. Brazing filler metals: AWS A5.8, as follows:

1. BCuP Series: copper-phosphorus alloys.
2. BAg1: silver alloy.

E. Welding filler metals: comply with AWS D10.12 for welding materials appropriate for wall thickness and chemical analysis of steel pipe being welded.
F. Solvent cements: manufacturer's standard solvent cements for the following:

1. ABS piping: ASTM D 2235.
2. CPVC piping: ASTM F 493.
3. PVC piping: ASTM D 2564. Include primer according to ASTM F 656.
4. PVC to ABS piping transition: ASTM D 3138.

G. Plastic pipe seals: ASTM F 477, elastomeric gasket.
H. Flanged, ductile-iron pipe gasket, bolts, and nuts: AWWA C110, rubber gasket, carbon-steel bolts and nuts.
I. Couplings: iron-body sleeve assembly, fabricated to match OD of plain-end, pressure pipes, with the following:

1. Sleeve: ASTM A 126, Class B, gray iron.
2. Followers: ASTM A 47 (ASTM A 47M) malleable iron or ASTM A 536 ductile iron.
3. Gaskets: rubber.
4. Bolts and nuts: AWWA C111.
5. Finish: enamel paint.

Dielectric fittings.--Dielectric fittings shall conform to the following:

A. General: assembly or fitting with insulating material isolating joined dissimilar metals, to prevent galvanic action and stop corrosion.
B. Description: combination of copper alloy and ferrous; threaded, solder, plain, and weld-neck end types and matching piping system materials.
C. Insulating material: suitable for system fluid, pressure, and temperature.
D. Dielectric unions: factory-fabricated, union assembly, for 1725 kPa minimum working pressure at 82°C.
E. Dielectric flanges: factory-fabricated, companion-flange assembly, for 1035 or 2070 kPa minimum working pressure as required to suit system pressures.
F. Dielectric-flange insulation kits: field-assembled, companion-flange assembly, full-face or ring type. Components include neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers. Provide separate companion flanges and steel bolts and nuts for 1035 or 2070 kPa minimum working pressure as required to suit system pressures.
G. Dielectric couplings: galvanized-steel coupling with inert and noncorrosive, thermoplastic lining; threaded ends; and 2070 kPa minimum working pressure at 107°C.
H. Dielectric Nipples: Electroplated steel nipple with inert and noncorrosive, thermoplastic lining; plain, threaded, or grooved ends; and 2070 kPa minimum working pressure at 107°C.

Flexible connectors.--Flexible connectors shall conform to the following:

A. General: fabricated from materials suitable for system fluid and that will provide flexible pipe connections. Include 860 kPa minimum working-pressure rating, unless higher working pressure is indicated, and ends according to the following:

1. 50 mm and smaller: threaded.
2. 65 mm and larger: flanged.
3. Option for 65 mm and larger: grooved for use with keyed couplings.

B. Bronze-hose, flexible connectors: corrugated, bronze, inner tubing covered with bronze wire braid. Include copper-tube ends or bronze flanged ends, braze welded to hose.
C. Stainless-steel-hose or stainless-steel pipe, flexible connectors: corrugated, stainless-steel, inner tubing covered with stainless-steel wire braid. Include stainless-steel nipples or flanges, welded to hose.
D. Rubber, flexible connectors: CR or EPDM elastomer rubber construction, with multiple plies of NP fabric, molded and cured in hydraulic presses. Include 860 kPa minimum working-pressure rating at 104°C. Units may be straight or elbow type, unless otherwise indicated.

Mechanical sleeve.--Mechanical sleeve seals shall be modular design, with interlocking rubber links shaped to continuously fill annular space between pipe and sleeve. Include connecting bolts and pressure plates. Use mechanical sleeve at all pipe penetrations of buried pipe into concrete vaults and man holes unless grouting around the pipe opening is specifically called for on the drawings.

Piping specialties.--Piping specialties shall conform to the following:

A. Sleeves: The following materials shall be for wall, floor, slab, and roof penetrations:

1. Steel sheet metal: 0.6-mm minimum thickness, galvanized, round tube closed with welded longitudinal joint.
2. Steel pipe: ASTM A 53, Type E, Grade A, Schedule 40, galvanized, plain ends.
3. Cast iron: cast or fabricated "wall pipe" equivalent to ductile-iron pressure pipe, with plain ends and integral waterstop, unless otherwise indicated.
4. Stack sleeve fittings: manufactured, cast-iron sleeve with integral clamping flange. Include clamping ring and bolts and nuts for membrane flashing.
5. Underdeck clamp: clamping ring with set screws.
6. PVC: manufactured, permanent, with nailing flange for attaching to wooden forms.
7. PVC pipe: ASTM D 1785, Schedule 40.
8. PE: manufactured, reusable, tapered, cup shaped, smooth outer surface, with nailing flange for attaching to wooden forms.

B. Escutcheons: Manufactured wall, ceiling, and floor plates; deep-pattern type if required to conceal protruding fittings and sleeves, including the following:

1. ID: closely fit around pipe, tube, and insulation of insulated piping.
2. OD: completely cover opening.
3. Cast brass: one piece, with set screw, finish rough brass or polished chrome-plate.
4. Cast brass: split casting, with concealed hinge and set screw, finish rough brass or polished chrome-plate.

5. Stamped steel: one piece, with set screw and chrome-plated finish.
6. Stamped steel: one piece, with spring clips and chrome-plated finish.
7. Stamped steel: split plate, with concealed hinge, set screw, and chrome-plated finish.
8. Stamped steel: split plate, with concealed hinge, spring clips, and chrome-plated finish.
9. Stamped steel: split plate, with exposed-rivet hinge, set screw, and chrome-plated finish.
10. Stamped steel: split plate, with exposed-rivet hinge, spring clips, and chrome-plated finish.
11. Cast-iron floor plate: one-piece casting.

Grout.--Grout shall conform to the following requirements:

A. Nonshrink, nonmetallic grout: ASTM C 1107, Grade B.
B. Characteristics: post-hardening, volume-adjusting, dry, hydraulic-cement grout, nonstaining, noncorrosive, nongaseous, and recommended for interior and exterior applications.
C. Design mix: 34.5-MPa, 28-day compressive strength.
D. Packaging: premixed and factory packaged.

Firestopping Sealants and Grout.--Firestopping material shall be asbestos-free and capable of maintaining an effective barrier against flame and gases. Provide joint sealants with fire resistance ratings indicated, as determined per ASTM E 119, but not less than that equaling or exceeding the fire-resistance rating of the assembly in which firestop material is installed. Provide products with flame-spread values of less than 25 and smoke-developed values of less than 50, as determined per ASTM E 84.

A. Prepackaged, dry mixes consisting of a blend of inorganic binders, hydraulic cement, fillers, and lightweight aggregate formulated for mixing with water at Project site to form a non-shrinking, homogeneous mortar.
B. Silicone Sealants: Moisture-curing, single-component, silicone-based, neutral-curing elastomeric sealants of grade indicated below:

    1. Grade: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces and nonsag formulation for openings in vertical and other surfaces requiring a nonslumping, gunnable sealant, unless indicated firestop system limits use to nonsag grade for both opening conditions.
    2. Grade for Horizontal Surfaces: Pourable (self-leveling) formulation for openings in floors and other horizontal surfaces.
    3. Grade for Vertical Surfaces: Nonsag formulation for openings in vertical and other surfaces.

Piping Systems - Common Requirements.--Piping shall be installed in conformance with the following requirements, unless specified otherwise in these special provisions:

A. The general location and arrangement of piping systems shall be shown on the plans. Locations and arrangements shown on the plans were used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Piping shall be

installed as shown on the plans, unless deviations to layout are approved on working drawings.

B. Install piping at indicated slope.
C. Install components with pressure rating equal to or greater than system operating pressure.
D. Install piping in concealed interior and exterior locations, except in equipment rooms and service areas.
E. Install piping free of sags and bends.
F. Install exposed interior and exterior piping at right angles or parallel to building walls. Diagonal runs are prohibited, unless otherwise indicated on the plans.
G. Install piping tight to slabs, beams, joists, columns, walls, and other building elements.
H. Install piping to allow application of insulation plus 25 mm clearance around insulation.
I. Locate groups of pipes parallel to each other, spaced to permit valve servicing.
J. Install fittings for changes in direction and branch connections.
K. Install couplings according to manufacturer's written instructions.
L. Install pipe escutcheons for pipe penetrations of concrete and masonry walls, wall board partitions, and suspended ceilings according to the following:

    1. Chrome-plated piping: cast brass, one piece, with set screw, and polished chrome-plated finish. Use split-casting escutcheons if required, for existing piping.
    2. Uninsulated piping wall escutcheons: cast brass or stamped steel, with set screw.
    3. Uninsulated piping floor plates in utility areas: cast-iron floor plates.
    4. Insulated piping: cast brass or stamped steel; with concealed hinge, spring clips, and chrome-plated finish.
    5. Piping in utility areas: cast brass or stamped steel, with set-screw or spring clips.

M. Sleeves are not required for core drilled holes.
N. Permanent sleeves are not required for holes formed by PE removable sleeves.
O. Install sleeves for pipes passing through concrete and masonry walls, and concrete floor and roof slabs, as follows:

    1. Install sleeves for pipes passing through concrete and masonry walls, gypsum-board partitions, and concrete floor and roof slabs. Cut sleeves to length for mounting flush with both surfaces, except extend sleeves installed in floors of mechanical equipment areas or other wet areas 50 mm above finished floor level. Extend cast-iron sleeve fittings below floor slab as required to secure clamping ring if ring is specified.
    2. Build sleeves into new walls and slabs as work progresses.
    3. Install sleeves large enough to provide 6 mm annular clear space between sleeve and pipe or pipe insulation. Use the following sleeve materials:
    4. PVC pipe sleeves: for pipes smaller than 150 mm.
    5. Steel pipe sleeves: for pipes smaller than 150 mm.
    6. Steel, sheet-metal sleeves: for pipes 150 mm and larger, penetrating gypsum-board partitions.
    7. Hot dip galvanized pipe sleeves: For pipe penetrations through tunnel walls.
    8. Stack sleeve fittings: for pipes penetrating floors with membrane waterproofing. Secure flashing between clamping flanges. Install section of cast-iron soil pipe to extend sleeve to 50 mm above finished floor level.
    9. Seal space outside of sleeve fittings with nonshrink, nonmetallic grout.

10. Except for underground wall penetrations, seal annular space between sleeve and pipe or pipe insulation, using elastomeric joint sealants in conformance with these special provisions.
11. Use Type S, Grade NS, Class 25, Use O, neutral-curing silicone sealant, unless otherwise indicated.

P. Aboveground, exterior-wall, pipe penetrations: seal penetrations using sleeves and mechanical sleeve seals. Size sleeve for 25 mm annular clear space between pipe and sleeve for installing mechanical sleeve seals, and as follows:

1. Install steel pipe for sleeves smaller than 150 mm in diameter.
2. Install cast-iron "wall pipes" for sleeves 150 mm in diameter and larger.
3. Assemble and install mechanical sleeve seals according to manufacturer's written instructions. Tighten bolts that cause rubber sealing elements to expand and make watertight seal.

Q. Underground, exterior-wall, pipe penetrations: install epoxy coated ductile-iron "wall pipe" or Schedule 40 hot dip galvanized pipe for sleeves. Seal pipe penetrations using mechanical sleeve seals. Size sleeve for 25 mm annular clear space between pipe and sleeve for installation of mechanical sleeve seals. Assemble and install mechanical sleeve seals according to manufacturer's written instructions. Tighten bolts that cause rubber sealing elements to expand and make watertight seal.

R. Fire-resistive joint sealants: Comply with ASTM C 1193, and with sealant manufacturer's installation instructions and drawings pertaining to products and applications indicated. Install joint fillers to provide support of sealants during application and at position required to product the cross-sectional shapes and depths of installed sealants relative to joint widths that allow optimum sealant movement capability and develop fire-resistance rating required. Install sealants by proven techniques that result in sealants directly contacting and fully wetting joint substrates, completely filling recesses provided for each joint configuration, and providing uniform, cross sectional shapes and depths relative to joint width that allow optimum sealant movement capability. Install sealants at the same time joint fillers are installed. Tool non-sag sealants immediately after sealant application and prior to the time skinning or curing begins. Form smooth, uniform beads of configuration indicated or required to produce fire resistance rating, as well as to eliminate air pockets, and to ensure contact and adhesion of sealants with sides of joint. Remove excess sealant from surfaces adjacent to joint. Contractor shall not use tooling agents that discolor sealants or adjacent surfaces or are not approved by sealant manufacturer.

S. Piping joint construction: join pipe and fittings as follows and as specifically required in these special provisions:

1. Ream ends of pipes and tubes and remove burrs. Bevel plain ends of steel pipe.
2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
3. Construct soldered joints according to AWS's "Soldering Manual," chapter "The Soldering of Pipe and Tube"; or CDA's "Copper Tube Handbook."
4. Construct brazed joints according to AWS's "Brazing Handbook," Chapter "Pipe and Tube."

5. Threaded joints: Thread pipe with tapered pipe threads according to ASME B1.20.1. Cut threads full and clean using sharp dies. Ream threaded pipe ends to remove burrs and restore full ID. Join pipe fittings and valves as follows: Note internal length of threads in fittings or valve ends, and proximity of internal seat or wall, to determine how far pipe should be threaded into joint; Apply appropriate tape or thread compound to external pipe threads, unless dry seal threading is specified; Align threads at point of assembly; Tighten joint with wrench; Apply wrench to valve end into which pipe is being threaded.
6. Damaged threads: Contractor shall not use pipe or pipe fittings with threads that are corroded or damaged. Contractor shall not use pipe sections that have cracked or open welds.
7. Welded joints: Construct joints according to AWS D10.12, "Recommended Practices and Procedures for Welding Low Carbon Steel Pipe," using qualified processes and welding operators according to the "Quality Assurance" article. Stainless steel pipe shall be welded in conformance with the provisions in "Tunnel Fire Protection" of these special provisions.
8. Flanged joints: Align flange surfaces parallel. Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically on the flange. Assemble joints by sequencing bolt tightening to make initial contact of flanges and gaskets as flat and parallel as possible. Use suitable lubricants on bolt threads. Tighten bolts gradually and uniformly using torque wrench.
9. Plastic piping solvent-cement joints: Clean and dry joining surfaces by wiping joint surfaces with clean cloth or paper towels. Join pipe and fittings according to the following: comply with ASTM F 402 for safe-handling practice of cleaners, primers, and solvent cements; ABS Piping: ASTM D 2235 and ASTM D 2661; CPVC Piping: ASTM D 2846 and ASTM F 493; PVC Pressure Piping: ASTM D 2672; PVC Nonpressure Piping: ASTM D 2855; PVC to ABS Nonpressure Transition Fittings: Procedure and solvent cement according to ASTM D 3138.
10. Plastic piping heat-fusion joints: Clean and dry joining surfaces by wiping joint surfaces with clean cloth or paper towels. Join according to ASTM D 2657 procedures and manufacturer's written instructions. Plain-End Pipe and Fittings: Use butt fusion. Plain-End Pipe and Socket Fittings: Use socket fusion.

T. Piping connections: Make pipe connections according to the following, unless otherwise indicated:

1. Install unions, in piping 50 mm and smaller, adjacent to each valve and at final connection to each piece of equipment with 50 mm or smaller threaded pipe connection.
2. Install flanges, in piping 65 mm and larger, adjacent to flanged valves and at final connection to each piece of equipment with flanged pipe connection.
3. Wet piping systems: install dielectric coupling and nipple fittings to connect piping materials of dissimilar metals.

PAINTING AND FINISHING

Painting shall conform to the provisions in Section 59 "Painting" of the Standard Specifications and these special provisions.

Exposed piping shall be painted in conformance with the following requirements, unless otherwise shown on the plans or specified in these special provisions:

A. Interior, ferrous piping: Contractor shall furnish semigloss, acrylic-enamel finish. Include finish coat over enamel undercoat and primer.
B. Interior, galvanized-steel piping: Contractor shall furnish semigloss, acrylic-enamel finish. Include two finish coats over galvanized metal primer.
C. Interior, ferrous supports: Contractor shall furnish semigloss, acrylic-enamel finish. Include finish coat over enamel undercoat and primer.
D. Exterior, ferrous piping: Contractor shall furnish semigloss, acrylic-enamel finish. Include two finish coats over rust-inhibitive metal primer.
E. Exterior, galvanized-steel piping: Contractor shall furnish semigloss, acrylic-enamel finish. Include two finish coats over galvanized metal primer.
F. Exterior, ferrous supports: Contractor shall furnish semigloss, acrylic-enamel finish. Include two finish coats over rust-inhibitive metal primer.

Piping specialties with factory-applied finish or stainless steel piping shall not be painted. Marred and damaged factory-painted finishes shall be repaired with materials and procedures to match original factory finish.

INSTALLATION

Equipment Installation - Common Requirements.--Equipment shall be installed in conformance with the following requirements, unless specified otherwise in these special provisions:

A. Install equipment to provide maximum possible headroom, if mounting heights are not indicated.
B. Install equipment according to approved submittal data. Some portions of the work are shown only in diagrammatic form. Refer conflicts to Engineer
C. Install equipment level and plumb, parallel and perpendicular to other building systems and components in exposed interior spaces, unless otherwise indicated on the plans.
D. Install mechanical equipment to facilitate service, maintenance, and repair or replacement of components. Connect equipment for ease of disconnecting, with minimum interference to other installations. Extend grease fittings to accessible locations.
E. Install equipment giving right of way to piping installed at required slope.
F. Install flexible connectors on equipment side of shutoff valves, horizontally and parallel to equipment shafts if possible.

Equipment Pads.--Concrete equipment pads shall be constructed with the dimensions as shown on the plans, but not less than 100 mm in height and not less than 150 mm larger in both directions than the supported unit. Coordinate size of equipment pads with approved equipment submittals. Supported equipment manufacturer's setting templates shall be used for anchor bolt and tie locations. Concrete for bases shall be minimum 20 MPa, 28-day compressive-strength concrete and reinforced as shown on the plans.

Erection of Metal Supports and Anchorage.--Miscellaneous metal supports shall be cut, fit, and placed accurately in location, alignment, and elevation to support and anchor mechanical materials and equipment.

Anchorages shall conform to the provisions for concrete anchorage devices in Section 75-1.03, "Miscellaneous Bridge Metal" of the Standard Specifications and these special provisions.

Cutting and Patching.--Floors, walls, partitions, ceilings, and other surfaces shall be cut, channeled, chased, and drilled as necessary for mechanical installations. Cutting shall be performed by skilled mechanics of the trades involved. Cut surfaces shall be repaired to match adjacent surfaces.

Grouting.--Grout shall be placed in conformance with the following requirements:

A. Install nonmetallic, nonshrink, grout for mechanical equipment base bearing surfaces, pump and other equipment base plates, and anchors. Mix grout according to manufacturer's written instructions.
B. Clean surfaces that will come into contact with grout.
C. Provide forms as required for placement of grout.
D. Avoid air entrapment during placing of grout.
E. Place grout, completely filling equipment bases.
F. Place grout on concrete bases to provide smooth bearing surface for equipment.
G. Place grout around anchors.
H. Cure placed grout according to manufacturer's written instructions.

DEMONSTRATION AND TRAINING

Upon completion of the work, and after all tests, the Contractor shall demonstrate and instruct the Department's designated operating, maintenance, and training personnel in the adjustment, operation, and maintenance of systems and equipment, including pertinent safety requirements. Each instructor shall be thoroughly familiar with all parts of the installation and shall be trained and certified in operating theory as well as practical operation and maintenance work. The training shall start after the Contractor has completed start-up of the mechanical systems, but before final acceptance tests. The field instruction shall cover all of the items contained in the operating and maintenance manuals as well as demonstrations of routine maintenance and servicing operations. The Engineer shall be notified at least 45 days prior to the proposed date and time. The Engineer and Contractor shall negotiate a mutually acceptable training schedule and training site. The instruction shall include, as a minimum, the following:

A. Description of each basic mechanical system including startup, normal operation, normal shutdown, emergency startup, emergency shutdown, normal testing and trouble-shooting conditions.
B. Explain identification system.
C. Describe interfaces with electrical system including interlocks, sequencing, start-up, shut-down, emergency, safety, system failure, security and other provisions.
D. Outline basic maintenance procedures including adjustments to optimize output and efficiency of systems.
E. Display and conduct a "thumb-through" explanation of the maintenance manuals, record drawings, spare parts inventory, metering, lubrication and other service items.
F. Conduct a detailed review of preventative maintenance measures.
G. Review trouble modes and remedies.

MEASUREMENT AND PAYMENT

Full compensation for mechanical materials and methods will be considered as included in the contract lump sum prices paid for the various items of work involved and no additional compensation will be allowed therefor.

10-5.__ TUNNEL FIRE PROTECTION

GENERAL

SUMMARY

Scope.--Tunnel fire protection shall consist of furnishing, installing and testing a tunnel wet standpipe fire protection system, including all the fire pump suction and discharge piping, all piping downstream of the backflow preventer and all other 200-mm and smaller piping in the fire pump room including the piping to and from the water storage tank. The scope also includes the standpipe system piping and valves in the tunnel and the niches including the 75-mm drain piping, valves and valve boxes in the tunnel. The scope shall include the fire department connections outside the tunnel portals and all other accessories required for a functional system in conformance with the details shown on the plans and the requirements specified in these special provisions.

SUBMITTALS

The Contractor shall submit manufacturer's technical data for all items listed under "Products" of these special provisions. In addition to the required product data, working drawings shall be developed and submitted.

Product data.--The equipment manufacturer's product data shall include the following:

A. Catalog Cuts.
B. Wiring diagrams for the components requiring electrical connections.
C. Description of installation and operation.
D. Maintenance data to be included in the maintenance manual.

Working drawings.--The Contractor shall submit working drawings in conformance with Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications and these special provisions.

Working drawings shall include complete details, information, drawings, and substantiating calculations of proposed materials, facilities, equipment to be used and method of construction.

The working drawings shall include the following:

A. A line layout for the fire pump room drawn to a minimum 1:40 scale shall show each standard pipe joint and each special joint or fitting by number and each hanger or support.
B. A scalable plan and section (1:100 minimum) detail of a typical 60 m section of tunnel standpipe buried in the walkway, with feeds to the niches at both ends, shall be submitted. Details of supports used for holding the standpipe in place and alignment, prior to the pouring of the concrete shall be included.
C. Standard details and sections of the niches at a minimum 1:25 scale shall assure that the detail design of the pipe and accessories will comply with the design concept and structural requirements.
D. Full details of concrete cover and penetration of concrete structures for the straight pipe, and details of special fittings and connections, including temporary and permanent supports shall be included.

QUALITY ASSURANCE

Codes & Standards.--The following codes, regulations, reference standards and specifications shall apply:

A. Manufacturers equipment, specialties and accessories shall be listed by product name and manufacturer in the UL Fire Protection Equipment Directory and the FM Approval Guide.
B. Equipment, specialties and accessories shall have label or approval stamp of listing agency. The terms "Listed" and "Labeled" shall be as defined in "National Electric Code," Article 100.
C. Equipment, accessories, installation and testing shall comply with the following NFPA standards:

    1. NFPA 13 "Standard for the Installation of Sprinkler Systems"
    2. NFPA 14 "Standard for the Installation of Standpipe and Hose Systems"
    3. NFPA 26 "Recommended Practice for the Supervision of Valves Controlling Water Supplies for Fire Protection"
    4. NFPA 70 "National Electric Code"

Other Requirements.--

A. Comply with the requirements of the San Mateo County Fire Marshall for approvals, hose threads, installation inspections and testing.
B. Submit design calculations signed by a Registered Fire Protection Engineer in the State of California.
C. Work shall be performed by firms qualified to install, service and repair fire protection piping and equipment. A qualified firm is one that is experienced with minimum of 5 previous projects similar in size and scope to this project. Submit qualifications to the Engineer upon request.

PRODUCTS

Ductile Iron Pipe (For Buried Service).--Ductile iron pipe shall be centrifugally cast in 5.5 m or 6.1 m nominal lengths conforming to AWWA C151, shall be seal coated, and shall have a double thickness cement mortar lining conforming to AWWA C104. Pipe shall be special thickness Class 52. Pipe shall be provided with mechanical joint or push on joint ends. Mix and matching of mechanical joint pipe with push on joint pipe will not be permitted. All joint ends, whether mechanical or push-on, shall be capable of using a restraint system supplied by the pipe manufacturer. Restrained joints shall be used at all locations shown on the plans and specified in these special provisions.

In special cases such as vaults and niches where mechanical grooved coupling and valves with mechanical grooved ends or flanged ends are specified, pipe shall be standard thickness Class 53. Pipe ends shall be prepared for mechanical grooved couplings or transition couplings. Where space permits, flanged ends will be allowed in lieu of mechanical grooved ends.

Ductile Iron Pipe Coating System.--The exterior surfaces or the pipe and fittings shall have the following coating systems in conformance with the requirements in AWWA C210:

A. Surface preparation shall be Solvent Clean (SSPC-SP-1) followed by abrasive blast-cleaning to Near White Metal (SSPC-SP-10) with an anchor profile between 0.075-mm

and 0.1-mm. The Contractor shall conform to the National Association of Pipe Fabricators (NAPF) Standard 500-03 and the pipe manufacturer's recommendations prior to any blast cleaning of the ductile iron pipe.

B. Two (2) uniform coats of coal tar epoxy conforming to AWWA C210 shall be applied to a total dry film thickness of 0.5-mm to 0.75-mm.

C. The drying time between coats shall be 12 hours minimum and 24 hours maximum at 21°C. Intercoat drying time is critical and shall be according to manufacturer's recommendations.

D. A double layer of 0.20 mm low density polyethylene wrap shall be provided over all the ductile iron fire protection pipe and fittings buried in the concrete sidewalk or beneath the roadway slab. The Contractor shall conform to AWWA C105 in the application of the polyethylene wrap and use heat shrink joint closure sleeves.

Fittings for Ductile Iron Pipe (Buried Service).--Fittings for mechanical joint or push on ductile iron pipe shall be ductile iron of Class 250 gray iron conforming to AWWA C110 and C111; fittings shall be seal coated and shall be double thickness cement mortar lined conforming to AWWA C104.

Restrained joints fittings shall conform to the details as shown on the plans, and at the ends of construction joints and ends of sections of pipe which need hydrostatic testing prior to backfilling with lean concrete. Joint restraint shall be incorporated in the design of the follower gland and shall include a restraining mechanism which when activated imparts a multiple wedging action against the pipe increasing its resistance as the pressure increases. Restrained device shall meet requirements of ANSI/AWWA C111/A21.10. Glands shall be of ductile iron conforming to ASTM A536.80 and shall be seal coated equal to that on the connecting pipe. The mechanical joint restraint device shall have a minimum working pressure of 1723 kPa.

Restrained push-on joints for pipe and fittings shall consist of stainless steel locking segments, integrally molded into the gasket. Restrained push-on joints shall be capable of being deflected after assembly.

At the Contractor's option and when approved by the Engineer, pipe and fitting joints consisting of ductile iron locking segment inserted through slots in the bell face can be used in lieu of joint restraint device. Pipe and fitting joints shall provide a positive axial lock between the bell interior surface and a retainer weldment on the spigot end of the pipe.

Flanged fittings in vaults shall conform to AWWA C115. Mechanical grooved end fittings shall be an acceptable alternate to flange fittings for use in vaults. Restrained and flanged joint fittings shall be compatible with the mating restrained and flanged joint pipe system used.

Gate Valves (Fire Protection Service In Fire Pump Room).--Gate valves for general shut off and isolation duty in the Fire Pump Room shall be iron body resilient seated solid wedge gate valves with a cast iron wedge fully encapsulated with molded rubber, designed to work equally well with pressure on either side of the gate. Valves shall be of the OS & Y type, complete with UL listed and FM approved supervisory switches.

Gate valves shall have flanged and gasketed ends complying with ANSI B16.1, Class 125. Valves shall be designed for a working pressure of 1723 kPa.

Bronze for interior parts of valves shall contain no more than 6 percent zinc.

All interior ferrous surfaces exposed to fluid flow shall be epoxy coated to a minimum dry film thickness of 0.25-mm. Epoxy coatings shall be factory applied by an electrostatic or thermosetting process in accordance with the manufacturer's printed instructions. The epoxy materials shall be 100 percent powder AWWA C550, and shall be certified to ANSI/NSF 61.

Valves shall conform to the requirements of AWWA C509, UL 262 and FM 1120/1130.

Gate Valves (Fire Hydrant Service).--Gate valves for shut off duty at the Fire Hydrants shall be iron body resilient wedge non-rising stem gate valves with end connection to match the piping shown on the plans. The iron wedge shall be fully encapsulated with molded rubber.

Valve shall conform to the requirements of ANSI/AWWA C509 and shall be certified to ANSI /NSF 61.

Valve shall be furnished with stainless steel trim. All bolts, nuts, and washers shall be of type 304 stainless steel. Valve body shall have minimum 0.25 mm epoxy coating on interior and exterior surfaces. Epoxy coating shall conform to the requirements of ANSI / AWWA C550.

Valve shall have triple O-ring seal stuffing box and be furnished with 51 mm square wrench nut or handwheel.

Valve shall be UL Listed and FM Approved for a working pressure of 1379 kPa.

Concrete Thrust Blocks.--Concrete thrust blocks and anchors for use on the buried pipeline shall be located as shown on the plans and at all changes in direction for the ductile iron pipe buried in soil.

Fire Hose Valves (FHV).--Valves shall be used as fire department outlet connections. Valves shall be 65 mm angle or straight type as shown on the plans, and shall be made of cast brass with a rough chrome plated finish. Valves shall be furnished with red handwheel, cap, chain, 150 mm female NPT inlet, and the Half Moon Bay Fire Department compatible male hose thread outlet. Valve shall be rated to 2068 kPa. Valves shall be UL listed and FM approved.

Fire Department Inlet Connection.--Fire Department Inlet Connections shall be two-way inlet type cast brass body with drop clappers. Furnish with two 65 mm inlets and one 150 mm bottom outlet or back outlet connection. Free standing inlets shall be complete with 460 mm long cover sleeve, identification base plate with "STANDPIPE" lettering, polished brass snoot, pin lug hose thread swivel, pin lug plugs and chains. Unit shall be UL Listed.

Iron Pipe Size (IPS) Piping System (Buried or Embedded)

This specification describes the 100 mm and smaller piping in the niches, the miscellaneous piping embedded in the concrete walls of the tunnel and the floor of the Fire Pump Room and the 150 mm buried piping connected to the Fire Department Connection near the South Portal of the tunnel. The pipe and fittings shall conform to the following:

A. All grooved components in the niches shall be of one manufacturer, shall conform to local code approval and shall be listed under ANSI-B31.1 or B-31.9 or ASME, and UL/FM for grooved end products. Manufacturer shall be ISO-9001 certified.
B. Grooved pipe: 100-mm and smaller pipe in the niches shall be Schedule 40, ASTM A53 galvanized in nominal 6.1 m lengths. Pipe and fittings shall be with roll groove or cut groove ends as appropriate for the pipe material, wall thickness, pressures, size and method of joining. Pipe ends shall be grooved in conformance with the requirements in ANSI/AWWA C-606.
C. Unless otherwise shown on the plans, the sections of pipe that are embedded in concrete walls of the tunnel, embedded in the concrete floor of the fire pump room and the buried 150 mm diameter pipe that is connected to the fire department connection at the south portal, shall be Schedule 40S, Type 304L, of fully welded construction. The 300 mm casing pipe, which encases the 150 mm feed to the NB Tunnel shall be Schedule 10S, Type 304L, furnished from the factory in one unbroken continuous length. Stainless

fittings for embedded or buried pipes, shall be type 304L conforming to ASTM A-403 Class CR or WP.

D. Mechanical transition couplings for joining ductile iron to galvanized steel pipe in the niche shall be rigid hot dip galvanized couplings, conforming to the requirements in ASTM A 536. The minimum pressure rating for a 100 mm coupling transitioning from ductile iron to a Schedule 40 steel pipe shall be 3450 kPa.
E. The rigid and the flexible couplings, used to connect steel pipe to steel pipe in the niche, shall be made of ductile iron conforming to ASTM A 536, hot dip galvanized or epoxy-coated to a dry film thickness of 0.25-mm outside and inside in conformance with the requirements in AWWA C 210. Minimum pressure rating for a 100 mm coupling on a Schedule 40 pipe shall be 5175 kPa.
F. Mechanical coupling bolts: mechanical coupling bolts shall be Type 316 stainless steel, hex head machine bolts per ASTM A-193, Grade B-8, Class 2. Nuts shall be ASTM A-194 B8M.
G. Flange adapters: ground joint flange, 50 mm through 200 mm nominal size for connection to ANSI Class 125/150 flanged components. Cast of ductile iron conforming to ASTM A-536 or malleable iron conforming to ASTM A-47. Flange adapter coating, bolts, nuts and washers and sealing gaskets shall be the same as that specified for the rigid and flexible grooved couplings.
H. Gaskets for the wet pipe grooved couplings shall be Grade "E" EPDM compound (green color coded). Temperature operating range shall be –34°C to +110°C.
I. Fittings shall be smooth turn full flow galvanized steel or ductile iron fittings with grooves designed to accept grooved end couplings. Fittings shall conform to the requirements in ASTM A-234, Class WPA or WPB.
J. Butt weld fittings for the stainless embedded or buried service pipe, shall be Type 304L SS conforming to ASTM-A-403 Class CR or WP.

IPS Grooved or Welded Piping System In The Fire Pump Room.--Grooved or welded piping in the fire pump room, including the 150 mm diameter section of feed to the north bound tunnel, which is encased in a 300 mm diameter pipe, shall conform to the following requirements:

A. All grooved components shall be of one manufacturer, and shall conform to local code approval and shall be listed under ANSI-B31.1 or B-31.9 or ASME and UL/FM for grooved end products. Manufacturer shall be ISO-9001 certified.
B. Steel pipe shall be ASTM A53, Grade B, ERW, Schedule 40 for pipe sizes 15 mm through 200 mm.
C. Fittings for 65 mm diameter and above shall be ASTM A234, Grade WPA or WPB steel, butt welding ends with grooved tangents welded to the ends or ductile iron grooved end fittings conforming to ASTM A-536 and as manufactured by the grooved end coupling manufacturer.
D. Flanges for pipe 65 mm and above shall be Class 150 forged steel, ASTM A105, weld neck, raised face or faced to match mating equipment or valves. Gaskets shall be ANSI B16-21, 1.6 mm thick, with design temperature range from -40°C to +371°C, maximum pressure of 6,895 kPa, synthetic finish with nitrate builder, suitable for water applications. Flange bolts shall be ASTM A307 Grade B bolts with A 563 Grade A heavy nuts.
E. Mechanical couplings for the grooved components shall be rigid style with angle pad design. Coupling housings shall be of ductile iron conforming to ASTM A 536.

Couplings from 50 mm through 150 mm size shall be rated for a working pressure of at least 4826 kPa. Coupling gaskets shall be Grade "E" EPDM, with design temperature range from –34°C to +110°C. Coupling bolts and nuts shall be heat treated, zinc electroplated to ASTM B-633 track-head style conforming to physical properties of ASTM A-183 and with minimum tensile strength of 758,340 kPa.

F. The 150 mm pipe that is encased in the 300 mm stainless casing, shall in addition to the above requirements be hot dip galvanized in accordance with ASTM A123. Sections of this pipe shall be installed in maximum 6.0 meter random lengths and the sections shall be connected to each other using hot dip galvanized mechanical grooved couplings. No butt welded joints will be permitted in this straight section of carrier pipe.

Butterfly Valves.--Butterfly valves shall be rated for 2068 kPa, and shall have ductile iron body with grooved ends and disc conforming to the requirements in ASTM A-536. The valve body shall be coated with polyphenylene sulfide blend. The disc shall have an EPDM coating. The valve shall be UL listed and approved for 1206 kPa service.

The valve shall have a gear operated actuator and handwheel. The actuator housing shall be plated steel. The valve shall be furnished complete with a supervisory switch wired to a junction box. The valve shall be capable of being padlocked in the open position.

Check Valves.--Check valves shall be made of ductile iron conforming to the requirements in ASTM A-536, Grade 65-45-12. The body seat shall be welded on nickel alloy. The disc shall be totally encapsulated with a Grade "E" EPDM coating. The valve shall be provided with stainless steel shaft and spring and be designed with a non-slam feature.

Check valves shall be furnished with upstream and downstream 15 mm diameter drain and plug, and shall be carbon steel zinc-plated in conformance with the requirements in ASTM B 633. Grooved ends shall allow connections to grooved end mating pipes using mechanical couplings. Check valves shall be UL listed.

Combination Air Valves.--Combination Air Valves 25 mm size, shall have double orifice in a single body allowing large volumes to escape out the large orifice when filling the pipeline and close when liquid enters the line. When the valve is closed and pressurized, the small air release orifice will allow small pockets of air to escape automatically and independently of the large orifice. The large orifice shall also allow large volumes of air to enter during pipeline drainage to break the vacuum. The body inlet shall be baffled to protect the float from the direct forces of rushing air and water to prevent premature valve shut off.

Body and cover shall be of cast iron ASTM A126 Gr. B. Float shall be stainless steel ASTM A240 and needle and seat shall be Buna-N. The plug center guided in hex bushings shall be of bronze, Leverage frame assembly shall be made of Delrin and Cast Iron.

Valve shall be furnished with NPT threaded inlet and outlet connections and factory applied red oxide primer paint.

Drain Valves.--Drain valves shall be standard port, end-entry valve with ductile iron body and end cap. Ball and stem shall be made of 316 stainless steel and seat shall be made of TFE. Valve shall be UL Listed and FM approved ball valve for fire line service and drain service on fire protection systems. Drain valves shall be of sizes as shown on the plans.

Tank Risers.--Tank risers from the water storage tank to the floor of the Fire Pump Room and North Equipment Chamber shall be "as welded" pipe. Material shall be ASTM 304C

stainless steel alloy, minimum 0.134 mm wall thickness and fabricated in accordance with ASTM A 788.

Manhole Frames and Covers.--Manhole frames shall be ferrous with 100 mm flange thickness and diameter to accommodate the riser sizes as shown on the plans. Frame and cover shall be ASTM A 48M gray iron, Class No. 35A minimum tensile strength. Covers shall have an indented top design with lettering "WATER" cast into cover.

INSTALLATION

Bedding and Backfill.--Temporary supports shall be provided for the 200 mm pipe in the walkway. Supports shall consist of masonry saddles or galvanized steel stanchions at minimum 3 meters on centers. All supports shall remain in place during and after the pour of lean concrete. Attention is directed to Section 73 "Concrete Curb & Sidewalk" of the Standard Specifications.

Construction Coordination and Scheduling.--The Contractor shall coordinate and schedule installation with the concrete fill over the walkway and roadway surfaces covering the pipe. Precast and cast in place boxouts for valves and branch piping shall be placed as shown on the plans.

Grade and Alignment.--The Contractor shall verify the locations and establish the depth of all new and existing utilities at the points where connections are to be made to the water main and crossings are required for the fire protection mains. The profile of the standpipe mains shall follow the slope of the tunnel to allow drainage at the south end of the tunnel.

Where elevation of pipeline and ground surface is shown on the plans, pipeline shall be laid to the elevation shown. Elevation changes required to miss existing utilities shall be made only with the express permission of the Engineer after all other avenues for resolution have been explored.

The buried wet standpipe piping shall be continuously sloped to the drainage points.

Trench Excavation (For Pipe Routed Outside The Tunnel).--The Contractor shall perform all excavation regardless of material encountered to the depth as shown on the plans or specified in these special provisions. Excavations shall be made by open cut. Trenches shall be excavated to true and smooth bottom grades in accordance with the lines shown on the plans. The trench bottom shall provide uniform bearing and support for each length of pipe.

Bell holes shall be excavated to the extent necessary to permit installation and inspection of the joints. The banks of the trenches shall be kept as nearly vertical as soil conditions permit. Where required to control trench width and protect adjacent structures, the trench shall be sheeted and braced. Standard excavating equipment shall be adjusted so as to excavate the narrowest trench possible.

The Contractor shall not excavate below the depth specified.

Bedding the Pipe (For Pipe Routed Outside The Tunnel).--Bedding material conforming to the requirements described in these special provisions shall be placed under the pipe and to a depth of at least 150 mm over the top of the pipe. The bedding material shall be rammed and tamped around the pipe by the use of shovels or other approved hand held tools, so as to provide firm and uniform support over the full length of all pipe, valves, and fittings.

Backfilling Trenches.--Prior to backfilling, all form lumber and debris shall be removed from the trench. Sheeting used by the Contractor shall be removed just ahead of the backfilling.

Backfill material meeting the requirements described in these special provisions shall be placed in maximum 150 mm lifts.

A minimum 75 mm sand cushion shall be placed between the buried fire protection lines and crossing water main or other pipelines or conduits encountered during construction unless otherwise directed by the Engineer.

Backfill shall be compacted to at least 95 percent of maximum density.

At locations where paved streets, roadway shoulders, driveways, or sidewalks will be constructed or reconstructed over the trench, the backfill shall be spread in layers (lifts), and be compacted by mechanical tampers. Each 150 mm layer shall be compacted with mechanical tampers to the density specified herein.

Coordinate With Utility Company and Other Contracts.--The Contractor shall coordinate work with the Engineer, NCCWD and whit the others contractors on site when interfacing to their work.

Hangers and Supports.--Piping shall be supported in the Fire Pump Room in conformance with the requirements specified in "Hangers and Supports" of these special provisions.

WELDING

The welders and welding procedures shall be qualified in accordance with the requirements of ASME Section IX of the Boiler and Pressure Vessel Code.

Major piping assemblies shall be shop fabricated. Field welding will not be permitted.

Make circumferential welds in stainless steel pipe using the tungsten inert gas (TIG) welding process. Use Tungsten non-consumable electrodes for the type of stainless and 100 percent commercially-dry and pure argon gas for internal pipe purging and for electrode shielding. All purge restriction devices shall be physically removed from systems prior to cleaning of the systems.

All welds shall have 100 percent penetration and smooth lines of fusion on the exterior and interior. Weld reinforcement shall not exceed 1.6 mm. Minimum thickness of the welded joint shall not be less than 90 percent of the pipe wall thickness.

Welds shall be examined in accordance with the requirements of ANSI B31.1. 100 percent of the welds that are embedded or buried shall be examined by radiography in the shop. A minimum of 10 percent of remaining circumferential butt welds shall be examined fully by random radiography. A report, interpreting the radiographs shall be submitted to the Engineer.

The Contractor shall clean interior and exterior of stainless shop welds by pickling and passivation after fabrication, and stainless welds with stainless steel wire brushes, resinoid or rubber-bonded aluminum grinding wheels which are free of carbon particles. The Contractor shall not use carbon steel tools, brushes, or grinding wheels which have been previously used on carbon steel material on stainless steel welds.

TESTING AND DISINFECTING

Piping equipment and instrumentation which will not safely withstand the test pressure shall be isolated and removed.

All lines shall be flushed prior to testing hydrostatically. The piping system shall be isolated, filled and pressure tested at 1400 kPa for 2 hours with no loss of pressure. The hydrostatic test pressure shall be measured at the low elevation point of the individual system or section being tested. If the tested system fails to meet the pressure test, the Contractor shall, at no additional

cost to the State, locate and repair the defects and then retest the system. Upon successful completion of the test, the system shall be drained and the temporary caps and blind flanges required for the test shall be replaced to preclude foreign objects entering the piping or tested system before the next stage of construction or testing.

All systems shall be flushed and disinfected after removal of all temporary testing equipment and installation of all permanent equipment.

All the fire protection system piping shall be disinfected in conformance with the requirements of the California Plumbing Code.

The testing of the ductile iron buried pipe shall be conducted with all the thrust blocks in place and prior to the back filling of trench.

The operation of the wet standpipe system shall be tested in conformance with the requirements in NFPA 14.

MEASUREMENT

Tunnel fire protection will be measured on a lump sum basis

PAYMENT

The contract lump sum price paid for tunnel fire protection shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the tunnel fire protection system, complete in place, including excavation, backfill, thrust blocks, valve boxes and cover plates, miscellaneous piping, fire hose valves, fire department connections and testing and disinfecting, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-5.__ FIRE PUMPS

GENERAL

Fire pumps shall conform to the provisions in Section 74, "Pumping Plant Equipment," of the Standard Specifications and these special provisions.

SUMMARY

Scope.--Fire pumps shall consist of electric-drive, horizontal and vertical fire pumps for the tunnel standpipe systems, and shall include the following:

A. Horizontal split-case fire pumps.
B. Vertical turbine fire pumps.
C. Vertical in-line pressure-maintenance (jockey) pumps.
D. Deep well submersible pressure-maintenance (jockey) pumps.
E. Full-service fire-pump controllers.
F. Pressure-maintenance-pump controllers.
G. Fire-pump specialties and accessories.
H. Pressure-maintenance-pump specialties and accessories.
I. Flow-measuring systems.

SUBMITTALS

The Contractor shall submit equipment list and working drawings in conformance with the provisions in Section 86-1.04 "Equipment List and Drawings" of the Standard Specifications and the requirements specified herein.

Product Data.--The Contractor shall submit the following manufacturer's technical product data and other required information on the fire pumps, jockey pumps and associated controllers:

A. Manufacturers' technical data, including rated capacities; certified pump performance curves with each selection point indicated; shipping, installed, and operating weights; furnished specialties; and accessories for each fire-pump and pressure-maintenance-pump unit and flow-measuring system.
B. Details of equipment assemblies and indicating dimensions, weights, loads, required clearances, methods of field assembly, components, and location and size of each field connection for each fire-pump and pressure-maintenance-pump unit.
C. Detailed wiring diagrams, electrical schematics and physical dimensions for the controllers. The Contractor shall provide details of the wiring for power, signal, and control systems and differentiate between manufacturer-installed and field-installed wiring.
D. Manufacturer seismic qualification certification indicating that fire pumps and drivers and fire-pump controllers, pressure-maintenance pumps, accessories, and specialties will withstand seismic forces specified in these special provisions. Seismic qualification certification shall include the following:

    1. Basis for certification indicating whether withstand certification is based on actual test of assembled components or based on calculation. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
    2. Dimensioned outline drawings of equipment to identify center of gravity and locate and describe mounting and anchorage provisions.
    3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

E. Product certificates signed by manufacturers of fire pumps and fire-pump controllers certifying that products furnished are in conformance with requirements specified in these special provisions.
F. Field test reports indicating and interpreting test results for compliance with performance requirements.
G. Maintenance data for each fire-pump and pressure-maintenance-pump unit, in conformance with the requirements specified in "Mechanical Material and Methods" of these special provisions.

Working Drawings.--The Contractor shall submit working drawings in conformance with Section 5-1.02 "Plans and Working Drawings" of the Standard Specifications and these special provisions.

Working drawings shall include plan layout drawings of the fire pumps in their final anchored locations in the fire pump room, to a scale of minimum 1:40, showing locations of all suction and discharge and relief piping connections. The Contractor shall coordinate information

with working drawings for the Fire Pump Room in conformance with "Tunnel Fire Protection" of these special provisions. Working drawings shall include layout of the associated controllers.

QUALITY ASSURANCE

Manufacturers shall be firms whose fire pumps, pressure-maintenance pumps, drivers, controllers, and accessories are listed by product name and manufacturer in UL's "Fire Protection Equipment Directory" and FM's "Fire Protection Approval Guide."

Fire-pump and pressure-maintenance-pump units shall be obtained through one manufacturer.

A listing or approval stamp, label, or other marking shall be provided on equipment made to specified standards. Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100.

Pumps shall conform to the requirements in NFPA 20, "Stationary Pumps for Fire Protection," for fire pumps, drivers, controllers, accessories, and installation.

Factory tests shall include hydrostatic and performance testing and running of the fire pumps before shipping. Pumps shall be tested at 150 percent of shutoff head plus suction head, but not less than 1725 kPa. Certified test curves shall be submitted to the Engineer showing head capacity and brake power of each pump.

DELIVERY, STORAGE, AND HANDLING

After assembling and testing fire pumps and pressure-maintenance pumps in the shop, the Contractor shall prepare for shipping and protect the entire unit, flanges, exposed machined metal surfaces, pipe openings, and nozzles. Shipping flange protective covers and protective coatings shall be retained during storage. Bearings and couplings shall be protected against damage from sand, grit, or other foreign matter.

DEFINITIONS

A. Fire-pump unit assembly: Complete assembly with fire pump, driver, controller, and related accessories.
B. Pressure-maintenance pump: Electric-drive pump used to maintain water pressure in fire-suppression piping system.
C. Pressure-maintenance-pump unit assembly: Complete assembly with pressure-maintenance pump, driver, controller, and related accessories.
D. HI: Hydraulic Institute.

SYSTEM PERFORMANCE REQUIREMENTS

Fire-pump systems shall consist of fire-pump and pressure-maintenance-pump unit assemblies and controllers that comply with performance requirements shown on the plans, and are compatible with tunnel fire-suppression systems and the interfacing electrical power and fire alarm systems.

Pump, equipment, accessory, and piping pressure rating shall be 1724 kPa minimum working-pressure rating, unless higher rating.

HORIZONTAL SPLIT-CASE FIRE PUMPS

Single-stage, horizontally mounted, split-case fire pumps shall be UL 448, factory-assembled and -tested, electric-drive, double-suction, horizontal type. Include pump and driver mounted on same base and connected with coupling.

The fire pump shall be labeled for fire service and shall be connected to the tunnel standpipe system. The suction supply for the fire pump shall be from a public water service main at a pressure of 410 kPa. The fire pump shall include the following:

A. Characteristics: Flow capacity and total head as shown on the plans and capable of furnishing not less than 150 percent of rated capacity at not less than 65 percent of total rated head. Shutoff head shall be limited to 120 percent of total rated head.
B. Casing: Axially split cast iron with suction and discharge flanges machined to ASME B16.1, Class 125 dimensions.
C. Impeller: Cast bronze of construction to match fire pump, statically and dynamically balanced, and keyed to shaft.
D. Wear rings: Replaceable, bronze.
E. Shaft and sleeve: Steel shaft with bronze sleeve.
F. Shaft bearings: Grease-lubricated ball bearings in cast-iron housing.
G. Seals: Stuffing box with minimum of four rings of graphite-impregnated braided yarn and bronze packing gland.
H. Coupling: Flexible and capable of absorbing torsional vibration and shaft misalignment. A metal guard shall be included with each coupling.
I. Driver: Electric motor, NEMA Design B, Open Drip Proof type with 1.15 service factor and listed for Fire Pump service.
J. Finish: Manufacturer's standard red paint applied to factory-assembled and -tested unit before shipping.
K. Nameplate: Complete with capacities, characteristics, and other pertinent data.

PRESSURE-MAINTENANCE (JOCKEY) PUMPS

Pressure-maintenance (jockey) pumps shall be as shown in the schedule on the plans. Pressure maintenance pumps shall consist of factory-assembled and -tested, electric-drive pumps with stainless-steel casing and stainless-steel impellers, stainless-steel motor shafts, and mechanical seals. Jockey pumps shall include flanged suction and discharge flanges machined to ASME B16.1, Class 125 dimensions except that connections may be threaded in sizes where flanges are not available for sizes 40 mm and smaller. Jockey pumps shall also conform to the following:

A. Multistage, pressure-maintenance pumps: Multiple-impeller type complying with (Hydraulic Institute) HI 1.1-1.5 requirements for multistage centrifugal pumps. Pump shall be vertical in-line type. Pump shall be provided with manufacturer's standard color paint applied to factory tested unit before shipping.
B. Nameplate: Complete with capacity, characteristics, and other pertinent data.

VERTICAL TURBINE FIRE PUMPS

Vertical turbine fire pumps shall consist of UL 448, factory-assembled and -tested, electric-drive, vertical-turbine fire pumps and the following:

A. The fire pump shall be labeled for fire service and shall be connected to the tunnel standpipe system. The suction supply for the fire pump shall be from a public water service underground water storage tank at atmospheric pressure.
B. Characteristics: Flow capacity and total head as shown on the plans. Pumps shall be capable of 150 percent of rated capacity at not less than 65 percent of total rated head. Shutoff head shall be limited to 140 percent of total rated head.

C. Fabricate base and attachment to fire pumps, pressure-maintenance pumps, and controllers with reinforcement to resist movement of pumps and controllers during a seismic event when their bases are anchored to building structure.
D. Finish: manufacturer's standard red paint applied to factory-assembled and -tested unit before shipping.
E. Nameplate: complete with capacities, characteristics, and other pertinent data.
F. Pump: vertical-turbine-type with impellers discharging into bowls and vertical pump column.
G. Pump head: cast iron, for aboveground discharge, with discharge flange machined to ASME B16.1, Class 125 dimensions, unless otherwise shown on the plans.
H. Line shaft: stainless steel or steel with corrosion-resistant shaft sleeves.
I. Pump line shaft bearings: rubber sleeve, water lubricated.
J. Impeller shaft: Monel metal or stainless steel.
K. Pump bowl assemblies: cast iron with closed-type bronze impellers.
L. Pump column: Steel pipe in sections 1.5 m to allow for ease of future replacement with the given height constraints of the fire pump room. The shaft sections shall be of similar length and staggered with respect to the column sections. Total length shall be as shown on the plans.
M. Suction strainer: cast or fabricated, bronze or stainless steel with free area not less than 4 times suction inlet cross-sectional area, with openings that will not permit passage of a 7.9 mm sphere for pump rating of 1892 L/minute or less, and openings that will not permit passage of a 12.7 mm sphere for pump ratings of 2838 L/minute and larger.
N. Drive motor shall conform to the requirements of NFPA 20 and shall have a 1.15 service factor.

DEEP WELL SUBMERSIBLE PRESSURE MAINTENANCE PUMPS

Deep well submersible pressure maintenance pumps shall be submersible-type, vertical-turbine well pump complying with HI 2.1-2.5 or AWWA E101, with the following:

A. Impeller material: stainless steel.
B. Motor: capable of continuous operation under water, with protected submersible power cable. Column pipe: ASTM A 53, Schedule 40, galvanized steel pipe with threaded ends and cast-iron or steel threaded couplings.

PUMP DRIVERS

In addition to the requirements specified in "Horizontal Split Case Fire Pumps" of these special provisions, the pump driver shall be NEMA MG 1, squirrel-cage, with induction motor mounted on steel base common to the pump, including construction complying with NFPA 20 and NFPA 70, wiring compatible with controller used, and with the following:

A. Finish: Manufacturer's standard red paint applied to factory-assembled and -tested unit before shipping.
B. Nameplate: Complete with motor power, characteristics, and other pertinent data.

PUMP CONTROLLERS

General.--Pump controllers shall conform to the requirements in UL 218 and NFPA 20, and be listed for electric-drive, fire-pump service and service entrance, combined automatic and non-

automatic operation, factory assembled and wired, factory tested for capacities and electrical characteristics, and conform to the following requirements:

A. Rate controllers for scheduled fire-pump power and short-circuit withstand rating at least equal to short-circuit current available at controller location. Take into account cable size and distance from substation or supply transformers.
B. Enclosure: UL 50, Type 2, drip-proof, indoor use. The outside of the enclosure shall have manufacturer's standard red paint applied in the shop.
C. Controls, devices, alarms, functions, and operations listed in NFPA 20 as required for drivers and controller types used, and specific items listed for each controller type.
D. Nameplate: Complete with capacity, characteristics, approvals and listings, and other pertinent data.
E. Controller sensing pipes: fabricate pipe and fittings according to NFPA 20 with nonferrous-metal sensing piping, 15 mm nominal size, with globe valves for testing controller mechanism from system to pump controller as indicated. Include bronze check valve with 2.4 mm orifice in clapper or ground-face union with non-corrosive diaphragm having 2.4 mm orifice.

Full-Service Fire-Pump Controller.--Full service fire pump controller shall conform to the requirements in UL 218 and NFPA 20 and shall be listed for electric-drive fire-pump service and service entrance, and shall conform to the following:

A. Type of starting for motors smaller than 20 kW: Across the line.
B. Type starting for motors 20 kW and larger: Solid state (soft start).

Controllers shall be rated for the scheduled horse power, including short-circuit withstand not less than 100,000 amps symmetrical at an operating voltage of 480 volts. Cable size and distance from substation or supply transformers shall be taken into account. Controllers shall include the following:

A. Isolating means and circuit breaker. Circuit overcurrent sensor shall be microprocessor type, calibrated and set at 300 percent motor full-load current and shall have a trip time between 8 and 20 seconds at 600 percent of motor full load current.
B. IEC rated, UL listed contactor, operable by and external emergency operating handle.
C. "Power on" pilot lamp.
D. Fire alarm system connections for indicating motor running condition, loss-of-line power, and line-power phase reversal. One normally closed and normally open dry contact shall be included for each alarm.
E. Three-phase power monitor shall trip on either low voltage, single phase, loss of power, or phase reversal. One green LED for normal power and one red LED for a tripped condition, shall be included.
F. Circuit for manual remote starting of controller per NFPA 20.
G. Automatic and manual operation, and minimum run-time relay to prevent short cycling, with pilot light to indicate when the timer is in the timing mode.
H. Water-pressure-actuated switch with independent high and low calibrated adjustments responsive to water pressure in fire-suppression system, sealable to prevent unauthorized adjustment. Include normal pressure indicator LED (green) and low pressure indicator LED (amber).
I. Automatic and manual shutdown.

J. System pressure recorder, electric AC driven with spring backup.
K. Control circuit transformer, minimum 150 VA rating, with integral overcurrent protection per NFPA 20.
L. Mounting: floor-stand type for field electrical connections.
M. Enclosure finish: manufacturer's standard red paint applied to factory-assembled and -tested unit before shipping.

Pressure-Maintenance-Pump Controllers.--Pressure-maintenance-pump controllers shall conform to the requirements in UL 508, factory-assembled, factory-wired, and factory-tested across-the-line type for combined automatic and non-automatic operation. Enclosure shall be NEMA 2 drip proof, wall-mounting type for field electrical wiring.

Controllers shall be rated for the scheduled horse power, including short-circuit withstand not less than 14,000 amps symmetrical at an operating voltage of 480 volts, and 10,000 amps symmetrical at an operating voltage of 208 volts. Cable size and distance from substation or supply transformers shall be taken into account. Controllers shall include the following:

A. Fusible disconnect switch.
B. Pressure switch.
C. Hand-off-auto selector switch.
D. Pilot light.
E. Running period timer.
F. Enclosure finish: manufacturer's standard color paint applied to factory-assembled and -tested unit before shipping.
G. Control transformer.

FIRE-PUMP SPECIALTIES AND ACCESSORIES

Fire pump specialties and accessories shall match fire-pump suction and discharge ratings as required for fire-pump capacity rating. The following shall be included:

A. Automatic air-release valve.
B. Circulation relief valve.
C. Suction and discharge pressure gages.
D. Eccentric-tapered reducer at suction inlet.
E. Concentric-tapered reducer at discharge outlet.
F. Test-header manifold: Ductile-iron or brass body for hose valves. Nozzle outlets shall be as show on the plans and shall have base plate with lettering equivalent to "PUMP TEST CONNECTION."
G. Escutcheon plate finish: Rough brass.
H. Hose valves: UL 668, straightway pattern, bronze with cap and chain. Valves shall be provided with NFPA 1963 hose threads that comply with Half Moon Bay Fire Department standards.
I. Ball drip valve: UL 1726.

PRESSURE-MAINTENANCE-PUMP SPECIALTIES AND ACCESSORIES

Pressure-maintenance-pump specialties and accessories shall match pressure-maintenance-pump suction and discharge ratings as required for pump capacity rating. The following shall be included:

A. Circulation relief valve.

B. Suction and discharge pressure gages.

GROUT

Grout shall be ASTM C 1107, Grade B, factory-mixed and prepackaged nonshrink, nonmetallic grout, suitable for interior and exterior applications, and conform to the following requirements:

A. Characteristics: post-hardening, volume-adjusting, dry, hydraulic-cement grout.
B. Properties: nonstaining, noncorrosive, and nongaseous.
C. Design mix: 35 MPa, 28-day compressive strength.

INSTALLATION

Installation shall conform to fire-pump, pressure-maintenance-pump, and controller manufacturers' written installation and alignment instructions and shall also conform to NFPA 20.

Pumps and controllers shall be installed to provide access for periodic maintenance, including removal of motors, impellers, couplings, and accessories.

Base-mounting-type pumps shall be set on concrete bases. Coupling halves shall be disconnected before setting. Couplings shall not be reconnected until alignment operations have been completed. Pump baseplates shall be supported on rectangular metal blocks and shims or on metal wedges having small taper, at points near foundation bolts to provide 19 to 38 mm gap between pump base and foundation for grouting, adjusting metal supports or wedges until pump and driver shafts are level. Coupling faces and pump suction and discharge flanges shall be verified level and plumb.

Vertical Turbine pump shall be attached to sole plate. Sole plate shall be set and leveled with grout pad and anchored to raise concrete equipment pad in conformance with manufacturer's instructions and additional requirements of paragraph "Alignment" of these special provisions. The Contractor shall coordinate with structural on locations and dimension of equipment pads and floor opening required.

Suction and discharge piping shall not be less than diameter of fire-pump connections. Valves shall be the same size as piping connecting to the fire pumps, bypasses and test headers.

Pressure gages shall be installed on fire-pump suction and discharge at pressure-gage tappings.

Pumps and piping shall be supported separately so weight of piping does not rest on pumps.

Piping accessories, hangers and supports, anchors, valves, meters and gages, and equipment supports shall be installed as required.

Flow meters and sensors shall be installed where indicated. Flow-measuring-system components and connections shall be installed according to manufacturer's written instructions.

The Contractor shall install electrical devices that are furnished by equipment manufacturer to be field installed. The Contractor shall furnish copies of manufacturers' wiring diagram submittals to the electrical installer, and shall verify that electrical wiring is installed according to manufacturers' submittal and installation requirements specified in these special provisions. Equipment startup shall proceed only after wiring installation is completed.

Submersible-type well pumps shall be installed according to HI 2.1-2.5 and providing access for periodic maintenance. The Contractor shall lower a mockup of pump into the water storage tank to verify that pump will fit and can be removed within the as built clearances available for installation. Before lowering the permanent pump into the tank, the pump shall be started to verify correct rotation. Discharge piping joints shall be securely tightened.

The motor shall be connected to the submersible pump and located near the well bottom. Power cables shall be connected while connection points are dry and undamaged. Power cables shall not be damaged during installation, using cable clamps that do not have sharp edges. A water-sealed surface plate shall be installed that will support the pump and piping.

Examination.--Prior to installation, equipment foundations and surrounding conditions shall be examined for compliance with manufacturer's requirements for guaranteed fire-pump performance. Roughing-in of fire-suppression piping systems shall be examined, verifying actual locations of piping connections before pump installation.

The Controllers shall also be provided with minimum 100 mm high concrete bases. Concrete bases shall extend minimum 75 mm beyond the outside dimensions of the controller.

Alignment.--Fire-pump and driver shafts shall be aligned after complete unit has been leveled on foundation, grout has set, and foundation bolts have been tightened.

After alignment is correct, foundation bolts shall be tightened. The baseplate shall be filled completely with grout, with metal blocks and shims or wedges in place. Foundation bolts shall be tightened after grout has hardened, and alignment shall be checked and corrected. Surfaces that will come into contact with grout shall be cleaned. Forms shall be provided for placement of grout, and air entrapment will not be permitted during placement of grout. Grout shall be cured according to manufacturers written instructions.

After making piping connections, alignment shall be checked and corrected. Alignment of pump and driver shafts shall be adjusted for angular and parallel alignment by one method in (Hydraulic Institute) HI 1.1-1.5, Section 1.4, "Installation, Operation and Maintenance." Alignment tolerances shall conform to manufacturer's written instructions.

Connections.--The general arrangement of piping and specialties shall conform to the details shown on the plans. Connections shall conform to the following requirements:

A. Install piping adjacent to fire and pressure-maintenance pumps to allow service and maintenance.
B. Connect water supply to fire and pressure-maintenance pumps.
C. Connect fire-pump and pressure-maintenance-pump discharge piping to the tunnel standpipe system.
D. Connect relief-valve discharge to point of disposal.
E. Connect flow-measuring-system meters and sensors according to manufacturer's written instructions.
F. Connect fire-pump controllers to the tunnel fire alarm system in conformance with "Fire Alarm and Detection System" of these special provisions.
G. Connect controllers to pumps.
H. Conform to Section 10-4 "Electrical Systems" of these special provisions for electrical wiring and connections and grounding of equipment.
I. Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not available, values specified in UL 486A and UL 486B shall be used.

FIELD QUALITY CONTROL

A factory-authorized service representative shall inspect field-assembled components and equipment installation, including fire-pump and pressure-maintenance-pump units, piping, and

electrical connections, and results shall be submitted to the Engineer. Field quality control shall include the following:

A. Leak test: after installation, charge system and test for leaks. Leaks shall be retested until no leaks exist.
B. Check suction line connections for tightness so no air gets into pumps.
C. Operational test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation. Malfunctioning units shall be replaced with new units, and retested.
D. Test and adjust controls and safeties. Damaged and malfunctioning controls and equipment shall be replaced.
E. Provide fire hoses in number, size, and length required to reach storm drain or other location to dispose of fire-pump test water. Fire hoses are for field-acceptance tests only and shall remain the property of the Contractor.
F. Final checks before startup: Perform the following preventive-maintenance operations and checks:

    1. Lubricate oil-lubrication-type bearings.
    2. Remove grease-lubrication-type bearing covers, flush bearings with kerosene, and clean thoroughly. New lubricant shall be applied in accordance with manufacturer's written instructions.
    3. Disconnect coupling and check electric motor for proper rotation. Rotation shall match direction marked on pump casing.
    4. Verify that pump is free to rotate by hand. If pump is bound or if it drags even slightly, pump shall not be operated until cause of trouble is determined and corrected.

G. Starting procedure for pumps shall be as follows:

    1. Prime pump by opening suction valve and closing drains, and prepare pump for operation.
    2. Open sealing liquid supply valves if pump is so fitted.
    3. Start motor.
    4. Open discharge valve slowly.
    5. Observe leakage from stuffing boxes and adjust sealing liquid valve for proper flow to ensure lubrication of packing. Gland shall only be tightened after packing is run in and change in leakage through stuffing boxes is observed.
    6. Check general mechanical operation of pump and motor.

H. Perform field tests for the fire-pump unit and system piping after installation is complete. Test shall be performed in the presence of the San Mateo County Fire Marshall. Test shall comply with operating instructions and procedures in NFPA 20 to demonstrate acceptance. Malfunctioning equipment shall be repaired or replaced and retested. Test results shall be submitted to the Engineer in writing.

DEMONSTRATION

A factory-authorized service representative shall train the Department's maintenance personnel to adjust, operate, and maintain units as specified below:

A. Train Department's maintenance personnel on procedures and schedules for starting and stopping, troubleshooting, servicing, and maintaining units.
B. Review data in maintenance manuals.
C. Schedule training with Department with at least seven days' advance notice.

PAYMENT

Full compensation for fire pumps shall be considered as included in the contract lump sum price paid for tunnel fire protection and no separate payment will be made therefor.

10-5.__ HANGERS AND SUPPORTS

GENERAL

SUMMARY

Scope.--Hangers and supports shall include furnishing and installing of concrete-embedded and surface-mounted channel shaped struts for mechanical system piping and equipment in conformance with the details shown on the plans, the provisions in Section 75 "Miscellaneous Metal" of the Standard Specifications and these special provisions.

Anchorages shall conform to the provisions for concrete anchorage devices in Section 75-1.03, "Miscellaneous Bridge Metal" of the Standard Specifications and these special provisions.

Performance Requirements.--Channel support systems and heavy-duty steel trapezes for piping shall be designed to support multiple pipes and be capable of supporting combined weight of supported systems, system contents and test water, and shall include seismic restraint hangers and supports designed for the piping and equipment.

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data of manufactured hangers and support systems, miscellaneous materials, thermal shield inserts and hanger support applications. In addition, brochures or other information describing the materials, construction methods and the general characteristics of the manufactured hangers and support systems, miscellaneous materials, thermal shield inserts and hanger support applications shall be included. Copies of welding certificates for welding procedures and operators shall also be included.

Working Drawings.--The Contractor shall submit working drawings including complete details, information and equipment selection criteria for the hangers and supports as shown on the plans and as specified in these special provisions:

Drawings of piping supports and hangers in the tunnel and for the wet fire protection main in the Fire Pump Room shall be signed by an engineer who is registered as a Civil Engineer or Mechanical Engineer in the State of California. In addition, contractor shall provide design calculations and indicate size and characteristics of components and fabrication details for all piping supports and hangers.

QUALITY ASSURANCE

Welding processes and operators shall be qualified according to ASME Boiler and Pressure Vessel Code: Section IX, "Welding and Brazing Qualifications."

The Contractor shall prepare the working drawings and design calculations for each pipe support, trapeze, and seismic restraint not fully detailed on the plans. The working drawings and design calculations shall be signed by an engineer who is registered as a Civil Engineer or Mechanical Engineer in the State of California.

DEFINITIONS

A. MSS: Manufacturers Standardization Society for the Valve and Fittings Industry.
B. Terminology: as defined in MSS SP-90, "Guidelines on Terminology for Pipe Hangers and Supports."

PRODUCTS

Manufactured Hangers and Support Systems.--Manufactured hangers and support systems shall conform to the following:

A. Pipe hangers, supports, and components: MSS SP-58, factory-fabricated components, as follows:

   1. Galvanized, metallic coatings (hot dipped galvanized type): for support systems used in the tunnel except stainless steel.
   2. Nonmetallic coatings: on attachments, for electrolytic protection where attachments are in direct contact with copper tubing.
   3. One shop coat of red chromate primer meeting the requirements of Federal Specification TT-A-336 for support systems in the tunnel equipment chambers and Fire Pump Room.

B. Channel support systems shall consist of factory-fabricated components for field assembly in conformance with the following:

   1. All embedded and surface mounted struts in the tunnel shall be 2.7 mm thickness, type 304 stainless steel. Embedded inserts shall be capable of taking a load of 3000 kg in each meter of length with a minimum safely factor of 3. Embedded struts shall be 41 mm wide and 35 mm deep with concrete anchor tabs spaced a minimum of 100 mm on center.
   2. All nuts, bolts, screws, clamps, brackets and miscellaneous hardware in the tunnel shall be stainless steel.
   3. Unless otherwise shown on the plans surface mounted struts shall be 41 mm wide and 41 mm deep.
   4. Nonmetallic coatings: on attachments for electrolytic protection where attachments are in direct contact with copper tubing.

C. Thermal-hanger shield inserts: insulation shall have 0.7-MPa minimum compressive strength, and shall be encased in sheet metal shield, as follows:

   1. Material for domestic cold water piping: ASTM C 552, Type I cellular glass or water-repellent-treated, ASTM C 533, Type I calcium silicate with vapor barrier.
   2. Material for hot piping: ASTM C 552, Type I cellular glass or water-repellent-treated, ASTM C 533, Type I calcium silicate.
   3. For trapeze or clamped system: insert and shield cover entire circumference of pipe.

4. For clevis or band hanger: insert and shield cover lower 180 degrees of pipe.
5. Insert length: extend 50 mm beyond sheet metal shield for piping operating below ambient air temperature.

Miscellaneous Materials.--Miscellaneous materials shall consist of the following:

A. Powder-actuated drive-pin fasteners: powder-actuated-type, drive-pin attachments with pull-out and shear capacities appropriate for supported loads and building materials where used. Powder actuated drive-pin fasteners are prohibited in tunnel.
B. Concrete and masonry anchor bolts and studs: insert-type attachments with pull-out and shear capacities appropriate for supported loads and building materials where used, as follows:

   1. Dry locations: steel-expansion wedge type.
   2. Tunnel anchor bolts: anchor bolts in the tunnel shall be stainless steel mechanical anchor type or epoxy anchor bolts. Both types shall be rated for dynamic loading.
   3. Mechanical anchor bolts: mechanical anchor bolts shall be stainless steel hex head finished bolt with a longitudinally tapered threaded end and a spring loaded multi-part conforming threaded zinc expander nut. Anchor shall meet Federal Specification FF-S-325, Group II, Type 2 Class 2, Style 1, be heat treated to SAE Grade 5 and zinc plated in accordance with ASTM B633-78, Type III, Class Fe/Zn 5, SC-I.
   4. Epoxy anchor bolts: epoxy anchor bolts shall be stainless steel all-thread, encapsulated epoxy type with embedment length and drilled hole diameter per the manufacturer's recommendations. Polyester and vinyl resin will not be permitted.

C. Structural steel: ASTM A 36/A 36M, steel plates, shapes, and bars, hot dip and galvanized after fabrication.
D. Grout: ASTM C 1107, Grade B, factory-mixed and pre-packaged, nonshrink and nonmetallic, dry, hydraulic-cement grout, as follows:

   1. Characteristics: post hardening and volume adjusting; with manufacturer recommendations for both interior and exterior applications.
   2. Properties: nonstaining, noncorrosive, and nongaseous.
   3. Design mix: 34 MPa, 28-day compressive strength.

Hanger and Support Applications.--Hangers shall be furnished and installed in conformance to the following requirements:

A. Equipment selections and applications shall be in conformance with Manufacturers Standardization Society (MSS) SP-69 for pipe hanger selections and applications that are not specified in piping system special provisions or shown on the plans.
B. Equipment selections and applications for horizontal-piping hangers and supports: Install the following types of hangers and supports unless otherwise indicated and except as specified in piping system special provisions or shown on the plans:

   1. Adjustable steel clevis hangers (MSS Type 1): for suspension of noninsulated or insulated stationary pipes, 15 to 300 mm nominal size. For suspension of stainless steel pipe, provide non-metallic sleeve to prevent direct contact between stainless pipe and galvanized hanger.

2. Carbon- or alloy-steel, double-bolt pipe clamps (MSS Type 3): for suspension of pipes, 20 to 300 mm nominal size, requiring clamp flexibility.
3. Pipe hangers (MSS Type 5): for suspension of pipes, 15 to 100 mm nominal size, to allow off-center closure for hanger installation before pipe erection.
4. Adjustable swivel split- or solid-ring hangers (MSS Type 6): for suspension of noninsulated stationary pipes, 20 to 200 mm nominal size.
5. Split pipe-ring with or without turnbuckle-adjustment hangers (MSS Type 11): for suspension of noninsulated stationary pipes, 10 to 200 mm nominal size.
6. U-bolts (MSS Type 24): for support of heavy pipe, 15 to 300 mm nominal size.
7. Clips (MSS Type 26): for support of insulated pipes not subject to expansion or contraction.
8. Pipe stanchion saddles (MSS Type 37): for support of pipes, 100 to 300 mm nominal size, with steel pipe base stanchion support and cast-iron floor flange and with U-bolt to retain pipe.
9. Adjustable pipe saddle supports (MSS Type 38): for stanchion-type support for pipes, 65 to 300 mm nominal size, if vertical adjustment is required, with steel pipe base stanchion support and cast-iron floor flange.
10. Single pipe rolls (MSS Type 41): for suspension of pipes, 25 to 300 mm nominal size, from two rods if longitudinal movement caused by expansion and contraction might occur.
11. Adjustable Roller Hangers (MSS Type 43): for suspension of pipes, 65 to 300 mm nominal size, from single rod if horizontal movement caused by expansion and contraction might occur.
12. Complete pipe rolls (MSS Type 44): for support of pipes, 50 to 300 mm nominal size, if longitudinal movement caused by expansion and contraction might occur but vertical adjustment is not necessary.
13. Pipe roll and plate units (MSS Type 45): for support of pipes, 50 to 300 mm nominal size, if small horizontal movement caused by expansion and contraction might occur and vertical adjustment is not necessary.
14. Adjustable pipe roll and base units (MSS Type 46): for support of pipes, 50 to 300 mm nominal size, if vertical and lateral adjustment during installation might be required in addition to expansion and contraction.

C. Vertical-piping clamps shall be installed with the following types:

1. Extension pipe or riser clamps (MSS Type 8): for support of pipe risers, 20 to 300 mm nominal size.
2. Carbon- or alloy-steel riser clamps (MSS Type 42): for support of pipe risers, NPS 20 to 300 mm nominal size, if longer ends are required for riser clamps.

D. Hanger-Rod attachments shall be installed with the following types:

1. Steel turnbuckles (MSS Type 13): for adjustment up to 150 mm for heavy loads.
2. Steel clevises (MSS Type 14): for 50°C to 230°C piping installations.
3. Swivel turnbuckles (MSS Type 15): for use with MSS Type 11, split pipe rings.
4. Malleable-iron sockets (MSS Type 16): for attaching hanger rods to various types of building attachments.
5. Steel weldless eye nuts (MSS Type 17): for 50°C to 230°C piping installations.

E. Building attachments shall be installed with the following types:

1. Side-beam or channel clamps (MSS Type 20): for attaching to bottom flange of beams, channels, or angles.
2. Center-beam clamps (MSS Type 21): for attaching to center of bottom flange of beams.
3. Welded beam attachments (MSS Type 22): for attaching to bottom of beams if loads are considerable and rod sizes are large.
4. Side-beam clamps (MSS Type 27): for bottom of steel I-beams.
5. Steel-beam clamps with eye nuts (MSS Type 28): for attaching to bottom of steel I-beams for heavy loads.
6. Linked-steel clamps with eye nuts (MSS Type 29): for attaching to bottom of steel I-beams for heavy loads, with link extensions.
7. Malleable beam clamps with extension pieces (MSS Type 30): for attaching to structural steel.
8. Welded-steel brackets: for support of pipes from below or for suspending from above by using clip and rod. Use one of the following for indicated loads unless specific sizes are shown on the plans.
9. Light (MSS Type 31): 340 kg.
10. Medium (MSS Type 32): 675 kg.
11. Heavy (MSS Type 33): 1350 kg.
12. Plate lugs (MSS Type 57): for attaching to steel beams if flexibility at beam is required.

F. Saddles and shields shall be installed with the following types:

1. Steel pipe-covering protection saddles (MSS Type 39): to fill interior voids with insulation that matches adjoining insulation.
2. Protection shields (MSS Type 40): of length recommended by manufacturer to prevent crushing insulation.
3. Thermal-hanger shield inserts: for supporting insulated pipe, 360-degree insert of high-density, 690 kPa minimum compressive strength, water-repellent-treated calcium silicate or cellular-glass pipe insulation, same thickness as adjoining insulation with vapor barrier and encased in 360-degree sheet metal shield.

INSTALLATION

Hanger and Support Installation.--Pipe hanger and support installation shall conform to the following:

A. Install hangers and supports in conformance with MSS SP-69 and MSS SP-89. Hangers, supports, clamps, and attachments shall be installed to support piping from building structure or the tunnel structure.
B. Install building attachments to structural steel. Unless otherwise shown on the plans, building attachments shall be spaced within maximum piping span length indicated in MSS SP-69. Additional supports shall be installed at concentrated loads, including valves, flanges, guides, strainers, and expansion joints, and at changes in direction of piping. Concrete inserts shall be installed before concrete is placed and fasten inserts to forms.

C. Install powder-actuated drive-pin fasteners after concrete is placed and completely cured. Inserts shall be installed by operators that are licensed by powder-actuated tool manufacturer. Fasteners shall be installed according to powder-actuated tool manufacturer's operating manual.
D. Install expansion anchors in concrete after concrete is placed and completely cured. Fasteners shall be installed in accordance with to manufacturer's written instructions.
E. Install hangers and supports complete with necessary inserts, bolts, rods, nuts, washers, and other accessories.
F. Install hangers and supports to allow controlled thermal and seismic movement of piping systems, to permit freedom of movement between pipe anchors, and to facilitate action of flexible couplings, expansion loops, expansion bends, and similar units.
G. Load distribution: install hangers and supports so that piping live and dead loads and stresses from movement will not be transmitted to connected equipment.
H. Pipe slopes: install hangers and supports to provide pipe slopes as shown on the plans, and in conformance with ASME B31.9, "Building Services Piping," for maximum pipe deflections.

Equipment Supports.--Structural steel stands shall be fabricated to suspend equipment from structure above or to support equipment above floor. Grout shall be placed under supports for equipment to provide a uniform bearing surface.

Metal Fabrication.--Miscellaneous metal fabrications shall be cut, drilled and fit for heavy-duty steel trapezes and equipment supports, fitting exposed connections together to form hairline joints.

Fabrication shall conform to AWS D1.1 procedures for shielded metal arc welding, appearance and quality of welds, and methods used in correcting welding work, and the following:

A. Use materials and methods that minimize distortion and develop strength and corrosion resistance of base metals.
B. Obtain fusion without undercut or overlap.
C. Remove welding flux immediately.
D. Finish welds at exposed connections so no roughness shows after finishing and contours of welded surfaces match adjacent contours.
E. Hot dip galvanize after fabrication.

Adjusting.--Hangers shall be adjusted to distribute loads equally on attachments and to achieve indicated slope of pipe.

PAINTING

Painting shall conform to the provisions in Section 59 "Painting" of the Standard Specifications and these special provisions, and the following:

A. Touching up: clean and abraded areas of shop paint. Paint exposed areas immediately after erecting hangers and supports. Use same materials as used for shop painting. Comply with SSPC-PA 1 requirements for touching up field-painted surfaces.
B. Apply paint by brush or spray to provide a minimum dry film thickness of 0.05-mm.
C. Galvanized surfaces: Clean welds, bolted connections, and abraded areas and apply galvanizing-repair paint to comply with ASTM A 780.

PAYMENT

Full compensation for hangers and supports shall be considered as included in the contract lump sum prices paid for various items of work involved and no additional compensation will be allowed therefor.

10-5.__ MECHANICAL VIBRATION CONTROLS AND SEISMIC RESTRAINTS

GENERAL

SUMMARY

Scope.--Mechanical vibration controls and seismic restraints shall include furnishing, installing, and testing of vibration isolators, vibration isolation bases, and seismic restraints and snubbers. All equipment and installation shall conform to the provisions in Section 75 "Miscellaneous Metal" of the Standard Specifications and these special provisions.

Performance Requirements.--Seismic bracing shall be provided in conformance with the requirements in the California Building Code. The following criteria shall apply:

A. Component Seismic Coefficient (Table 16 Q): 0.48
B. Seismic Importance Factor (I_p, Table 16 K): 1.00
C. In-Structure Component Amplification Factor (a_p, Table 16-O): 1.00

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data of isolator pads, spring isolators, restrained spring isolators, rubber hangers, spring hangers, resilient isolation washers and bushings and restraining cables. In addition, brochures or other information describing the materials, construction methods and the general characteristics of the isolator pads, spring isolators, restrained spring isolators, rubber hangers, spring hangers, resilient isolation washers and bushings and restraining cables shall be included. Manufacturers' technical data shall indicate types, styles, materials, and finishes for each type of isolator specified, including load deflection curves.

Working Drawings.--The Contractor shall submit working drawings including complete details, information and equipment selection criteria for the mechanical vibration controls and seismic restraints as shown on the plans and as specified in these special provisions. Working drawings shall be signed by an engineer who is registered as a Civil Engineer or Mechanical Engineer in the State of California, and shall include the following:

A. Design calculations for selection of vibration isolators, design of vibration isolation bases, and selection of seismic restraints. Calculation details shall include combining shear and tensile loads.
B. Vibration isolation base details including anchorages and attachments to the structure and to the supported equipment. Details shall include auxiliary motor slides and rails, and base weights.
C. Seismic restraint details including fabrication and attachment of restraints and snubbers.

QUALITY ASSURANCE

Seismic restraint devices shall have horizontal and vertical load testing and analysis performed in conformance with the requirements of OSHPD (Office of Statewide Health Planning & Development for the State of California) and shall bear anchorage pre-approval "R" number, from OSHPD showing maximum seismic restraint ratings. Ratings shall be based on independent testing. Testing and calculations shall include both shear and tensile loads and at least one test or analysis at 45 degrees to the weakest mode.

Ductwork, piping and equipment shall be seismically restrained to resist lateral forces acting in any direction in conformance with the requirements in Section 1632 of the 2001 California Building Code. An engineer who is registered as a Civil Engineer or Mechanical Engineer in the State of California shall prepare seismic calculations for equipment restraints to determine the restraint loading results from seismic forces. A certificate signed by the Registered Engineer shall be submitted stating that the seismic calculations for equipment have been completed in conformance with the requirements of the California Building Code.

PRODUCTS

Vibration Isolators-Isolator Pads.--Isolator pads shall be oil and water resistant and factory cut to sizes that match requirements of the equipment supported, and shall conform to the following:

A. Rubber isolator pads: elastomer (neoprene or silicone) arranged in single or multiple layers and molded with a nonslip pattern and steel baseplates of sufficient stiffness to provide uniform loading over the pad area.
B. Fiberglass or cork isolator pads: molded cork or glass fiber not less than 25 mm thick and precompressed through 10 compression cycles at 3 times the rated load.
C. Load range: from 69 to 345 kPa and a deflection not less than 2 mm per 25 mm of thickness. Load on isolator pad shall not exceed a loading of 345 kPa.
D. Rubber isolator mounts: double-deflection type, with molded, oil-resistant rubber or neoprene isolator elements, with encapsulated top and baseplates. Rubber isolator mounts shall be factory-drilled and tapped top plate for bolted equipment mounting and include factory-drilled baseplate for bolted connection to structure. Rubber isolator mounts shall be color-coded to indicate capacity range.

Vibration Isolators-Spring Isolators.--Spring isolators shall be freestanding, laterally stable, open-spring-type isolators, in conformance with the following:

A. Outside spring diameter: not less than 80 percent of the compressed height of the spring at rated load.
B. Minimum additional travel: 50 percent of the required deflection at rated load.
C. Lateral stiffness: more than 1.2 times the rated vertical stiffness.
D. Overload capacity: support 200 percent of rated load, fully compressed, without deformation or failure.
E. Baseplates: factory drilled for bolting to structure and bonded to a 6 mm thick, rubber isolator pad attached to the baseplate underside. Baseplates shall be sized to limit floor loading to 690 kPa.
F. Top plates: provide threaded studs for fastening and leveling equipment.
G. Finishes: Manufacturer's standard corrosive-resistant finish.

Vibration Isolators-Restrained Spring Isolators.--Restrained spring isolators shall be vertically restrained, freestanding, laterally stable, steel open-spring-type isolators, in conformance with the following:

A. Housing: welded steel with resilient vertical limit stops to prevent spring extension due to wind loads or when weight is removed. Housing shall have factory-drilled baseplate for bolting to structure and shall be bonded to a 6 mm thick, rubber isolator pad attached to the underside of the baseplate. Housing shall include adjustable equipment mounting and leveling bolt.
B. Outside spring diameter: not less than 80 percent of the compressed height of the spring at rated load.
C. Minimum additional travel: 50 percent of the required deflection at rated load.
D. Lateral stiffness: more than 0.8 times the rated vertical stiffness.
E. Overload capacity: support 200 percent of rated load, fully compressed, without deformation or failure.
F. Finishes: baked enamel for metal components on isolators for interior use. Hot-dip galvanized for metal components on isolators for exterior use.

Vibration Isolators-Rubber Hangers.--Rubber hangers shall be double-deflection type, with molded, oil-resistant rubber or neoprene isolator elements bonded to formed-steel housings with threaded connections for hanger rods, and color-coded to indicate capacity range.

Vibration Isolators-Spring Hangers.--Spring hangers shall be combination spring and elastomeric hangers with coil springs and elastomeric inserts in compression, in conformance with the following:

A. Frame: formed steel, fabricated for connection to threaded rods and to allow for 30 degrees of angular hanger rod misalignment without binding or reducing isolation efficiency.
B. Outside spring diameter: not less than 80 percent of the compressed height of the spring at rated load.
C. Minimum additional travel: 50 percent of the required deflection at rated load.
D. Elastomeric element: molded, oil-resistant rubber or neoprene.
E. Finishes: baked enamel for metal components. Finishes shall be color-coded to indicate capacity range.

Seismic Restraint Devices-Resilient Isolation Washers and Bushings.--Resilient isolation washers and bushings shall be factory fabricated using welded structural-steel shapes and plates, anchor bolts, and replaceable resilient isolation washers and bushings, in conformance with the following:

A. Anchor bolts for attaching to concrete shall be seismic-rated, drill-in, and stud-wedge or female-wedge type.
B. Resilient isolation washers and bushings: 1-piece, molded, bridge-bearing neoprene complying with AASHTO M 251 and having a durometer of 60, plus or minus 5.

Seismic Restraint Devices-Restraining Cables.--Restraining cables shall be galvanized steel aircraft cables with end connections made of steel assemblies that swivel to final installation angle and utilize two clamping bolts for cable engagement.

Anchors shall be seismic-rated, drill-in, and stud-wedge or female-wedge type with strength required for anchor and as tested according to ASTM E 488/E 488M.

INSTALLATION

The Contractor shall install and anchor vibration-, sound-, and seismic-control products according to manufacturer's written instructions.

Mounts, isolators, hangers, and snubbers shall be anchored to vibration isolation bases. Isolator baseplates shall be bolted to structural floors.

Pipe connectors shall be installed at connections for equipment supported on vibration isolators. Seismic snubbers shall be installed on isolated equipment and bolted to equipment base and supporting structure. Seismic snubbers shall be installed at locations that minimize the distance between the snubbers and installed vibration isolators.

Restraining cables shall be installed at each trapeze and individual pipe hanger. At trapeze anchor locations, piping shall be shackled to trapeze. Cables shall be installed so they do not bend across sharp edges of adjacent equipment or building structure.

Steel angles or channels, sized to prevent buckling, shall be clamped with ductile-iron clamps to hanger rods for trapeze, individual pipe hangers and hanging equipment. At trapeze anchor locations, piping and hanging equipment shall be shackled to trapeze. Angles shall not be welded to rods.

Resilient bolt isolation washers shall be installed on equipment anchor bolts.

Adjusting and Cleaning.--The Contractor shall adjust and clean anchor vibration-, sound-, and seismic-control products according to manufacturer's written instructions and requirements specified in the following:

A. Limit stops on restrained spring isolators shall be adjusted to mount equipment at normal operating height. After equipment installation is complete, limit stops shall be adjusted so they are out of contact during normal operations. Thrust restraints shall be adjusted for a maximum of 6 mm of movement at start and stop.
B. Active height of spring isolators and snubbers shall be adjusted according to manufacturer's written recommendations. Seismic restraints shall be adjusted to permit free movement of equipment within normal mode of operation.
C. Anchor bolts shall be tightened according to equipment manufacturer's written recommendations to resist seismic forces.

PAYMENT

Full compensation for mechanical vibration controls and seismic restraints shall be considered as included in the contract lump sum prices paid for various items of work involved and no additional compensation will be allowed therefor.

10-5.__ MECHANICAL IDENTIFICATION

GENERAL

SUMMARY

Mechanical identification, consisting of materials, devices and requirements for identification of mechanical systems and equipment, shall conform to these special provisions.

Mechanical identification requirements unique to particular systems and equipment shall be included in the sections that specify those systems and equipment such as "Leach Water Pumping Station Piping and Appurtenances."

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data of identifying devices and labels, valve tags and equipment signs and markers. In addition, brochures or other information describing the materials, construction methods and the general characteristics of the identifying devices and labels, valve tags and equipment signs and markers shall be included. Samples of color, lettering style, and graphic representation required for each identification material and device shall also be included.

Working Drawings.--The Contractor shall submit working drawings that include compete details, information and equipment selection criteria for the mechanical identification equipment as shown on the plans and as specified in these special provisions:

A. Valve schedules: for each piping system. Reproduce on standard-size bond paper. Tabulate valve number, piping system, system abbreviation as shown on tag, room or space location of valve, and variations for identification. Mark valves intended for emergency shutoff and similar special uses. Besides mounted copies, furnish copies for maintenance manuals specified in these special provisions.

QUALITY ASSURANCE

Identification shall conform to the requirements in ASME A13.1, "Scheme for the Identification of Piping Systems" for lettering size, length of color field, colors, and viewing angles of identification devices.

SEQUENCING AND SCHEDULING

Installation of identifying devices shall be coordinated with completion of covering and painting of surfaces where devices are to be applied. Identifying devices shall be installed before installing acoustical ceilings and similar concealment.

PRODUCTS

Identifying devices and labels.--Identifying devices and labels shall conform to the following:

A. If more than single type is specified for listed applications, selection is installer's option.
B. Equipment Nameplates: Metal permanently fastened to equipment with data engraved or stamped as follows:

    1. Data: manufacturer, product name, model number, serial number, capacity, operating and power characteristics, labels of tested compliances, and essential data.
    2. Location: accessible and visible.
    3. Stencils: standard stencils, prepared with letter sizes conforming to recommendations of ASME A13.1. Minimum letter height is 30 mm for ducts, and 20 mm for access door signs and similar operational instructions.
    4. Material: fiberboard or brass.

5. Stencil paint: exterior, oil-based, alkyd gloss black enamel, unless otherwise indicated. Paint may be in pressurized spray-can form.
6. Identification paint: exterior, oil-based, alkyd enamel in colors according to ASME A13.1, unless otherwise indicated.

C. Snap-on plastic pipe markers: manufacturer's standard preprinted, semirigid, snap-on type. Include color-coding according to ASME A13.1, unless otherwise indicated.
D. Pressure-sensitive pipe markers: manufacturer's standard preprinted, color-coded, pressure-sensitive, vinyl type with permanent adhesive.
E. Pipes with OD, including insulation, less than 150 mm: full-band pipe markers, extending 360 degrees around pipe at each location.
F. Pipes with OD, including insulation, 150 mm and larger: either full-band or strip-type pipe markers, at least 3 times letter height and of length required for label.
G. Lettering: use piping system terms indicated and abbreviate only as necessary for each application length.
H. Arrows: either integrally with piping system service lettering, to accommodate both directions, or as separate unit, on each pipe marker to indicate direction of flow.
I. Plastic duct markers: manufacturer's standard laminated plastic, in the following color codes:

1. Green: cold-air supply.
2. Yellow: hot-air supply.
3. Blue: exhaust, outside, return, and mixed air.
4. Hazardous material exhausts: use colors and designs recommended by ASME A13.1.
5. Terminology: include direction of airflow; duct service such as supply, return, and exhaust; duct origin, duct destination, and design flow.

J. Plastic tape: manufacturer's standard color-coded, pressure-sensitive, self-adhesive, vinyl tape, at least 0.08-mm thick:

1. Width: 40 mm on pipes with OD, including insulation, less than 150 mm; 65 mm for larger pipes.
2. Color: comply with ASME A13.1, unless otherwise indicated.

K. Valve tags: stamped or engraved with 6-mm letters for piping system abbreviation and 13-mm sequenced numbers. Include 4-mm hole for fastener. Material shall be 1.0 mm thick, stainless steel. Size: 40 mm diameter, except 50 mm square for fire protection system.
L. Valve tag fasteners: brass, wire-link or beaded chain; or brass S-hooks.
M. Valve schedule frames: glazed display frame for removable mounting on masonry walls for each page of valve schedule, including screws, and as follows:

1. Frame: finished hardwood.
2. Frame: extruded aluminum.
3. Glazing: ASTM C 1036, Type I, Class 1, Glazing quality B, 2.5-mm, single-thickness glass.

N. Engraved plastic-laminate signs: ASTM D 709, Type I, cellulose, paper-base, phenolic-resin-laminate engraving stock; Grade ES-2, black surface, black phenolic core, with white melamine subcore, unless otherwise indicated, and the following:

1. Provide holes for mechanical fastening.
2. Engraving: engraver's standard letter style, of sizes and with terms to match equipment identification.
3. Thickness: 2 mm, for units up to 130 sq. cm or 200 mm in length, and 3 mm for larger units.
4. Fasteners: self-tapping, stainless-steel screws or contact-type, permanent adhesive.

O. Plastic equipment markers: manufacturer's standard laminated plastic, in the following color codes:

1. Green: cooling equipment and components.
2. Yellow: heating equipment and components.
3. Brown: energy reclamation equipment and components.
4. Blue: equipment and components that do not meet criteria above.
5. Hazardous equipment: use colors and designs recommended by ASME A13.1.
6. Terminology: match schedules as closely as possible. Include the following: Caltrans identification number, name and plan number, equipment service, design capacity, and other design parameters such as pressure drop, entering and leaving conditions, and speed.
7. Size: 65 by 100 mm for control devices, dampers, and valves; 115 by 150 mm for equipment.

P. Plasticized tags: preprinted or partially preprinted, accident-prevention tags, of plasticized card stock with mat finish suitable for writing, as follows:

1. Size: 85 by 145 mm.
2. Fasteners: brass grommets and wire.
3. Nomenclature: large-size primary caption such as DANGER, CAUTION, or DO NOT OPERATE.

Q. Lettering and graphics: coordinate names, abbreviations, and other designations used in mechanical identification with corresponding designations indicated. Use numbers, letters, and terms indicated for proper identification, operation, and maintenance of mechanical systems and equipment.

R. Multiple systems: identify individual system number and service if multiple systems of same name are indicated.

Labeling and identifying piping systems.--Labeling and identifying piping systems shall conform to the following:

A. Install pipe markers on each system. Include arrows showing normal direction of flow.
B. Marker type: stenciled markers with painted, color-coded bands or rectangles.
C. Marker type: stenciled markers complying with ASME A13.1.
D. Marker type: plastic markers, with application systems. Install on pipe insulation segment where required for hot, noninsulated pipes.

E. Fasten markers on pipes and insulated pipes smaller than 150 mm OD by one of following methods:

1. Snap-on application of pretensioned, semirigid plastic pipe marker.
2. Adhesive lap joint in pipe marker overlap.
3. Laminated or bonded application of pipe marker to pipe or insulation.
4. Taped to pipe or insulation with color-coded plastic adhesive tape, not less than 20 mm wide, lapped a minimum of 40 mm at both ends of pipe marker, and covering full circumference of pipe.

F. Fasten markers on pipes and insulated pipes 150 mm in diameter and larger by one of following methods:

1. Laminated or bonded application of pipe marker to pipe or insulation.
2. Taped to pipe or insulation with color-coded plastic adhesive tape, not less than 40 mm wide, lapped a minimum of 75 mm at both ends of pipe marker, and covering full circumference of pipe.
3. Strapped to pipe or insulation with manufacturer's standard stainless-steel bands.

G. Locate pipe markers and color bands where piping is exposed in finished spaces; machine rooms; accessible maintenance spaces such as shafts, tunnels, and plenums; and exterior non-concealed locations according to the following:

1. Near each valve and control device.
2. Near each branch connection, excluding short takeoffs for fixtures and terminal units. Mark each pipe at branch, where flow pattern is not obvious.
3. Near penetrations through walls, floors, ceilings, or non-accessible enclosures.
4. At access doors, manholes, and similar access points that permit view of concealed piping.
5. Near major equipment items and other points of origination and termination.
6. Spaced at a maximum of 15 m intervals along each run. Reduce intervals to 7.5 m in areas of congested piping and equipment.

Valve tags.--Valve tags shall conform to the following:

A. Install on valves and control devices in piping systems, except check valves, valves within factory-fabricated equipment units, plumbing fixture supply stops, shutoff valves, faucets, convenience and lawn-watering hose connections, and HVAC terminal devices and similar roughing-in connections of end-use fixtures and units. List tagged valves in valve schedule.
B. Tag valves with captions similar to those indicated.
C. Tag color: according to the following:

1. Cold water: blue.
2. Fire protection: red.

D. Letter color: according to the following:

1. Cold water: white.

2. Fire protection: black.

E. Install mounted valve schedule in each major equipment room.

Equipment Signs and Markers.--Engraved plastic-laminate signs or equipment markers shall be installed on or near each major item of mechanical equipment, and as follows:

A. Include signs for the following general categories of equipment:

1. Main control and operating valves, including safety devices and hazardous units such as gas outlets.
2. Fire department hose valves and hose stations.
3. Meters, gages, thermometers, and similar units.
4. Pumps, compressors, chillers, condensers, and similar motor-driven units.
5. Fans, blowers, primary balancing dampers, and mixing boxes.
6. Packaged HVAC central-station and zone-type units.
7. Strainers, filters, humidifiers, water-treatment systems, and similar equipment.

B. Optional Sign Types: Stenciled signs may be provided instead of engraved plastic, at Installer's option, where lettering larger than 25 mm high is needed for proper identification because of distance from normal location of required identification, as follows:

1. Lettering size: minimum 6 mm for name of units if viewing distance is less than 600 mm, 13 mm for viewing distances up to 1800 mm, and proportionately larger lettering for greater viewing distances. Include secondary lettering two-thirds to three-fourths the size of principal lettering.
2. Terms on signs: distinguish between multiple units, indicate operational requirements, indicate safety and emergency precautions, warn of hazards and improper operations, and identify units.

C. Plasticized tags: install within concealed space, to reduce amount of text in exposed sign outside concealment, if equipment to be identified is concealed above acoustical ceiling or similar concealment. Identify operational valves and similar minor equipment items located in unoccupied spaces, including machine rooms, by installing plasticized tags.

D. Duct systems: identify air supply, return, exhaust, intake, and relief ducts with duct markers; or provide stenciled signs and arrows showing service and direction of flow. Locate signs near points where ducts enter into concealed spaces and at maximum intervals of 15 m in each space where ducts are exposed or concealed by removable ceiling system.

ADJUSTING AND CLEANING

The Contractor shall relocate mechanical identification materials and devices that have become visually blocked by subsequent work, and shall clean faces of identification devices and glass frames of valve charts.

MEASUREMENT AND PAYMENT

Full compensation for mechanical identification will be considered as included in the contract prices paid for the various items of work involved and no additional compensation will be allowed therefor.

10-5.__ WATER MAINS

GENERAL

SUMMARY

Scope.--Water mains shall include the following:

A. Site water distribution including the underground ductile iron water main from the north end of the tunnel to the OMC Building site.
B. All underground branch domestic water piping at the OMC site. This work shall include installation of the fire hydrant, the backflow preventer assembly for the vegetative roof irrigation system and installation of the 75 mm water meter furnished by the State.
C. The 200 mm branch feed to the fire pump room. This work shall include the associated vaults and valves, the fire hydrant and hydrant feed at the north portal, the backflow preventer in the fire pump room and installation of the 250 mm water meter furnished by the State.
D. The fire hydrant and hydrant feed at the south portal.

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data of piping and piping specialties, valves and accessories, protective enclosures, backflow preventers and fire hydrants. In addition, brochures or other information describing the materials, construction methods, and the general characteristics of the piping and equipment shall be included.

Working Drawings.--The Contractor shall submit working drawings in conformance with Section 5-1.02 “Plans and Working Drawings” of the Standard Specifications and these special provisions.

Working drawings shall include complete details, information, drawings and substantiating calculations for the proposed materials, facilities, equipment and method of construction. The working drawings shall include the following:

A. Precast and cast in place concrete vaults, including frames and covers, ladders, and drains.
B. Wiring diagrams for equipment with electrical connections.
C. Details of valves and piping in vaults.
D. Plan and elevation views of water meter assemblies drawn to a minimum 1:25 scale.
E. Locations and details of all thrust blocks.
F. Details of fire hydrant piping.
G. Operation and maintenance data for the following:
    1. Valves.
    2. Backflow preventer assemblies.
    3. Fire Hydarnts.

Field Quality Control Test Reports.--The contractor shall submit field quality control test reports as specified in these special provisions.

CODES AND STANDARDS

The site water distribution shall conform to the following:

A. Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to San Mateo County Fire Department, and marked for intended use.
B. FM's "Approval Guide" or UL's "Fire Protection Equipment Directory" for the fire hydrant products.
C. NFPA 24 for materials, installations, tests, flushing, and valve supervision for fire-service-main piping for fire suppression.
D. NSF compliance: comply with NSF 61 for materials for water-service piping and specialties for domestic water.
E. The October 2004 edition of the North Coast County Water District (NCCWD) Standard Specification and Construction Details for potable-water-service piping, including materials, installation, testing, and disinfection.
G. Standards of the San Mateo County Fire Department for the fire hydrant hose threads, installation, and testing.
H. All equipment shall bear label, stamp, or other markings of specified testing agency.

DELIVERY, STORAGE, AND HANDLING

Delivery, storage, and handling shall conform to the following:

A. Store valves indoors in dry location and internally protected against rust and corrosion. Support valves off the ground or on pavement in watertight enclosures when outdoor storage is necessary.

B. Protect valves against damage to threaded ends and flanged faces.
C. Set valves in position for handling without imposing loads on the handles and operators
D Use sling to handle valves and fire hydrants if size requires handling by crane or lift. Rig valves to avoid damage to exposed parts. Do not use handwheels or stems as lifting or rigging points.
E. Deliver piping with factory-applied end caps. Maintain end caps through shipping, storage, and handling to prevent pipe-end damage and to prevent entrance of dirt, debris, and moisture.
F. Protect stored piping from moisture and dirt. Elevate above grade.
G. Protect flanges, fittings, and specialties from moisture and dirt.
H. Store pre-cast concrete vaults at project site as recommended by manufacturer to prevent physical damage. Arrange so identification markings are visible. Lift and support pre-cast concrete units only at designated lifting or supporting points.

DEFINITIONS

Fire-service main: Exterior buried or above grade fire-suppression-water piping in tunnel.
Fire-suppression-water piping: Interior fire-suppression-water piping in fire pump room.

Water service main: Exterior buried domestic-water piping.
PA: Polyamide (nylon) plastic.
PE: Polyethylene plastic.
PEX: Crosslinked polyethylene plastic.
PP: Polypropylene plastic.
PVC: Polyvinyl chloride plastic.
RTRF: Reinforced thermosetting resin (fiberglass) fittings.
RTRP: Reinforced thermosetting resin (fiberglass) pipe.

PRODUCTS

Ductile Iron Pipe (Buried Service).--Ductile iron pipe shall be centrifugally cast in 5.5 m or 6.1 m nominal lengths conforming to AWWA C151, shall be seal coated and shall have a double thickness cement mortar lining conforming to AWWA C104. Pipe shall be special thickness Class 52. Pipe shall be provided with mechanical joint or push on joint ends. Only one of the above two systems shall be used for the piping. Mix and matching of systems shall not be allowed except for specific cases after approval by the Engineer. All joint ends whether mechanical or push on shall be capable of using a suitable restraint system supplied the pipe manufacturer, to be used where indicated on the plans.

Pipe Coating System.--The exterior surfaces or the pipe shall have the following coating systems per AWWA C210:

A. Surface preparation shall be Solvent Clean (SSPC-SP-1) followed by abrasive blast-cleaning to Near White Metal (SSPC-SP-10) with an anchor profile between 0.075 and 0.100-mm.
B. Two (2) uniform coats of coal tar epoxy conforming to AWWA C210 shall be applied to a total dry film thickness of 0.50 to 0.75-mm.
C. The drying time between coats shall be 12 hours minimum and 24 hours maximum at 21°C. Intercoat drying time is critical and shall be according to manufacturer's recommendations.

Polyethylene wrap over the standard ashphltic factory coating applied in accordance with AWWA C 105 shall be considered as an alternate to the above described coating for the pipe and fittings.

Fittings and Joints (For Buried Service).--Fittings for Mechanical joint ductile iron pipe shall be ductile iron of Class 250 gray iron conforming to AWWA C110 and C111; fittings shall be seal coated and shall be double thickness cement mortar lined conforming to AWWA C104.

Where shown on the plans and in other locations where there is a change in the direction of the pipe and the soil is unsuitable for thrust blocks, joint restraint shall be incorporated in the design of the follower gland and shall include a restraining mechanism which when activated imparts a multiple wedging action against the pipe increasing its resistance as the pressure increases. Restrained device shall meet requirements of ANSI/AWWA C111/A21.10. Glands shall be of ductile iron conforming to ASTM A536.80 and shall be seal coated equal to that on the connecting pipe. The mechanical joint restraint device shall have a minimum working pressure of 1700 kPa.

Restrained push-on joints for pipe and fittings shall consist of stainless steel locking segments, integrally molded into the rubber gasket. Restrained push-on joints shall be capable of being deflected after assembly.

As an alternate to the joint restraint device described above, pipe and fitting joints shall consist of ductile iron locking segments inserted through slots in the bell face and shall provide a positive axial lock between the bell interior surface and a retainer weldment on the spigot end of the pipe.

Flanged joints conforming to AWWA C115 shall be allowed for use in vaults. Restrained and flanged joint fittings shall be compatible with the restrained and flanged joint pipe system specified and used.

Piping Specialties.--Piping specialties shall conform to the following:

A. Dielectric fittings: combination of copper alloy and ferrous; threaded, solder, or plain end types; and matching piping system materials.
B. Dielectric flanges: factory-fabricated companion-flange assembly, for 1035 or 2070 kPa minimum working pressure to suit system pressures.
C. Dielectric-flange insulation kits: field-assembled companion-flange assembly, full-face or ring type. Components include neoprene or phenolic gasket, phenolic or polyethylene bolt sleeves, phenolic washers, and steel backing washers.
D. Provide separate companion flanges and steel bolts and nuts for 1035 or 2070 kPa minimum working pressure to suit system pressures.

Gate Valves.--AWWA, cast iron gate valves shall conform to the following:

A. Nonrising-stem, high-pressure, resilient-seated gate valves: AWWA C509, ductile-iron body and bonnet; with bronze or ductile-iron gate, resilient seats, bronze stem, and stem nut.
B. Minimum working pressure: 1725 kPa.
C. End connections: push-on or mechanical joint.
D. Interior coating: complying with AWWA C550.

Bronze gate valves shall conform to the following:

A. Nonrising-stem gate valves: MSS SP-80, Class 125, Type 1, bronze with solid wedge, threaded ends, and malleable-iron handwheel.

Gate Valve Accessories & Specialties.--Valve boxes for gate valves shall be cast iron. Valve boxes shall be three piece design. Each three piece box shall be complete with base, center section, top section and cover plate. Valve boxes shall be extension type with screw adjustment. Each base and bottom section shall be the proper type for the valve served. Each valve box assembly shall be the proper length for the valve served. The minimum thickness of metal shall be 5 mm. The word "WATER" shall be cast in each valve box cover. Operating wrenches shall be steel tee handles of suitable length to operate deepest operating nut extension stem. Conform to NCCWD Standard Detail NC-18 except that in locations where the asphalt layer is not required use a 200 mm thick concrete pad to set the lid and riser.

Backflow Preventors.--The 200mm backflow preventer serving the tunnel fire protection system shall be reduced-pressure-principle backflow preventers conforming to ASSE 1013, suitable for continuous pressure application at 1035 kPA working pressure minimum, with stainless steel body, corrosion-resistant internal components, and flanged ends. Outside screw and yoke gate valves shall be included on inlet and outlet, with thermoplastic cam-check

assembly with stainless steel hinge pins, cam arm, and cam bearing; test cocks and stainless steel pressure-differential relief valve with ASME A112.1.2, air-gap fitting located between two positive-seating check valves. There shall be no brass or bronze parts used within the check assembly or relief valve. Backflow preventers shall conform to the following:

A. Maximum pressure loss: 83 kPa through middle third of flow range.
B. 200mm backflow preventer end-to-end length: 749 mm maximum.

The 50mm backflow preventer serving the building at the OMC site shall be reduced-pressure-principle backflow preventers conforming to ASSE 1013, suitable for continuous pressure application at 1035 kPA working pressure minimum, with bronze body, internal pressure differential relief valve located in a zone between two positive seating check modules with captured springs and silicon seat discs. Seats and seat discs shall be replaceable. The assembly shall also include two resilient seated isolation valves, four resilient seated test cocks and an air gap drain fitting. Backflow preventer shall conform to the following:

A. Maximum pressure loss: 90 kPa through middle third of flow range.

Concrete Vaults.--Concrete vaults shall be precast, reinforced-concrete vault, designed for A-16 or H-20 load designation according to ASTM C 857 and made according to ASTM C 858, and shall include the following:

A. Design structure according to sizes indicated on plans.
B. Structural design loading: ASTM C 857, Class A-16 and AASHTO H20 traffic loading.
C. Joint sealant: continuous extrusion of asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground-water level at grade.
D. Provide 203 mm diameter cast-in sump.
E. Source quality control: inspect structures according to ASTM C 1037.
F. Pulling eyes in walls: eyebolt with reinforcing-bar fastening insert 51 mm diameter eye and 25 mm x 102 mm bolt. Working load embedded in 152 mm, 27 MPa concrete: 57.8 kN minimum tension.
G. Pulling and lifting irons in floor: 22 mm diameter, hot-dip-galvanized, bent steel rod; stress relieved after forming; and fastened to reinforced rod. Exposed triangular opening. Ultimate yield strength: 178 kN shear and 269 kN tension.
H. Expansion anchors for installation after concrete is cast: stainless-steel-wedge type with stainless-steel expander clip with 13 mm bolt, 23.6 kN rated pullout strength, and minimum 30.2 kN rated shear strength.
I. Manhole cover and frame: ASTM 48M Class No. 35A minimum tensile strength, gray-iron traffic frame and cover, 300 mm diameter, unless indicated otherwise, with lettering "WATER".

Freestanding Fire Hydrants.--Wet-barrel fire hydrants shall conform to the requirements in AWWA C503, with one 115 mm and two 65 mm outlets, 150 mm threaded or flanged inlet, and base section with 150 mm mechanical-joint inlet. Interior coating shall conform to the requirements in AWWA C550. Hydrant shall have 1035 kPa minimum working pressure design, and the following:

A. Outlet threads: NFPA 1963, with external hose thread used by local fire department. Include cast-iron caps with steel chains.
B. Operating and cap nuts: pentagon, 40 mm point to flat.
C. Direction of opening: open hydrant valves by turning operating nut to left or counterclockwise.
D. Exterior finish: red alkyd-gloss enamel paint, unless otherwise indicated.

Water Meters.--The water meter for the fire protection system in the tunnel will be furnished by the State and installed by the Contractor. Water meter shall be 200 mm size fire service assembly. The meter assembly shall be complete with high capacity turbo meter, strainer, detector check valve, by-pass turbo meter to capture low flows complete with ball valves and check valve in by-pass line. Meter shall be suitable for flows from 0.25 L/s to 220 L/s. Meter shall be Invensus Model FM 720, UL approved. Meter shall be furnished complete with electronic communication registers (ECR) for above ground on-site reading.

The water meter for the domestic water feed to the OMC Building will be furnished by the State and installed by the Contractor. Water meter shall be 50 mm size AWWA Class II single register high performance compound meter. The meter shall be furnished complete with inlet strainer. Meter shall consist of essentially two meters within a single housing one for low flows and the other for high flows. The measurements of the two chambers shall be coordinated and recorded on a single billing register. Meter shall be suitable for flows from 0.02 L/s to 10 L/s. Meter shall be Invensys Model SRH furnished complete with the "Touchread Pitlid" fully sealed system for automated meter reading.

NCCWD approval of water meter installation shall be obtained prior to use.

Piping Applications.--Pipe, fittings, and joining methods for piping systems shall be used according to the following applications:

A. Transition couplings and special fittings with pressure ratings at least equal to piping pressure rating may be used in applications below, unless otherwise indicated.
B. Do not use flanges, unions, or keyed couplings for underground piping.
C. Flanges, unions, keyed couplings, and special fittings may be used, instead of joints indicated, on aboveground piping and piping in vaults.
D. Underground domestic water-service piping nominal size 90 mm or smaller: Use the following piping materials for each size range:

    1. 20 to 90 mm nominal size: Soft copper tube, Type A; wrought-copper fittings; and brazed or soldered joints.
    2. Option for 65 to 90 mm nominal size: Use 80 and 100 mm nominal size; ductile-iron mechanical-joint pipe; ductile-iron, mechanical-joint fittings; and mechanical joints.

E. Water main piping inside tunnel fire pump room: 100 to 200 mm Ductile-iron, mechanical joint pipe and fittings or alternate push-on joint pipe specified in these special provisions.
F. Underground combined water-service and fire-service-main piping: 100 to 300 mm ductile-iron, mechanical joint pipe and fittings or alternate push-on joint pipe specified in these special provisions.

Valve Applications.--Mechanical-joint or slip-on-joint-end valves shall be used for 80 mm and larger underground installation. Threaded or flanged-end valves shall be used for

installation in vaults. Corporation valves and curb valves with ends compatible with piping shall be used for 50 mm and smaller installations.

Plans indicate valve types to be used. Where specific valve types are not indicated, the following requirements shall apply:

A. Underground valves, 80 mm and larger: AWWA, cast-iron, nonrising-stem, resilient-seated gate valves with valve box.
B. Use the following for valves in vaults and aboveground:

1. Gate valves, 50 mm and smaller: bronze.
2. Gate valves, 80 mm and larger: AWWA, cast iron, non-rising stem, resilient seated.

Joint Construction.--Pipe joints shall conform to the following:

A. Ductile-iron piping, gasketed joints for water-service piping: AWWA C600 and AWWA M41.
B. Ductile-iron piping, gasketed joints for fire-service-main piping: UL 194.
C. Ductile-iron piping, grooved joints: cut-groove pipe. Assemble joints with keyed couplings, gaskets, lubricant, and bolts according to coupling manufacturer's written instructions.
D. Copper tubing soldered joints: ASTM B 828. Use flushable flux and lead-free solder.
E. Dissimilar materials piping joints: use adapters compatible with both piping materials, with OD, and with system working pressure.

Construction Materials.--Mortar: comply with ASTM C270, Type M, except for quantities less than 56,634 cc where packaged mix cmplying with ASTM C387, Type M, may be used.

Controlled Density Fill (CDF) shall conform to "Controlled Low Strength Material" of these special provisions.

Concrete: Use 25 Mpa minimum, 28-day compressive strength and 10 mm maximum aggregate size. Concrete and reinforcement are specified in "Concrete Structures" of these special provisions.

INSTALLATION

Piping Installation.--Piping installation shall conform to the following:

A. Comply with NFPA 24 for fire-service-main piping materials and installation.
B. Install ductile-iron, water-service piping according to AWWA C600 and AWWA M41.
C. Install copper tube and fittings according to CDA's "Copper Tube Handbook."
D. Bury piping with depth of cover over top as indicated on the plans, or at least 750 mm, with top at least 300 mm below level of maximum frost penetration, and according to the following:

    1. Under driveways: with at least 910 mm cover over top.
    2. Under railroad tracks: with at least 1220 mm cover over top.
    3. In loose gravelly soil and rock: with at least 300 mm additional cover.

E. Install piping by tunneling, jacking, or combination of both, under streets and other obstructions that cannot be disturbed.

F. Extend water-service piping and connect to water-supply source and building water piping systems at outside face of building wall in locations and pipe sizes indicated. Terminate water-service piping at building wall until building water piping systems are installed. Terminate piping with caps, plugs, or flanges as required for piping material. Make connections to building water piping systems when those systems are installed.
G. Install underground piping with restrained joints at horizontal and vertical changes in direction. Use restrained-joint piping, thrust blocks, anchors, tie-rods and clamps, and other supports.
H. Anchor service-entry piping to building wall.

Anchorage Installation.--Anchorages shall be installed for tees, plugs and caps, bends, crosses, valves, and hydrant branches. Anchorages shall be included for the following piping systems:

A. Gasketed-joint, ductile-iron, water-service piping: according to AWWA C600.
B. Fire-service-main piping: according to NFPA 24.

A full coat of asphalt or other acceptable corrosion-resistant material shall be applied to surfaces of installed ferrous anchorage devices.

Valve Installation.--AWWA gate valves shall conform to the requirements in AWWA C600 and AWWA M44. Each underground valve shall be installed with stem pointing up and with valve box.

UL/FM gate valves shall conform to the requirements in NFPA 24. Each underground valve and valves in vaults shall be installed with stem pointing up and with vertical cast-iron indicator post.

Corporation valves and curb valves shall be installed with head pointed up and with service box.

Water Meter Installation.--Water meters, piping, and specialties shall be installed according to manufacturer's written requirements.

The OMC building water meter shall be installed in meter vault and include shutoff valves on water-meter inlet and outlet and valved bypass around meter. Meter, valves, and piping shall be supported on brick or concrete piers.

Backflow Preventer Installation.--The Contractor shall install backflow preventers of type, size, and capacity indicated, including valves and test cocks, and according to the requirements of plumbing and health department and authorities having jurisdiction. Backflow preventers shall not be installed with relief drains in vaults or other spaces subject to flooding. Bypass piping shall not be installed around backflow preventers.

65 mm and larger backflow preventers, valves, and piping shall be supported near the floor and on brick or concrete piers.

Vault Installation.--Vault installation requires close coordination with the rock boring and civil work to assure adequate depth is available at locations indicated on plans. Coordinate layout and installation of vaults.

Install precast concrete vaults according to ASTM C 891. Connect drain outlet to storm drainage piping, or daylight.

Install precast concrete vaults with rooftop flush at finished pavement for roadway and sidewalk located vaults, and set roof surface 25 mm above grade for outdoor non-paved locations.

Unless otherwise indicated, support units on a level bed of crushed stone or gravel, graded from 25 mm sieve to No 4 sieve and compacted to same density as adjacent undisturbed earth.

Fire Hydrant Installation.--Each fire hydrant shall be installed with a separate gate valve in the supply pipe, anchored with restrained joints or thrust blocks, supported in an upright position, and conforming to the following:

A. Wet-barrel fire hydrants: install with valve below frost line. Provide for drainage.
B. AWWA-type fire hydrants: comply with AWWA M17.
C. UL/FM-type fire hydrants: comply with NFPA 24.

FIELD QUALITY CONTROL

Piping shall be tested before joints are covered and after thrust blocks have hardened sufficiently. The pipeline shall be filled 24 hours before testing and the test pressure applied to stabilize the system, using only potable water.

Hydrostatic tests shall be performed at not less than 1.5 times working pressure for 2 hours. The pressure shall be increased in 350 kPa increments and each joint inspected between increments. The test pressure shall be held for one hour, and then decreased to zero kPa. The pressure shall be slowly increased again to the test pressure and held for one more hour. Leaking joints shall be remade with new materials and test repeated until there is no perceptible leakage. The Contractor shall prepare reports of the testing activities.

Identification.--Continuous underground detectable warning tape shall be installed during backfilling of trenches for underground water-service piping, located below finished grade, directly over piping.

Cleaning.--Water distribution piping shall be cleaned and disinfected as follows:

A. Purge new water-distribution piping systems and parts of existing systems that have been altered, extended, or repaired before use.
B. Use purging and disinfecting procedure prescribed by authorities having jurisdiction or, if method is not prescribed by authorities having jurisdiction, use procedure described in AWWA C651 or as described below:

    1. Fill system or part of system with water/chlorine solution containing at least 50 ppm of chlorine; isolate and allow to stand for 24 hours.
    2. After standing time, flush system with clean, potable water until no chlorine remains in water coming from system.
    3. Submit water samples in sterile bottles to authorities having jurisdiction. Repeat procedure if biological examination shows evidence of contamination.

C. Prepare reports of purging and disinfecting activities.

MEASUREMENT AND PAYMENT

The contract lump sum price paid for water mains shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for performing all the work

involved in furnishing and installing the water mains, complete in place, including vaults, excavation, backfill, testing and cleaning, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-5.__ LEACH WATER SYSTEM AND CARBON DIOXIDE STORAGE TANK

GENERAL

This work includes a pre engineered water treatment system and equipment using CO2 as the primary treatment fluid for reducing the alkalinity of the treated water to acceptable standards prior to discharge to a detention basin.

SUMMARY

Scope.--Leach water system and carbon dioxide storage tank shall consist of furnishing and installing a three stage leach water treatment system including treatment tanks, mixers, circulation pumps, and carbon dioxide delivery system, accessory piping and valves, metering, and monitoring and control system, in conformance with the details shown on the plans and the requirements specified in these special provisions.

The carbon dioxide storage tank shall consist of insulated tank, tank accessories, refrigeration unit, and vaporizer. Furnishing of industrial grade carbon dioxide to the maximum capacity of the tank shall be included. Tank, piping and accessories shall conform to the details shown on the plans and the requirements specified in these special provisions.

PERFORMANCE REQUIREMENTS

The system shall be capable of accepting water flow at a rate that varies from zero to 63 L/s without interrupting incoming flow. Flow versus influent chemistry handling capability of the system shall be as follows:

Flow	pH	Alkalinity
63 L/s	pH < 11.0	<50 mg/L

Effluent aggregate of the waste stream shall be primarily alkaline. The waste stream temperature shall range from 15.5°C to 40°C.

The pH of the effluent stream shall be between 6.5 and 8.5. Stability of the waste stream shall be demonstrated prior to purge to the detention pond. The discharge range shall be user configurable and variable from 0-14 pH units. The stability time measurement shall also be user configurable.

The effluent monitoring stage shall continuously monitor and record the flow rate and pH of the system discharge. The system shall be equipped with a flow totalizer and pH alarms. The final effluent measuring probe shall be independent of the primary treatment pH probe and shall be continuously monitored by the control system. In the event that the effluent pH exceeds the user defined effluent alarm setpoints, the system discharge shall be halted until the pH is back within the acceptable range.

When system effluent discharge is halted due to high set point alarm or any other malfunction of the treatment plant, electric operated butterfly valves provided on the influent side of the system, shall divert influent water to the emergency sump until the malfunction is

fixed and the system reset to operate in normal treatment mode. See plans and leach water flow diagram.

Recirculation pumps shall be duplex pairs with automatic failure detection and backup. If one pump fails, it shall be detected and the process shall not be interrupted.

QUALITY ASSURANCE

All components of the pH adjustment system shall be free of defects. Any defects or design flaws shall be corrected by the manufacturer prior to acceptance of the unit.

The pre-engineered system designer shall provide a process guarantee which ensures that the system will handle the prescribed flows and chemistries.. This guarantee shall be fulfilled with a demonstration of the system with flows varying from 30 L/s to 63L/s and field encountered influent chemistries. All upgrades required to meet the requirements of these special provisions shall be made at no cost to the State.

System designer shall provide three references from owner operators of similar systems, designed by them.

Factory tests shall be performed on the major system components in accordance with the applicable pump, valve and agitator standard, and results shall be submitted in writing.

Field tests shall be performed as specified in these special provisions, and results shall be submitted in writing.

Manufacturer's seismic qualification certification: The Contractor shall submit certification that leach water treatment system and components will withstand seismic forces in conformance with the provisions in "Mechanical Vibration Controls and Seismic Restraints" of these special provisions. The submitted information shall include the following:

A. Basis for certification: indicate whether withstand certification is based on actual test of assembled components or on calculation.
B. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified."

SUBMITTALS

The Contractor shall submit working drawings in conformance with the details shown on the plans and with the provisions in Section 5-1.02, "Plans and Working Drawings" of the Standard Specifications and the requirements specified in these special provisions.

Product Data.--Component product data to be submitted shall include the following:

A. Manufacturers' technical data, including rated capacities, operating characteristics, furnished specialties, and accessories for complete leach water treatment system. Include manufacturer's catalog cuts and certificates of conformance for the following items:

    1. Treatment tanks.
    2. Mixers.
    3. Circulation pumps.
    4. Pipe and fittings.
    5. Joints and couplings (including gaskets).
    6. Valves.
    7. Flow switches.
    8. Gauges.
    9. Water meters.

10. pH control devices.
11. Main control panel.
12. Treatment service support skid.
13. Carbon dioxide storage tank with refrigeration and vaporizer unit.

B. Factory test reports.
C. Field quality control test reports.
D. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements.
E. Operation and maintenance manuals shall include the following;

1. Data and detailed drawings for all equipment components and parts.
2. Written sequence of operation on an annual basis for the application as required to achieve the water quality specified in these special provisions.

Working Drawings.--Working drawings shall include complete details, information, and drawings for the leach water system. The working drawings shall include the following:

A. Field erection drawings showing complete and accurate information and dimensioned layout of all components of the leach water treatment system, including tanks and skid-mounted components, piping layout, complete with locations of all supports. The field erection drawings shall include plans, elevations, sections, details, attachments to other work, and maintenance space required. The drawings shall include numbers on match marked components, for ease of identification in the field.
B. Dimensioned outline drawings of equipment unit: Identify center of gravity and locate and describe mounting and anchorage provisions for the treatment tanks, carbon dioxide tank, and skid-mounted equipment.
C. Schematic flow diagram of entire system complete with bill of materials and all instruments and instrument locations shown on the plans and these special provisions.

PRODUCT DELIVERY, STORAGE, AND HANDLING

Damaged products shall be removed from the job site and replaced with new products. Products shall be stored safe from damage or deterioration, keeping the interior of pipe, fittings, valves, and appurtenances free from dirt or foreign matter. Valves shall be drained and stored in a manner that will protect valves from damage by freezing. Gaskets, plastic pipe and fittings, and other products, which will be deteriorated by sunlight, shall be stored in a cool location, out of direct sunlight. Gaskets shall not come in contact with petroleum products.

LEACH WATER TREATMENT SYSTEM DESCRIPTION

System shall consist of 2-stage treatment system and final stage effluent monitoring system. The first stage is a coarse adjustment stage that shall neutralize most, if not all of the influent alkalinity while the second stage shall be designed to be a fine tune stage, and a stabilization stage filtering oscillations from the first stage. The second stage shall act as a primary treatment step should the pH adjustment system within the first stage either fail or be shutdown for service. Both stages shall employ a pH control algorithm providing feed-back control based upon a programmed titration curve, absolute value of pH, and pH rate of change. Linear control algorithms such as PID loops shall not be employed. The final stage is a final effluent monitoring system that shall measure the effluent flow and the pH level using an independent pH probe, on a circular chart recorder.

The system shall be configured to use carbon dioxide and mineral acid as a supplement, if carbon dioxide tank refills are required more than once a week.

As soon as leached ground water is available from the tunnel site for titration testing, the treatment equipment supplier shall arrange for testing to determine the anticipated carbon dioxide usage. If it is determined that supplementary acid treatment will be required, the equipment manufacturer shall design and provide the supplementary on site acid holding tank, covered structure, containment structure and associated pump and piping in complete compliance with all the State of California safety regulations. The supplementary acid holding tank, if required, shall be located within the confines of the retaining wall and traffic protection bollards as shown on the plans.

The equipment supplier shall include an allowance for providing the supplementary acid system as a separate line item on the bid form so that it can be deleted or modified in the future as required.

SYSTEM COMPONENTS

The entire system with the exception of the two treatment tanks and carbon dioxide tank shall be skid mounted, and shall be supplied as a completely fabricated, pre-piped, pre-wired and tested system. The major components on the treatment service support skid will be the Main Control Panel (MCP), recirculation pumps, and the carbon dioxide distribution and metering system. All components shall be sized by the leach water treatment system designer and system integrator to achieve water quality defined in "Performance Requirements" of these special provisions.

Treatment Tanks.--The treatment tanks shall be vertical cylindrical FRP with flat bottom and flat tops. The tanks covers shall be integral to the tank and shall be equipped with mixer bridges, all required ports and a 610 mm manway. The first stage tank shall be 22,710 liter with dimensions of 2,590 mm x 4,620 mm high; while the second stage shall be 37,850 liters with dimensions of 3,580 mm x 4,040 mm high. Influent shall flow into the top of the first stage, down through the first stage exiting the bottom and gravity flowing to the bottom of the second stage; influent continues up through the second stage and finally out through a top mounted discharge port. Tank connections shall be flanged. Hold down lugs shall be provided on all vertical flat bottom tanks. The design, number, and attachment of the lugs shall be the responsibility of the fabricator, based on the wind and seismic loads specified for California Zone 4.

Agitator/Mixers.--The mixers shall be gear reduced propeller-type mixers, 316 stainless steel construction, sized to provide 1.5 tank turns per minute of agitation.

Recirculating Pumps.--The two (2) first stage and two (2) second stage recirculation pumps shall be horizontal centrifugal pumps, each supplying 10 L/s @ 24.4 meter TDH of recirculation flow each, through a series of eduction mixers. Motors shall be 3.7 kW, non overloading, TEFC, 3 phase. Each pump shall be equipped with a liquid filled pressure gauge and a gauge isolator. In the event of a first stage or second stage pump failure, automatic backup shall be employed.

Recirculation Piping.--Recirculation loop piping shall be Schedule 80 PVC; with isolation and check valves, pH probe and chemical injection point in the loop, accessibly located. The pH probes and chemical injection (other than the carbon dioxide spargers) shall not be installed in the treatment tanks. The recirculation loops shall be fitted with a flow switches. The entire piping system shall be rated for 345 kPa @ 60°C, or higher.

Eduction Mixers.--Three eduction mixers shall be provided for each treatment tank for mixing and carbon dioxide introduction. The eductors shall provide 63 L/s of effective mixing per treatment tank. Isolation valves shall be provided to enable each eduction mixer to be serviced independently.

Monitoring System.--Final stage effluent monitoring system shall continuously monitor the quality of the effluent flow discharged from the treatment system. A totalizing function on the recorder, or on the flow measuring instrumentation shall totalize effluent flow. If the pH of the treated effluent deviates from the specified parameters, the pH adjustment system shall automatically discontinue discharging, an alarm shall be activated and the electric operated diverting valves shall be driven to their by pass positions. The alarm points shall be sufficiently within the discharge window so that by the time the system reacts to the deviation, fluid pH will not have drifted out of the acceptable discharge range. Major components shall include the following:

A. Microprocessor based two pen circular chart recorder for simultaneously recording final effluent pH and flow. The recorder chart time is programmable from one hour to one week.
B. One pH probe, flat surface, self cleaning, double junction; and pH transmitter.
C. One ultrasonic open-channel flow monitoring system, 0-94.6 L/s.
D. CSA approved control components including ph probe and transmitter, flow switch, and high level sensor.

Reagent distribution/injection.--After the titration tests, if it is determined that supplementary chemical injection is required, the system and equipment shall be capable of controlling up to 8 chemical injection pumps and systems. There shall be controls for two bulk chemical addition pumps for the first stage and for two bulk chemical addition pumps for the second stage. In the current configuration, provide for a total of two chemical addition systems, one for bulk carbon dioxide addition to the first stage and bulk carbon dioxide addition to the second stage. The controls for the other 6 shall be used when the need for supplementary mineral acid is determined. The configuration shall allow for bidirectional pH control using either carbon dioxide or mineral acids.

A. Two precision carbon dioxide CO2 addition systems shall be provided. Each system shall accept carbon dioxide from the storage tank and distribute carbon dioxide to the first and second stage treatment systems. Fine bubble diffusers (spargers) in each treatment tank shall be used to ensure that the carbon dioxide is completely dissolved into the water.
B. The fine bubble diffusers shall be sized to ensure that a sufficient volume of carbon dioxide is dissolved into solution to neutralize an influent alkalinity of up to 1,000 mg per Liter at a flow of up to 82 L/s. Additionally the diffusers shall be installed through a nozzle in the tank wall, near the bottom, and shall be able to be removed from service for cleaning or replacement.
C. The distribution system shall include a 304SS header, isolation valves, and control valve.

Treatment service support skid.--Provide a single shop-fabricated skid to serve all treatment system components, except the treatment tanks. The frame of the skid shall be fabricated from 102 mm steel C channel and topped with a 6.4 mm steel deck plate. A 51 mm box tube shall form the 4 walls to which all pipe and conduit supports are attached. The entire

steel structure shall be bead blasted, primed and coated with a 2 part epoxy coating. The skid will then be lined by a polypropylene liner with a floor drain. Lifting pads beneath the skid shall be supplied to allow fork lift entry under the skid for moving the system during installation.

Instruments & Controls.--

A. The pH sensor employed by this system shall be PVC bodied double junction combination "self cleaning" type electrode. The probes shall be configured with quick connect electrical connections and shall be able to be removed from service. Measuring range of the sensor shall be 0-14 pH.
B. The pH transmitters shall be microprocessor based units that provide pH buffer solution tables that assist the operator in the calibration of the pH probe. The transmitter shall provide a 4-20 mA output. The pH indicator shall be a dedicated backlit LCD display or LED capable of providing readout in a wide range of lighting conditions. The display resolution shall be 0.01 units over a range of 0.00 to 14.00. The unit shall employ probe diagnostics to warn of a pH probe problem.
C. The effluent recorder shall be a fully programmable two pen circular chart recorder. Pen 1 (red pen) shall display the effluent pH and pen 2 (green pen) shall display the effluent flow rate. Both pens shall be configured to accept isolated 4-20 mA inputs from the respective transmitters. Chart rotation time shall be programmable from 1 to 168 hours.
D. The effluent flow sensor shall employ a magnetic flow sensor and tube that is directly interfaced to a transmitter to provide an isolated 4-20ma signal to the chart recorder. Flow measuring range shall be 0 to 106 L/s.

ELECTRICAL REQUIREMENTS

All electrical components shall conform to industry standards for use in wet corrosive environments. Electrical enclosures shall be NEMA 4X and all conduit shall be watertight and corrosion resistant. Galvanized metallic conduit shall not be considered corrosion resistant. All metal enclosures shall be epoxy coated and all motors shall be painted with a baked on Epoxy OSHA safety blue coating. The electrical system, as an entity, shall be "hose down proof" after the system is completed. Frequent cleanings with a pressurized water stream shall not affect the integrity of the system. The system shall comply with NFPA 79 and shall be UL508 certified. The main control panel (MCP) shall be constructed by a certified UL 508A shop.

Main control panel (MCP).-- The MCP and all associated wiring and documentation shall conform to all applicable industry standards such as NEC, NEMA, ISA, ANSI, and NFPA79, and UL 508A:

A. The MCP shall house the central control system. The central control system shall include the following:

    1. A main disconnect switch, fused control transformer, distribution block, and lighting panel.
    2. Programmable Logic Controller (PLC), with a central processing unit (CPU), an Operator Interface/message display center, pH transmitter and pH indicator.
    3. Power supplies, annunciator lights, alarm horn, common trouble alarm contacts for interface to the OMC Bldg. PLC.
    4. Motor starters for the agitators, duplex motor starters for the pumps and branch circuit protection.

B. Electrical: 460 V(ac), 3 phase, 60 Hz.
C. Main disconnect for single point power connection, sized in accordance with the NEC.
D. The MCP shall be a NEMA 4X epoxy coated electrical enclosure sized to house all the required components. All conduit penetrations to the panel shall be watertight and the integrity of the panel shall not be violated by any of the penetrations.
E. Three-phase 208460 V(ac) lighting distribution panel with overcurrent protection devices. Panel shall contain 1-pole and 2-pole breakers for distribution to loads. Panel shall be designed and installed in accordance with the NEC.
F. The status of the pumps, valves, and mixers, CO2 tank refrigeration unit and vaporizer unit shall be indicated on the MCP with pilot lights. An OPEN - CLOSED - AUTO selector switch shall be provided for the automatic valves. A panel mounted HAND - OFF - AUTO switch shall be provided for the recirculation pumps and mixer.
G. The control circuit shall operate from ground isolated 24 V(dc) to assure operator protection.
H. Motor load switching devices shall protect the motor from long term overload and short circuit protection, phase loss, and brown outs. All wiring shall comply to NEC, NFPA79, UL 508 and local codes.
I. Motor power wiring is to be 14 (or 12) AWG BLK MTW, 24 V(dc) control circuit wiring shall be 18 (or 16) AWG BLU MTW, signal wiring shall be equal to Belden 8760.
J. Pilot lights shall be 24V(dc) and equipped with a Push To Test (PTT) button for lamp check. The following status and alarms shall be annunciated with pilot lights.
K. Level Alarms: All of the following alarms shall be annunciated via an individual red light, for each alarm and an audible alarm. The audible alarm shall be equipped with a silence pushbutton to temporarily mute the horn for the current even. The following alarms shall be individually displayed on the MCP:

    1. Treatment Tank High.
    2. Carbon Dioxide Pressure Low.
    3. Final Effluent pH Alarm.

L. Status indicators: status indicators, consisting of pilot lights shall display the following system status:

    1. First Stage Recirculation Pump1 Run.
    2. First Stage Recirculation Pump 2 Run.
    3. Second Stage Recirculation Pump 1 Run.
    4. Second Stage Recirculation Pump 2 Run.
    5. First Stage Mixer Run.
    6. Second Stage Mixer Run.
    7. 120 V(ac) Control Power On.
    8. 24 V(dc) Control Power On.

M. All of the alarms listed above shall also be displayed on the Operator Interface Unit (OIU). These alarms shall be latched such that they remain visible on the screen until acknowledged by an operator. In addition to the alarms listed above any other alarm or significant event shall also be displayed on the OIU, including the following:

    1. Excessive Treat Alarm (Detects pH not responding).

2. Final Effluent pH Alarm.
3. Probable Pump Failure (detects loss of recirculation pump).

N. An audible alarm with silence button shall be provided to indicate the presence of any alarm or anomaly. The silence circuit shall allow reactivation of the horn when a new alarm is detected.

O. At least two separate programmable alarm contacts shall be available to provide an indication of an alarm state at a remote location. The alarm contacts shall be field programmable and shall be able to represent any failure mode or system status.

P. The PLC shall include a modular input and output (I/O) platform that will accommodate input only, output only, or combination I/O modules with analog and digital I/O circuits, in densities including 4, 8, 12, 16, and 32 point. The PLC shall allow for a maximum I/O capacity of 4096 points. The PLC shall be provided with power supply to serve the total quantity of I/O modules, and each power supply shall have an LED indicating proper supply power. The power supply shall be designed to withstand a brief power loss without affecting the operation of the system (20 millisecond to 3 second hold-up time). The I/O modules shall interface to AC, DC, and TTL voltage levels. The PLC shall have the necessary battery-backed EEPROM memory capacity to control all automated system components, but not less than 16 kilobytes, and shall be equipped with DH-485 and RS-232 communication ports. The communication ports shall be compatible with the operator interface unit. The entire PLC shall be UL listed.

Q. The PLC shall be provided with all parameters factory programmed based on preliminary information supplied by the user. The PLC shall provide control over all automated system components such as pumps, mixers, and alarms. The control systems shall be capable of being configured for any titration curve. A PI control algorithm shall be provided that allows for control curve customization. An independent six slope curve for each metering pump shall be user defined to fit the titration curve for the waste stream to be treated. The response curve shall be defined in the field by the operator, via the use of the OIU.

R. A multiple window control mechanism shall be established that defines an acceptable discharge window, a discharge limit window, a treatment window, and a bulk assist window. The definition for the windows shall be as lollows::

1. The discharge limit window is an operator configurable set of parameters that defines the absolute limits of the system discharge. If the discharge, as indicated by the effluent monitor, reaches either end of this window then a process alarm is initiated and the system reverts back to the treatment mode.
2. The acceptable discharge window is an operator configurable set of parameters which define the pH range that the system discharge may occur. This window always resides inside of the discharge limit window.
3. The treatment window is an operator configurable set of parameters that defines the treatment goals for the metering pumps. This window always resides inside of the acceptable discharge window.
4. Initial settings for the windows shall be as follows:

Treatment Window	: 7.00 < pH < 8.00
Acceptable discharge	: 6.50 < pH < 8.50
Alarm Window	: 6.20 < pH < 8.80

S. The PLC shall control the recirculation pumps, discharge pumps, and mixer in the neutralization tank. All pumps and mixers shall be setup as conventional alternating duplex units each sharing in the duty cycle. Automatic failure detection shall be employed that will assure that a lag pump will be put online automatically upon determination of a problem with the lead pump.

T. A modem interface shall be supplied for the PLC that allows for remote access by the system supplier for the purpose of monitoring the system, performing tuning changes or programming changes, and for diagnostics.

Field Wiring.--All shop and interconnect field wiring shall be sized by the leach water treatment system designer and the component suppliers in accordance with the NEC, for power and controls, and in accordance with Section 10-3 "Electrical Systems" of these special provisions.

Operator Interface Unit (OIU).--An Operator Interface Unit (OIU) shall be directly interfaced to digital communication port on the PLC. This interface shall provide direct indication of system mode or alarm status through it's message display center. All user configurable set points and parameters shall be accessible through this unit. A detailed manual shall be provided by the system manufacturer describing the use of each variable and the meaning of all messages.

CARBON DIOXIDE STORAGE TANK

The liquid carbon dioxide storage tank shall be a horizontal arrangement with a nominal carbon dioxide storage capacity of 12,700 kg. Tank shall be complete with insulation and outer jacket, saddle mounts, lifting lugs, piping and valves, safeties, inspection manway, refrigeration unit with weather cover and electric vaporizer. Carbon dioxide storage tank shall be built per ASME code Section 8, Div. 1 for a design pressure of 2,410 kPa and a minimum design temperature of minus 40 degrees Celsius. The carbon dioxide storage tank shall be insulated using 100 mm of closed cell polyurethane foam with a 1.6 mm pre-finished white aluminum jacket. Tank appurtenances shall include schedule 80 seamless pipe, 907.2 kg forged steel fittings, liquid level gage, pressure gauge, stainless steel vented ball valves, an ASME direct spring loaded or pilot operated relief valve sized for outdoor installation and a high pressure bleeder valve set at 2,350 kPa. The storage tank shall be equipped to sound an alarm if the pressure in the vessel is 170 kPa above or below normal. Refrigeration unit shall consist of semi-hermetic condensing unit utilizing R404A refrigerant, pressure switch for automatic operation, low and high pressure reset, compressor motor thermal overload reset, disconnect switch, NEMA 3R electrical enclosure, and shall be tank mounted using aluminum angle framework and shall have a weather enclosure that can be removed to access the refrigeration unit. Refrigeration unit shall maintain carbon dioxide at 2,070 kPa and -17.8 degreee Celcius (adjustable). Capacity shall be 2.8 kW at minus 28.9 degree Celsius evaporation temperature and electrical characteristics shall be 460 V, 60 Hz, 3 phase. All electrical components shall be UL listed. Vaporizer shall be electric pressure build-type, 25mm blow down drain, high temperature shutdown switches, 3,100 kPa relief valve, disconnect switch, NEMA 3R control enclosure. Capacity shall be 18 kW, 222.26 kg/hr at 460 V, 60 Hz, 3 phase. Vaporizer shall operate between 1,690 kPa and 1,760 kPa (adjustable). All carbon dioxide high pressure stainless steel piping and valves between the main carbon dioxide tank and the spargers on the treatment tanks shall be included. The carbon dioxide tank shall be shipped skid mounted complete with tank mounted control cabinet to house all the controls for the refrigeration system and the vaporizer. The Control Cabinet shall be NEMA 3R rated complete with service

disconnect and built to accept a single 460V, 3 phase , 60 Hz power supply as shown in the plans. Provide all carbon dioxide required to initially fill and conduct all test on the system. Refill the system to maximum capacity after tests are accepted by the Engineer.

INSTALLATION

Leach water treatment support skid, treatment tanks, and carbon dioxide storage tank shall be installed on concrete bases, plumb and level, maintaining manufacturer's recommended clearances and arranging units so controls and devices that require servicing are accessible. Coordinate with all interfacing structural work shown on the plans for equipments bases and support pads. ~~Concrete bases shall conform to the details shown on the plans, coordinate with the structural concrete contractor providing the support pads for all locations, sizes and anchor bolt requirements. All work shall be in conformance with "Basic Mechanical Materials and Methods" of these special provisions~~.

Anchorage shall be provided for fastening work securely in place. Equipment anchors shall be set in concrete as the work progresses and spaced as shown on the plans. Where anchors and other supports for piping and equipment are not specifically shown on the plans, provide in compliance with "Hangers and Supports" of these special provisions. All anchors, bolts, nuts and washers shall be Type 316 stainless steel. ~~Sizes, kinds, and spacing of anchors not indicated or specified shall be as necessary for the purpose, as approved. Anchorage not otherwise specified or indicated includes slotted or embedded inserts, expansion shields, drop-in-anchors; toggle bolts and through bolts for masonry; machine and carriage bolts for steel; through bolts and lag bolts. Inserts of suitable and approved types shall be provided where required for support or anchorage of equipment and finish construction. Inserts shall be stainless steel unless indicated or specified otherwise. Slotted inserts shall be of types required to engage with anchors. Anchors and anchor bolts in walls shall be stainless steel, nuts shall be heavy duty corrosion resistant alloy. Stainless steel lock washers shall be used under all nuts.~~

Mixers, piping, valves, electrical and control devices, provided by the leach water treatment system designer and equipment suppliers for field installation, shall be installed in accordance with the designer and system integrators written instructions and approved field erection drawings.

Seismic restraints shall be provided for equipment and tanks and anchored to the structure, in conformance with the provisions in "Mechanical Vibration Controls and Seismic Restraints" of these special provisions.

Interconnecting control wiring shall be installed for treatment system controls and sensors. All power and control wiring, conduit, and all miscellaneous accessory devices for wiring shall be provided for a complete and functional leach water treatment system in conformance with these special provisions, NFPA 70, and all local code requirements. Equipment shall be grounded in conformance with the provisions in "Grounding and Bonding" of these special provisions.

FIELD QUALITY CONTROL

A factory-authorized service representative shall inspect assemblies, equipment installation and all connections. The representative shall also conduct start up and functional testing, adjust components and report results in writing.

The Contractor shall test and inspect individual components of leach water treatment system for compliance with manufacturers installation instructions. In addition to manufacturer's testing and inspection requirements, the following shall be performed:

A. Inspect field-assembled components and equipment installation, including piping and all electrical connections.
B. The Contractor shall not put the system into operation until all mechanical and electrical connections are inspected, the piping systems are leak tested and satisfactory test results are achieved.
C. Test for leaks and defects. Submit separate report for each tested segment, complete with diagram of section of piping tested. Repair leaks and defects with new materials and retest piping until no leaks exist.
D. Malfunctioning units shall be repaired or replaced, and retested.

DEMONSTRATION

A factory-authorized service representative shall train the Department's maintenance personnel to adjust, operate, and maintain the leach water treatment system.

MEASUREMENT

The leach water system shall be measured on a lump sum basis.
The carbon dioxide storage tank shall be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for leach water system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the leach water system, complete in place, including testing, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

The contract lump sum price paid for the carbon dioxide storage tank shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing carbon dioxide storage tank, complete in place, including testing and wiring, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-5.__ LEACH WATER PUMPING STATION PIPING AND APPURTENANCES

GENERAL

Leach water pumping station and emergency pumping station piping and appurtenances, and associated force main and gravity piping systems shall conform to these special provisions.

SUMMARY

Scope.--The work covered by this special provision includes the following:

A. 250 mm diameter buried force main routed from the pump station located outside the south portal to the leach water treatment system at the OMC site.
B. Buried gravity drainage piping routed between the leach water drainage manholes outside the south portal structure, including the 375 mm pipe between MH-5 and the sump.
C. Buried and embedded leach water gravity drainage piping at the south cut and cover ends of the two tunnels.
D. Buried 250 mm diameter treated leach water gravity drain from the leach water treatment system outlet to the area drain at the OMC site.

E. Pump discharge ductile iron piping, valves and accessories at the two pump stations.
F. Leach Water system manholes shown on the plans.

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical product data for the following items:

A. Pipe and fittings
B. Joints and couplings (including gaskets)
C. Valves
D. Gauges
E. Wall sleeves
F. Pipe to wall penetration closure
G. Access hatches.

Working Drawings.--The Contractor shall submit working drawings in conformance with Section 5-1.02 "Plans and Working Drawings" of the Standard Specifications and these special provisions.

Working drawings shall include complete details, information, drawings and substantiating calculations of the proposed materials, facilities and equipment to be used.

The working drawings shall include the following:

A. Complete and accurate dimensioned piping layout, with locations of all above grade supports. Include in tabular format description of each support type. Layout shall be at a minimum scale of 1:25.
B. Access hatch shop drawings shall include dimensions, operating weights, loads, required clearances, and installation details. Installation details shall show access hatch frame and covers installed in cast-in-place manholes as shown on the plans.
C. Manhole shop drawings which are fully dimensioned and show rebar details, access openings and openings for the connecting pipes.
D. Pipe support calculations and manufacturers load capacity data.
E. Operation and maintenance manuals. Provide data for all equipment and parts requiring periodic maintenance.

DELIVERY, STORAGE, AND HANDLING

Damaged products shall be promptly remove from the job site and replaced with undamaged products. Products shall be stored safe from damage or deterioration in accordance with manufacturer's recommendations, keeping the interior of pipe, fittings, valves, and appurtenances free from dirt or foreign matter. Valves shall be drained and stored in a manner that will protect valves from damage by freezing. Gaskets, plastic pipe and fittings, and other products, which will be deteriorated by sunlight shall be stored in a cool location, out of direct sunlight. Gaskets shall not come in contact with petroleum products.

Stacking of ductile iron, plastic, and steel pipe shall meet the requirements of the pipe manufacturer. Fittings, valves, or valve stands shall not be stacked.

QUALITY ASSURANCE

A. Piping materials shall comply with the specified American Water Works Association (AWWA) and or the American Society of Testing materials (ASTM) Standards for the pipipng des cribbed in these special provisions.
B. Piping materials shall bear label, stamp or other markings of the specified agency.

PIPE AND FITTINGS

All pipe, fittings, valves, and appurtenances shall be new and unused.

Ductile Iron Pipe.--Piping inside the leach water pumping station wet well, inside the downstream valve vault, buried pipe between the leach water pumping station and the valve vault, and all the pump discharge piping at the OMC site to the point of connection by others, shall be Grade C ductile iron pipe conforming to AWWA C151, as modified by Fed. Spec. WW-P-421 and shall have a minimum metal wall thickness of Class 53 for flanged or grooved wall pipe. The exterior surface of the pipe shall be coated with coal tar epoxy, minimum 0.5-mm thick. Flanged pipe shall conform to the requirements in AWWA C115. Pipe shall have cement mortar lining conforming to AWWA C104 Type V cement.

Non-buried joints shall be mechanical grooved type joints or flange joints with screwed on ductile iron flanges for connection to flanged valves. Flanges shall meet the requirements of AWWA Standard C115. Grooved type couplings shall meet the requirements of ANSI/AWWA C606. Field made-up flanges will not be allowed.

Non-buried couplings shall couple piping with grooved ends by engaging and holding these ends to form a watertight joint by means of a bolted, segmental clamp housing enclosing a sealing gasket. Couplings shall provide a rigid joint comparable to a flanged system. Clamp housing shall consist of two or more parts and shall be made of ductile iron conforming to ASTM A 536. Bolts and nuts for connecting clamp housing connections shall be track bolts and nuts conforming to ANSI B18.10; bolts shall be roundhead, square neck type conforming to ANSI B18.5, with hex nuts conforming to ANSI B18.22; bolts and nuts shall be zinc plated to ASTM A 164. Bolt holes shall be of a shape to hold fast the necks of the bolts used. Gaskets shall be of molded nitrile synthetic rubber, flush seal type, conforming to ASTM D 2000 and be supplied by the coupling vendor. Gasket shall be of such shape that, when compressed, it will effectively seal the joint against leakage. Grooved ends of piping shall be in accordance with the published recommendations of the manufacturer of the coupling, as approved. Strength of coupling shall not be less than that of the pipe. Grooved couplings shall have a factory applied, 0.075-mm thick, coal tar epoxy coating.

Groove-type mechanical flange adapters shall join fittings with grooved ends to flanged pipe and fittings. Flange adapters shall engage groove in pipe or fitting and hold this end to the adjoining flange to form a rigid, watertight joint. Clamp housing, 300 mm size and smaller, shall consist of two or more parts and shall be made of malleable iron conforming to ASTM A 536. Bolts and nuts shall be heavy hex cadmium plated steel. Gasket shall be nitrile and be supplied by the flange adapter manufacturer. A flange washer shall be used between the flange adapter gasket and the flange or flange gasket if so stipulated by the adapter manufacturer. Flange shall conform to the requirements in ANSI B16.1: Class 125 drilling. Coating of the flange adapters shall be equal to the approved coating for the grooved couplings

Gaskets for flange joints shall meet the requirements of ANSI/AWWA C110 and ANSI/AWWA C115/A21.11. Gaskets shall be full face. Gaskets shall be 3.2 mm thickness neoprene. Nuts and bolts shall be zinc plated steel, heavy hex nuts.

Non-buried fittings shall be designed and manufactured fittings for a minimum pressure rating of 1700 kPa. Fittings shall have mechanical grooved ends. Flange joints shall meet the requirements of ANSI/ AWWA C110. Grooved type joints shall meet the requirements of

ANSI/AWWA C110, for center to end dimensions and AWWA C153 or ANSI 21.10/AWWA C-110 for wall thickness. Lining cement mortar conforming to AWWA C210 Type V cement. Fittings shall have factory furnished exterior coating equal to that of the connecting pipe.

Coating for the Ductile Iron Pipe and Fittings.--The exterior surfaces of the pipe shall have the following coating systems in conformance with AWWA C210:

A. Surface preparation shall be Solvent Clean (SSPC-SP-1) followed by abrasive blast-cleaning to Near White Metal (SSPC-SP-10) with an anchor profile between 0.075-mm and 0.100-mm. Use extreme caution during external blast cleaning of ductile iron pipe. Refer to the National Association of Pipe Fabricators (NAPF) Standard 500-03 and consult with the pipe manufacturer prior to any blast cleaning of the ductile iron pipe.
B. Two (2) uniform coats of coal tar epoxy conforming to AWWA C210 shall be applied to a total dry film thickness of 0.5-mm to 0.75-mm.
C. The drying time between coats shall be 12 hours minimum and 24 hours maximum at 21°C. Inter-coat drying time is critical and shall be according to manufacturer's recommendations.

Fabricated Wall Pipe.--Fabricated ductile iron wall pipe, grooved end by plain end shall be provided as shown on the plans, complete with intermediate flange fabricated from hot rolled steel. Wall pipe shall be of the same thickness class, exterior coating and interior lining as the connecting pipe.

PVC Force Main, Pressure Piping (Buried).--The buried leach water pumped discharge piping system downstream of the valve vault shall be AWWA C900, Class 150 PVC pressure pipe, in conformance with the following:

A. Joints: gasketed joints using ASTM F477, elastomeric seals.
B. Fittings 100 to 200 mm nominal size: PVC pressure fitting complying with AWWA C907, for gasketed joints and using ASTM F477, elastomeric seals.
C. Fittings 250 mm nominal size and larger: Ductile-iron, compact fittings complying with AWWA C153, for push-on joints and using AWWA C111, rubber gaskets.
D. PVC pressure pipe, PVC pressure fittings, gaskets, and gasketed joints.

PVC Sewer, Non-Pressure Pipe Ribbed (Buried).--Buried leach water gravity drainage piping upstream of the South Portal pump station, shall be ASTM F794/AASHTO M304 PVC profile gravity sewer pipe with bell-and-spigot ends, and conform to the following:

A. Joints: gasketed, ASTM F477 elastomeric seals.
B. Fittings: ASTM D 3034 fittings, with bell ends.

This specification describes the externally ribbed smooth interior gravity drainage pipe and fittings to be used for the listed applications. The minimum waterway wall thicknesses for the the ribbed PVC non-pressure piping shall be as follows:

A. 2.2 mm for the 200 mm nominal pipe size
B. 2.3 mm for the 250 mm nominal pipe size
C. 2.6 mm for the 300 mm nominal pipe size
D. 2.8 mm for the 375 mm nominal pipe size

PVC Sewer, Non-Pressure Pipe Smooth (Buried).--The gravity PVC pipe and fittings embedded in south portal structure of the tunnel or buried at the OMC site, shall conform to the following requirements:

A. Thickness class shall be SDR 35 with smooth interior and exterior surfaces.
B. Pipe material compounds shall meet ASTM D 1784. Gaskets shall meet ASTM F 477.
C. Pipe design shall meet ASTM D3034 and pipe stiffness shall be at least 320 kPa when tested in accordance with ASTM D2412.

Fittings shall be fabricated or molded, manufactured using a PVC compound in conformance with the D1784 standard and design conforming to the ASTM D3034 and ASTM F1336 standards and shall be compatible for use with the connecting pipe.

The pipe and fitting system shall be capable of withstanding without leakage a 345 kPa hydrostatic test pressure.

VALVES

All isolation, check and drain valves, shown on the discharge side of the leach water pumps, shall be as shown on the plans and specified in these special provisions.

Plug Valves.--All plug valves shall be eccentric plug type unless otherwise specified herein or on the plans.

Valves shall be of the non-lubricated eccentric type with Neoprene resilient faced plugs and shall be furnished with flanged end connections. Flanges shall be faced and drilled to the ANSI/ASME B16.1 standard. Valve bodies shall be of the rectangular ported design and made of ASTM A126 Class B cast iron and with bolted bonnets. Bodies shall be furnished with welded overlay seats of not less than 90% pure nickel. Seat area shall be raised with surface completely covered with weld to insure that the plug face contacts only nickel.

Plug shall be of ASTM A 126 Class B cast iron. The plug shall have a cylindrical seating surface eccentrically offset from the plug shaft. The interference between the plug face and the body seat shall be externally adjustable in the field with the valve in the line under pressure.

Valves shall have sleeve type metal bearings of sintered, oil impregnated, permanently lubricated, type 316, stainless steel. Stem seals shall be multi-V ring adjustable packing type and shall be replaceable in-line without valve disassembly. Port area of valves shall not be less than 80% of the mating pipe area.

Valve shall be gear operated requiring not more than 0.22 kN force at the rim of the hand wheel under all operating conditions. Valve shall be furnished with travel stops for the full open and closed positions and be provided with intermediate position indication in 15 degree increments.

Valves shall be rated for minimum 1200 kPa working pressure.

Swing Check Valves.--Swing check valves shall be cast iron per ASTM A-126 Class B, with a steel reinforced, Buna-N rubber lined flapper with bubble-tight seating. The valve shall have an unrestricted flow area, a Class 125 rating and a 1200 kPa working pressure. The inside of the valve shall be rubber lined such that internally the valve shall have no exposed metal surfaces. For the purpose of backflushing the pumps, the valve shall have a positive non-slip backflow device. Valve shall have a phenolic primer red oxide exterior coating.

Ball Check Valves.--Ball check valves for use in the sump pump vertical discharge piping as shown on the plans shall be made of nodular cast iron with flanged end connections. Cast iron shall conform to GGG40, DIN 1693. Ball shall be made of aluminum with a nitril coating of hardness 63º shore A. Bolts and nuts shall be zinc coated. Check valve shall be low resistance with resilient seated ball and unrestricted passage. Valve shall have alkyd base coat, color black, of 40 microns.

Ball Valves, 50 mm and smaller for drain service.--Ball valves 50 mm and smaller shall be cast iron body, ASTM A 126, Class B and with threaded end connections. Valve shall have cast iron ASTM A 126 Class B or ductile iron ASTM A 536 ball. Seats shall be Cast Monel, ASTM B 127 or BUNA-N rubber. Packing shall be TFE V-flex. Valve shall be tested to the design working pressure (1000 kPa) with the ball in the closed position to determine tightness of the ball and seats.

HANGERS AND SUPPORTS

Pipe hangers and floor supports shall be provided in conformance with the requirements in MSS SP-58, MSS SP-69, Fed. Spec. WW-H-171E, ANSI B31.1, as shown on the plans and as specified in these special provisions. All materials shall be stainless steel in the wet well areas, and stainless steel or hot dip galvanized pipe hangers and supports in the outside ambient or service vaults.

APPURTENANCES

Gauges shall be ANSI B40.1, single style pressure gauge for water with 115 mm dial, brass or aluminum case, bronze tube, gauge cock and pressure snubber. The scale range shall be suitable for the intended service.

Above-grade sleeves in masonry and concrete walls and floors shall be ASTM A53 Schedule 40 or Standard Weight, hot-dip galvanized steel pipe sleeves or cast-in-place with smooth inside surfaces. Below-grade sleeves (one side in contact with dirt) shall be thermoplastic with integral seal ring.

Pipe to wall and pipe to floor penetration closure seals shall be modular mechanical type, consisting of interlocking synthetic rubber links shaped to continuously fill the annular space between the pipe and wall opening. Links shall be loosely assembled with bolts to form a continuous rubber belt around the pipe with a pressure plate under each bolt head and nut. After the seal assembly is positioned in the sleeve, tightening of the bolts shall cause the rubber sealing elements to expand and provide an absolutely watertight seal between the pipe and wall opening. All steel parts shall be 316 stainless steel.

Miscellaneous steel including pipe supports, hangers, anchors, sleeves, and associated steelwork shall be hot dip galvanized steel, configuration as shown on plans. Galvanizing shall conform to the requirements in ASTM A 153, with 600 g/m^2 minimum.

Expansion shields shall conform to the requirements in Federal Specification FF-S-325, of group, type, class, suited for the purpose. Shields shall be recessed not less than 60 mm into concrete or masonry, unless indicated otherwise. Devices of Groups IV, V, VI, and VII shall not be used in sizes greater than 12.7 mm unless so indicated. Materials shall be stainless steel.

Access hatch shall be designed for H-20 wheel loads in off-road locations. Frames shall be designed for casting into concrete. Materials shall be 6061-T6 aluminum for bars, angle and extrusions and diamond plate cover shall be 5086 aluminum, 6.35 mm thick. Hatch shall be designed using a maximum design stress of 119,280 kPa per the Aluminum Association, Inc. "Specifications for Aluminum Structures" with a safety factor of 2.2 applied to the minimum allowable tensile strength. Each door leaf shall be provided with a spring-assist mechanism and

a grade 316 stainless steel hold open arm. Hold open arm shall hve a red vinyl grip handle and shall be fastened to the frame with a 100 mm grade 316 stainless steel bolt. Channel frame shall be minimum 6 mm thick, extruded aluminum with 30 mm anchor flange. Frame shall be designed to accept a silicone cushion gasket. Hinges shall be brass alloy with a 448,169 kPa tensile strength and shall be bolted to the channel frame and diamond plate with grade 316 stainless steel bolts and nylock nuts. Each hatch shall be supplied with a grade 316 stainless steel slam lock with keyway protected by a threaded aluminum plug flush with top of diamond plate. Each hatch shall be equipped with a stainless steel lift handle. Design of access hatch shall conform to OSHA standard 1910.23.

PIPING IDENTIFICATION

Piping shall be identified with permanent flexible non-fading markers conforming to the requirements in ANSI A13.1 in color, letter size and label size. Piping identification shall be permanent washable, chemical, and environmental resistant. Non-metallic fasteners shall be provided with each marker. Labels for leach water system shall be white lettering on a green background. Flow direction arrows shall be provided adjacent to labels. Label spacing shall not exceed 3 m.

LEACH WATER SYSTEM MANHOLES

Leach water system manholes shall conform to Section 51-1.02 "Minor Concrete" of the Standard Specifications and the details as shown on the plans.

INSTALLATION

Installation of piping and accessories shall be in conformance with the general requirements of special provision "Mechanical Methods and Materials" for installation of pipelines and with the requirements of ANSI/ASME B31.1 and AWWA C600 each as applicable, except as otherwise specified in these special provisions or indicated on the plans. Piping shall be installed on supports as shown on the plans. Provide additional supports as required by the referenced MSS SP standards. Flange bolts shall be coated with anti-seize compound.

Pipe Laying And Jointing.--The Contractors quality control representative shall inspect pipe, fittings, valves, and accessories, before and after installation, and those found defective shall be rejected. Pipe and fittings shall be free from fins and burrs. Before being placed in position, pipe, fittings, valves, and accessories shall be cleaned and shall be maintained in a clean condition. Temporary equipment shall be provided for lowering sections of pipe into position. Under no circumstances shall pipe, fittings, valves, or any other water line material shall be dropped or dumped into the work area. Pipe shall be cut accurately to measurements established at the site and shall be worked into place without springing or forcing. A pipe or fitting that does not allow sufficient space for installation of jointing material shall be replaced by one of acceptable dimensions. Anchors and support shall be provided as shown on the plans. The wet well shall be kept free of water until the force main has been connected and pipe penetrations have been sealed. Open ends of pipe shall be closed temporarily with plastic or wood end caps or bulkheads.

Erection damage to pipe lining shall be repaired in conformance with the requirements in AWWA C104. Repair of buried pipe coatings and covering of field joints shall be a two-coat epoxy coating in conformance with Steel Structures Painting Council Paint No. 16, applied to a minimum dry film thickness of 0.5-mm. Bare steel surface shall be brushed to remove all mill

scale prior to the application of the protective coating. Surface preparation shall conform to manufacturer's instructions.

Flanged Joints.--Flanged joints and flanged adapter joints shall be made up tight. Undue strain on flanges, valves, fittings, and other equipment and accessories shall be avoided. Bolt holes shall be aligned for each flanged joint. Bolts shall be full size for the bolt holes, use of undersized bolts will not be permitted. Adjoining flange faces shall not be out of parallel to such degree that the flanged joint cannot be made watertight without overstraining the flange.

Grooved Pipe.--Where grooved pipe is employed, grooving by the supplier or Contractor in the shop under controlled conditions is recommended. Field grooves shall be made with equipment supplied by the manufacturer of the couplings. End separation between straight pipe lengths shall be of that rated for flexible radius cut grooves to allow for expansion and contraction of piping systems

Installation of Valves.--Valves shall be installed in conformance with the requirements in AWWA C600. Valves shall be installed in locations shown on the plans and in conformance with manufacturer's written instructions.

Installation of Pipe Sleeves.--Pipe sleeves shall be provided for all piping passes through the concrete walls and lids of sumps and vaults unless otherwise indicated on the plans.

The required inside diameter of each individual wall opening or sleeve shall be determined before ordering, fabricating or installing any pipe or sleeve. The inside diameter of each wall opening shall be sized as recommended by the manufacturer to fit the pipe to wall sleeve closure, to assure a watertight joint.

Sleeves shall be secured in proper position and location during construction. Sleeves shall be of sufficient length to pass through entire thickness of walls or roofs.

Installation of Pipe to Wall Penetration Closure.--Pipe to wall penetration closures shall be installed in conformance with manufacturer's written instructions. Bolt heads for wall closures shall be inside the pump station, bolt heads for floor closures shall be on the service chamber side of the opening.

Anchorage.--Anchorages shall conform to the provisions for concrete anchorage devices in Section 75-1.03, "Miscellaneous Bridge Metal" of the Standard Specifications and these special provisions.

Anchorages shall be provided to fasten work securely in place. Anchors shall be set in concrete as the work progresses and spaced as shown on the plans. Anchorage not otherwise specified or indicated includes slotted/embedded inserts, expansion shields, drop-in-anchors, toggle bolts and through bolts for masonry, machine and carriage bolts for steel, through bolts and lag bolts. Inserts of suitable and approved types shall be provided where required for support or anchorage of equipment and finish construction. Embedded inserts shall be stainless steel unless indicated or specified otherwise. Slotted inserts shall be of types required to engage with anchors. Anchors and anchor bolts in walls shall be stainless steel, nuts shall be heavy duty corrosion resistant alloy. Stainless steel lock washers shall be used under all nuts.

FIELD TESTS

Hydrostatic Test.--Test procedures for ductile iron piping shall conform to the requirements in AWWA Standard C600. The piping shall be complete, and shall have been in place for not

less than two days prior to being tested. Concrete thrust blocks shall have been in place for not less than five days.

The ends of ductile iron pressure piping being tested shall have test plugs, caps or blind flanges fitted with a tap of adequate diameter to fill and pressurize the system with water. The test plugs or caps or blind flanges shall be capable of withstanding an internal pressure of 1700 kPa. Remove instruments or other items that may be damaged by the test pressure. Fill all piping with water and expel all air from the piping. Tap the piping at high points, if necessary, to release all air from the piping. Apply 200 kPa for eight consecutive hours to allow the cement lining to absorb moisture. Add water as required to make up loss. Test piping at a static pressure of 1034 kPa over a period of not less than two consecutive hours. The test will be considered successful when the pressure drop over the test period is 35 kPa or less. Repair all leaks. Repeat the test until the pressure drop over the test period is 35 kPa or less. Remove all test equipment and plug all test holes at completion of test. Plugs shall be watertight.

Test procedures for PVC pressure piping shall conform to the requirements in "Testing and Maintenance" of AWWA M23. PVC pressure piping shall be tested at a pressure not less than 1.5 times the maximum system operating pressure, but not less than 450 kPa.

PVC non pressure piping allowable leakage shall be a maximum of 4.6 L/mm of nominal pipe size per kilometer of pipe, during 24-hour period.

Functional Test.--Each pump shall be run individually for at least 20 minutes. Pumps shall be cycled through their normal operating sequence by operating them in automatic mode through the level control system. Parallel operation of two or more pumps shall be witnessed during this latter mode of operation. Water required for testing shall be provided by the Contractor at no additional cost to the State.

Pressure shall be recorded with permanently installed gauges, and flows shall be recorded with portable measuring equipment. The field test for each size of pump, operating individually, shall be conducted by recording pressure and flow. The flow rate may be measured by using portable measuring equipment or by noting the drop in the height of the water level in the sump during operation for a minimum period of time. This minimum operation time period for calculating flow shall be determined by the Engineer prior to the test. The voltage, amps, power and power factor shall be recorded during all test modes of operation.

Plug valves shall be adjusted to control flow rate if directed to do so by the Engineer.

PAYMENT

Full compensation for leach water pumping stations and appurtenances shall be considered as included in the contract lump sum price paid for the leach water system and no separate payment will be made therefor.

10-5.__ STORM WATER PUMPS

GENERAL

Storm water pumps shall conform to the provisions in Section 74 "Pumps" of the Standard Specifications and these special provisions.

SUMMARY

Scope.--Storm water pumps shall consist of pumps and appurtenances for the leach water pump station pumps LWP-1 and LWP-2 and the emergency pump station pumps LWP-3 and LWP-4, and shall include the following items all furnished by the same manufacturer:

A. Pumps
B. Lifting Chains
C. Guide Rails
D. Discharge Elbow
E. Mix Flush Valve
F. Over temperature and leak detection monitoring system
G. Control Panel for the emergency pump station

Attention is drawn to "Tunnel Control Systems" of these special provisions for description of the level control system for the leach water pump station (LWP-1 and LWP-2) including analog type level transmitters and high level probe and control relay. The pump manufacturer shall be responsible for the selection of and testing of these components in the field to deliver a fully functional operating system.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings of the Standard Specifications and the requirements specified herein.

Product Data.--The submittal shall include complete details, information and drawings for the storm water pumps as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Certified copies of reports of factory tests specified in these special provisions in conformance with the Hydraulic Institute Standards for factory tests.
B. Catalog information with performance data, pump physical characteristics, weight of unit and access hatch requirements..
C. Pump and motor performance chart shall be furnished showing curves for torque, current, power factor, input and output power and efficiency.
D Discharge Elbow and guide rail support details.
E. Submersible power and monitoring cable and monitoring system details.
F. Schematic and wiring diagrams for the Control Panel servicing pumps LWP-3 and LWP-4.
D. Manufacturer's installation instructions.
E. Manufacturer's operation and maintenance material and manuals, in conformance with the special provisions "Mechanical Materials and Methods" of these special provisions.

PRODUCT DELIVERY, STORAGE & HANDLING

The Contractor shall be responsible for the delivery, storage, and handling of products. Damaged products shall be removed from the job site and replaced with undamaged products.

Equipment, components, and subassemblies shall be thoroughly cleaned of all water, sand, grit, weld splatter, grease, oil, and other foreign materials before preparation for shipment. Machined surfaces shall be protected against physical damage and exposure to the elements during shipment, handling, storage, and installation. Pumps shall be packed to provide

protection from damage during shipment, handling, and storage. Cap and seal all openings prior to shipment and while in storage at the site..

PUMPS

The submersible non-clog pumps shall be equipped with a submersible cable manufactured for the application. Each pump shall be furnished with a mating cast iron discharge connection of size as shown on the plans. Each pump shall be fitted with a 9 meter long stainless steel lifting cable. The working strength of the lifting system shall be 50% greater than the pump unit weight.

The pumps shall be capable of delivering the flow at the total dynamic head (TDH) as shown in the schedule on the plans. Pumping units shall meet the applicable requirements of the Hydraulic Institute Standards.

The pumps shall be automatically and firmly connected to the discharge connection, guided by no less than two guide bars extending from a bracket at the access opening to the discharge connection below. Sealing of the pumping unit to the discharge connection shall be accomplished by a machined metal to metal watertight contact. No portion of the pump shall bear directly on the sump floor. The discharge shall be a Class 125 cast iron flange.

Major pump components shall be of gray cast iron, ASTM A-48, Class 35B, with smooth surfaces devoid of blow holes and other irregularities. All exposed nuts and bolts shall be AISC type 304 stainless steel. Metal surfaces coming into contact with the storm water, other than stainless steel or brass, shall be protected by a factory applied spray coating of acrylic dispersion zinc phosphate primer with a polyester resin paint finish on the exterior of the pump.

Each unit shall be provided with a cooling system with a water jacket encircling the stator housing. Impeller back vanes shall provide the necessary circulation of the water through the jacket. The cooling media channels shall be non-clogging by virtue of their dimensions. Provisions for external cooling and seal flushing shall also be provided. The cooling system shall provide for continuous pump operation in water temperatures of up to 40°C.

The cable entry seal design shall preclude specific torque requirements to insure a watertight and submersible seal. The strain relief function shall be separate from the function of sealing the cable. The assembly shall provide ease of changing the cable, when service is required, using the same entry seal. The cable entry junction chamber and motor shall be separated by a terminal board which shall isolate the interior of the motor. The cable shall be 12 m in length sized according to NEC and ICEA standards. The outer jacket of the cable shall be oil resistant chloroprene rubber.

The pump motor shall be of the induction type with a squirrel cage rotor, shell type design, housed in an air filled watertight chamber. Design shall be NEMA type B with Class H insulation. The stator shall be dipped and baked three times in Class F varnish and heat shrink fitted into the stator housing. The motor shall be designed for continuous duty handling storm water at 40°C and capable of up to 15 evenly spaced starts per hour. Thermal switches set to open at 125°C shall be embedded in the stator lead coils to monitor the temperature of each phase winding. These thermal switches shall be used in conjunction with and supplemental to external motor overload protection. The junction chamber containing the terminal board shall be hermetically sealed from the motor by an elastomer O-ring seal. Connection between the cable conductors and stator leads shall be made with threaded compression type binding posts permanently affixed to the terminal board.

The motor and pump shall be designed and assembled by the same manufacturer. The motor shall be designed for operation up to 40°C ambient with a maximum 80°C temperature rise. The motor shall have a combined service factor of 1.15 and a voltage tolerance of plus or minus 10%.

The motors and associated cable shall be suitable for installation in a Class 1, Division 2, Group D classified area.

The nameplate motor power shall be selected such that it is non-overloading throughout the entire pump performance curve from shut-off to run-out. The motor and cable shall be capable of continuous submergence under 20 m depth of water.

The pump shaft shall rotate on two bearings. Motor bearings shall be permanently grease lubricated. The upper bearing shall be single roller type the lower bearing shall be two row angular contact type to compensate for axial thrust and radial forces.

Each pump shall be provided with a tandem mechanical shaft seal system consisting of two independent seal assemblies. The seals shall operate in a lubricant reservoir that hydro dynamically lubricates the lapped seal faces of the stationary and rotating tungsten carbide rings. Each seal interface shall be held in contact by its own spring system. The seals shall not require maintenance or adjustment and shall not depend on direction of rotation for sealing.

The lubricant chamber shall be designed to prevent overfilling and to provide for expansion. The drain and inspection plug shall be easily accessible from the outside. The seal system shall not rely upon the pumped media for lubrication. Seal lubricant shall be FDA approved non-toxic.

The pump and motor shaft shall be the same unit, couplings shall not be acceptable. The shaft shall be made of AISC type 431 stainless steel.

The impeller shall be of gray cast iron, class 35B, dynamically balanced, and double shrouded non-clogging design. The impeller shall be capable of handling solids, fibrous materials, heavy sludge and other matter found in wastewater. Impellers shall be keyed to the shaft, retained with an Allen head bolt and shall be capable of passing a minimum 75 mm diameter solid. Impeller shall have stainless steel wear ring heat-shrink fitted onto the suction inlet of the impeller. Impellers shall be coated with an acrylic dispersion zinc phosphate primer.

Pump volute shall be single piece gray cast iron, Class 35B, non-concentric design with smooth passages large enough to pass solids of size previously specified herein. Brass or nitrile rubber coated wear rings, drive fitted to the volute inlet, shall be used to provide efficient sealing between the volute and the suction inlet of the impeller.

Furnish for one of the two pumps in each pump station, a factory furnished flush valve made specifically to mate and bolt to an opening in the volute of the respective pump, for the purpose of churning up the liquid in the sump to re-suspend any built up sludge. The system shall be based on the ejector principle with a ball valve closing in a period of 20 to 50 seconds after the pump start. A means of adjustment shall be provided on the outside of the valve to obtain the desired flushing period.

In addition to the thermal switches for each phase, which shall be wired in series to open at 125°C, a float type leakage sensor (FLS) shall be provided to detect water in the stator chamber. The thermal switches and FLS shall be connected to a control and monitoring unit provided by the pump manufacturer for mounting in the field in an electrical panel as shown on the plans.

PUMP STATION CONTROL PANEL (LWP-3 AND LWP-4)

Furnish a duplex automatic pump control center in a NEMA 4X stainless steel enclosure. Panel shall be designed for submersible pump application and supplied by the pump manufacturer. The control panel shall be designed for 460 V, three phase power supply. The panel shall be conform to the NEC, NEMA, ISA, ANSI, NFPA 79 and UL 508A industry standards.

Soft starters shall be provided by the manufacturer in a configuration suitable for panel mounting. All power devices and components shall be accessible during routine maintenance or set up.

The soft start shall utilize a thyristor (SCR) bridge consisting of at least two SCRs per phase to control the starting and stopping of industry standard motors. The soft start shall provide torque control for linear acceleration without external feedback, independent of motor load or

type of application. The soft start shall be controlled by a microprocessor that continuously monitors the current and controls the phasing of the SCRs. All soft start power ratings will utilize the same control module. Power terminals shall be provided to simplify shorting contactor integration without additional components. The soft start shall accept control logic either by operator devices (push buttons, selector switches, etc.) wired directly to the unit or from external relay logic.

Circuit breakers shall be indicating type, providing "on – off –trip" positions of the operating handle.

A control power transformer shall provide 120 Volts for the external level sensing circuits and other pilot circuitry. Fuse or circuit breaker shall protect the primary and secondary of the control power transformer. The panel shall incorporate a separate motor thermal protection circuit for each pump motor. The circuit shall be manually reset after a stator thermal overload but automatically reset after a power failure.

All control relay components shall be mounted on DIN rails. Terminals shall be provided for all incoming and outgoing circuits, except for the motor load cables, which may be connected directly to the overload relay terminals. All wires in the control panel shall be color coded by voltage. Power supply wires shall be isolated from the control wires. Control wiring is to be run in wire channels and not simply tied together. A nameplate shall be permanently affixed to the inside of the control enclosure. The nameplate shall have a stamped or engraved serial number and shall also identify the motor horsepower and amperage of the pump(s).

A self-contained solid-state control switchboard device to operate two pumps and two alarms shall be included. The unit will display status information for pumps, pump fault, mode of operation, next to start and level alarms. Controller will permit all essential operating parameters to be adjusted via the front key pad including setting levels; time delays; sensitivities; pump alternation; hand-off-auto; and fault resets. The unit will accept level information from a pressure transducer made and marketed by the pump manufacturer. Included with this device shall be the following functions:

A. An electronic alternator providing automatic alternation of the pumps under normal operating conditions and allowing the capability for future operation of both pumps during a high level condition.
B. Wet well level indication.
C. Improved pump station efficiency by automatically changing the pump start levels to suit demand. Accomplished by setting a start frequency for the station. For instance, if four station starts per hour have been set and the LEAD pump is called earlier than 15 minutes from the last pump operation, then the controller will automatically increase the level at which the pump starts, up to the next sensor.
D. Maximum pump off time. If no pump has activated within the set time the Lead pump will be run. (This function is used to prevent stations becoming septic.) Operator selectable time interval from 15 minutes to 10 hours.
E. Maximum pump run time operator selected from 15 minutes to 10 hours. If a pump run exceeds the set time it will be deactivated and wait for the next start signal.
F. Maximum pump start frequency. The controllers provide the facility to set limits on the number of pump starts per hour to reduce the risk of damage to pumps.
G. Level alarm override. The level alarm can be set to override the maximum pump starts per hour and maximum pump run times.
H. Random duty start delay. This function delays the start of the Lead pump by a random amount from zero to a selectable maximum time. Helps keep wet well clean.

I. Interrupt delay. Ability to select a delay to prevent any pump starting within a certain period of another pump starting or stopping. Used to prevent water hammer problems.
J. Lead lockout on consecutive starts. This function helps to detect failure of the Lead pump by detecting repeated starts of the Lag pump.
K. Start/Stop delay: programmable start and stop delays for all pumps and level alarms.
L. Hand-Off-Auto (H-O-A) selector switches for each pump.
M. Run lights. Lights to show that a pump is running, pump failure and high water in lift station shall be included in the station.
M. A high water alarm using a separate float type sensor shall be provided.
O. A low water level sensor using a separate float shall inhibit pump operation.
P. Capability of integrating the control system "Auto mode" with the future Irrigation Controller, by allowing pump start enable input from the Irrigation Controller and by providing a high alarm signal output to the Controller, to override its built in timer and allow the pump to start.
W. Provide common trouble alarm contact for interface to the OMC Bldg. PLC.
X. Accept FLS sensor input providing the same functions as the Mini-CAS relay(s).
Y. Provide an RS 232 communications link.

The following additional functions shall be provided.

A. Elapsed time meters.
B. Pump starts counters.
C. Amps meters for each pump.
D. Dome light for high water condition.
E. Wiring diagrams.
F. Convenience outlet 15 amps.
G. Anti-condensation heaters.
H. Control panel intrusion alarm.
I. Padlock hasp and eye for outside door of panel.
J. Two days On-site start-up assistance.
K. Furnish a separate 460/120 V single phase industrial transformer rated 2 KVA, to service the Irrigation Controller and its miscellaneous loads. Transformer shall be furnished with factory installed primary and secondary fusing. Furnish with factory wired circuit breaker type disconnect on load side of transformer.

PUMP INSTALLATION

Contractor shall verify that equipment purchased will function within the spaces provided allowing for equipment access and simultaneous operation of two pumps without affecting each other. Contractor shall verify that the pumps proposed will work with the given geometry of the pump basin. Contractor shall verify that pumps can be installed and removed through floor access hatches provided and propose modifications as necessary at no additional expense to the State. Contractor shall be responsible for installing a code-compliant operational and tested system.

The pumps shall be installed as shown on the plans and in accordance with the manufacturer's written instructions. Moving parts shall be lubricated as recommended in the manufacturer's written instructions. Each pump shall be securely anchored and connections tightened. Pumping units shall be installed level and plumb to ensure the units are uniformly supported. The Contractor shall check for ease of pump movement on slide rails before

permanently securing the discharge flange in place. The Contractor shall also check for leakage at pump discharge flange and make adjustments to eliminate any leakage.

Level sensors and controls for LWP-3 and LWP-4 shall be installed and paid for under this special provision. Level sensors and controls for LWP-1 and LWP-2 will be installed under the Special Provision titled "Tunnel Control Systems".

The following installation and post installation work shall be included:

A. Nameplate. Install nameplate for each storm water pump in location where it can be easily read.
B. Controls installation. Coordinate with instrumentation and electrical regarding purchase, installation and adjustment of controls
C. Access requirements. Coordinate with the structural concrete sump work on the location of access hatches, temporary lifting device and grout work shown on the plans to ensure that pumps can easily be removed and serviced.
D. Cleaning. Clean grease, oil, or other debris from the exterior surfaces of the pumps and motors.
E. Instruction. Manufacturer's service representatives shall provide instruction in maintenance and operation of the pumps and control panel as described in the special provision "Mechanical Materials and Methods".

Testing.--After installation, each pump shall be tested in accordance with the manufacturer's written instructions. Contractor shall provide water required for the tests at no additional cost to the State. Each pump shall be field tested to establish field head, flow and overall efficiency. Report and test shall include flow, discharge pressure, voltage, power and amperage measurements. Additional performance tests are specified in the special provision "Leach Water Pumping Station Piping and Appurtenances"

PAYMENT

Full compensation for storm water pumps shall be considered as included in the contract lump sum price paid for leach water system and no additional compensation will be allowed therefor.

10-5.__ ROADWAY DRAINAGE SYSTEM

GENERAL

The roadway drainage system shall consist of furnishing, installing, testing and commissioning the roadway drainage piping and appurtenances downstream of the slotted drainage system in the tunnel.

SUMMARY

Scope.--The roadway drainage system shall include the following:

A. Vaults interfacing to the slotted drainage system and all piping and accessories downstream of these interface vaults, including manholes MH-6 through MH-11, including the manway access cover plates and vent lines in the Oil/Water Separator Tank and the Wash Water Storage Tank.

B. The work shall include the gravity drainage piping between MH-11 and the area inlet "k" of Caltrans' Drainage System No 4 as shown on the plans..
C. The road drainage slotted drains and road drainage interceptors which are not in the scope of work of this section are described in "Reinforced Concrete Drain" of these special provisions.
D. The concrete and excavation work for the Oil/Separator Tank and the Wash Water Storage Tank are described and paid for under pay items "Structure Concrete Portal" and "Structure Excavation (South Portal)" of these special provisions.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04 "Equipment List and Drawings" of the Standard Specifications and the requirements specified herein.

Product Data.--The Contractor shall submit manufacturer's technical data for each type of product in the roadway drainage system.

Working Drawings.--The Contractor shall submit working drawings in conformance with Section 5-1.02 "Plans and Working Drawings" of the Standard Specifications and these special provisions. The working drawings shall include the following:

A. Working drawings showing dimensions, details, anchorage details, reinforcement and the manner of installation.
B. A scalable (1:125 minimum) plan layout of the drainage system showing each standard pipe joint and each special joint or fitting by number. The layout shall include invert elevations at all intersections with manholes, vaults and tanks.
C. A transverse section looking north across manholes MH-6 through MH-9 showing all utility crossings.
D. Details of concrete manholes, including rebar details and access lid details.

DUCTILE IRON PIPE (FOR BURIED SERVICE)

Ductile iron pipe shall be centrifugally cast in 5.5 m or 6.1 m nominal lengths conforming to AWWA C151. Pipe shall be seal coated and shall have standard thickness cement mortar lining conforming to AWWA C104. Pipe shall be pressure Class 2.41 MPa pipe and shall be provided with push on joint ends.

Pipe Coating System: Outside coating of pipe and fittings shall be minimum 0.025 mm asphaltic coating in accordance with AWWA C151, Section 51-9.

A. The exterior of the pipe and fittings shall have field applied polyethylene encasement in tube or sheet form conforming to the requirements of AWWA C105. The wrap material shall be minimum 0.102 mm thick high density, cross laminated polyethylene film.

FITTINGS (FOR BURIED SERVICE)

Fittings for the pus-on joint ductile iron pipe shall be ductile iron of Class 250 gray iron conforming to ANSI/AWWA C110 or C153. Joint components shall conform with the requirements for push-on joints in ANSI /AWWA C111. Fittings shall be seal coated and shall be standard thickness cement mortar lined conforming to AWWA C104. External coating and encasement shall be similar to that specified for the connecting pipe.

Flanged joint fittings conforming to AWWA C115 shall be allowed for use in MH-10 when connecting to plug valves and tees in the manhole.

PLUG VALVES

Plug Valves: All plug valves shall be eccentric plug type unless otherwise specified herein or shown on the plans.

A. Valves shall be of the non-lubricated eccentric type with Buna-N resilient faced plugs and shall be furnished with flanged end connections. Flanges shall be faced and drilled to the ANSI 125/150 lb. standard. Valve bodies shall be of the rectangular ported design and made of ASTM A126 Class B cast iron and with bolted bonnets. Port area shall not be less than 100% of the pipe area. Bodies shall be furnished with welded overlay seats of not less than 90% pure nickel. Seat area shall be raised with surface completely covered with weld to insure that the plug face contacts only nickel.
B. Plug shall be of ASTM A 126 Class B cast iron. The plug shall have a cylindrical seating surface eccentrically offset from the plug shaft. The interference between the plug face and the body seat shall be externally adjustable in the field with the valve in the line and in contact with water.
C. Valves shall have sleeve or journal type metal bearings of sintered, oil impregnated, permanently lubricated, type 316, stainless steel. Grit seals shall be furnished in the upper and lower journals to prevent abrasive media from entering the bearing and seal areas. Stem seals shall be multi-V ring adjustable packing type and shall be replaceable in-line without valve disassembly. Bronze cartridge type seals with two "O" rings shall be an acceptable alternate.
D. Valve shall have gear operator on extended bonnet as shown on the plans and shall require not more than 50 lbs. force at the rim of the hand wheel under all operating conditions. Valve shall be furnished with travel stops for the full open and closed positions and be provided with intermediate position indication in 15 degree increments. Valve shall be furnished with dry contact limit switch mounted on the gear box to indicate movement from the normal position.
E. The valve interior shall be coated with 0.152 mm of a two part hi-build epoxy. The exterior of the valve shall be prime coated with a universal base primer.
F. Valves shall be rated for minimum 1.21 MPa working pressure.

PRECAST OR CAST IN PLACE MANHOLES

The Contractor shall provide and install manholes as shown and detailed on the plans. Refer to Section 8-2 "Concrete" of these special provisions for concrete material requirements. The minimum strength of the concrete used shall be 28 MPa.

GRADE AND ALIGNMENT

The Contractor shall verify the locations and establish the depth of new and existing utilities at the points where crossings are required for the drainage lines. Coordinate with structural for the lines that are embedded in the south portal cut and cover structures.

Where elevation of pipeline and ground surface is shown on the plans, pipeline shall be laid to the elevation shown. Elevation changes where required to miss new or existing utilities shall be made after submittal of request for change is approved by the Engineer.

TRENCH EXCAVATION (FOR PIPE ROUTED OUTSIDE THE TUNNEL)

The Contractor shall perform all excavation of earthwork encountered to the depth shown on the plans or specified in these special provisions. Excavations shall be made by open cut. Trenches shall be excavated to true and smooth bottom grades and in accordance with the lines approved by the Engineer. The trench bottom shall provide uniform bearing and support for each length of pipe.

Bell holes shall be excavated to the extent necessary to permit accurate work in making and inspecting the joints. The banks of the trenches shall be kept as nearly vertical as soil conditions will permit. The trench shall be sheeted and braced. to control trench width or to protect adjacent structures,

Over excavation below that depth shall be backfilled with select backfill material and compacted as specified herein in these special provisions.

BEDDING THE PIPE (FOR PIPE ROUTED OUTSIDE THE TUNNEL)

Bedding material meeting the requirements described in these special provisions shall be placed under the pipe and to a depth of at least 150 mm over the top of the pipe. The bedding material shall be rammed and tamped around the pipe by the use of shovels or other approved hand held tools, so as to provide firm and uniform support over the full length of all pipe, valves, and fittings without damage to the pipe and fittings.

BACKFILLING TRENCHES

Prior to backfilling, all form lumber and debris shall be removed from the trench. Sheeting used by the Contractor shall be removed just ahead of the backfilling.

Backfill material meeting the requirements described in these special provisions shall be placed in maximum 150 mm lifts.

A minimum 75 mm sand cushion shall be placed between the buried fire protection lines and crossing water main or other pipelines and conduits encountered during installation.

Bedding and backfill conditions shall conform to Type 4 or Type 5 as described and detailed in Table 2 of ASTM A 746.

Backfill shall be compacted to at least 95 percent of maximum density or until the density of the backfill and the adjacent material at the same elevation is accepted by the Engineer.

At locations where paved streets, roadway shoulders, driveways, or sidewalks will be constructed or reconstructed over the trench, the backfill shall be spread in layers (lifts) as described above, and be compacted by mechanical tampers. Each 150 mm layer shall be compacted with mechanical tampers to the density specified herein. Mechanical tampers shall be of the impact type, or as shown on the plans or specified in these special provisions.

COORDINATION

The Contractor shall coordinate work with all other utility work on site.

TESTING

Test the drainage piping for leaks in accordance with Section 61.1.02 paragraph F of the Standard Specifications.

MEASUREMENT AND PAYMENT

The contract lump sum price paid for roadway drainage system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for performing all the work involved in furnishing and installing the roadway drainage system

complete in place, including testing as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-5.__ HEATING AND VENTILATION OF TUNNEL ANCILLARY SPACES

GENERAL

Heating and ventilation of tunnel ancillary spaces shall conform to the details as shown on the plans and the requirements specified in these special provisions.

SUMMARY

Scope.--Heating and ventilation of tunnel ancillary spaces shall include the following:

A. Draw-through, constant volume central-station air-handling units with electric heating coils required to meet specified performance requirements for ventilation, heating, pressurization, filtration and distribution. These units shall be suitable for indoor use at the tunnel service chambers and fire pump room.
B. The tubular centrifugal fans used to ventilate and pressurize the tunnel cross-passages.
C. Fiberglass reinforced plastic fresh air ducts used to convey the fresh air to the spaces in the tunnel service chambers, fire pump room, and tunnel cross-passages.
D. Floor drains, embedded and indoor drain piping serving the outside and relief air plenums at the north and south electric chambers.
E. Buried piping serving the outside air and relief air structures at the north and south portal cut and cover areas.

SUBMITTALS

Product data.--The Contractor shall submit manufacturer's technical data of heating, ventilating, and distributing equipment. Manufacturers' technical data for each item of equipment specified shall include the following:

A. Certified fan-performance curves with system operating conditions indicated.
B. Certified fan-sound power ratings.
C. Certified heating coil-performance ratings with system operating conditions indicated.
D. Motor ratings and electrical characteristics plus motor and fan accessories.
E. Material gages and finishes.
F. Filters with performance characteristics
G. Dampers including housings, linkages, and operators.

Working drawings.--

The Contractor shall submit working drawings in conformance with Section 5-1.02, "Plans and Working Drawings," of the Standard Specifications and these special provisions.

Working drawings shall include complete details, information, drawings, and substantiating calculations of proposed materials, facilities, equipment to be used and method of construction.

The working drawings shall include the following:

A. Drawings or catalog cuts from manufacturer detailing equipment assemblies including all factory furnished accessories and indicating dimensions, weights, loadings, required

clearances, method of field assembly, components, and location and size of each field connection.

B. Catalog cut of the buried fiberglass fresh air duct including all chemical and physical properties. Furnish layout drawings for this duct drawn to a minimum 1:100 scale and clearly indicating all changes in direction.
C. Electric heating terminal box, diagram showing wiring and other components in the terminal box and electrical schematic showing all components of the electric heating coil package.
D. Wiring diagrams detailing wiring for power and control systems and differentiating between manufacturer-installed and field-installed wiring.
E. Variable frequency drive connection and power wiring diagrams.
F. Coordination drawings including the following:

    1. Floor plans and sections drawn to scale.
    2. Service chamber layout and relationships between components and adjacent structural and mechanical elements.
    3. Support locations, type of support, and weight on each support.
    4. Attachments to structural walls and ceilings.

G. Maintenance data for each heating and ventilation unit and pressurization fan to be included in the operation and maintenance manual in conformance with the requirements specified in Section, "Mechanical and Materials and Methods," of these special provisions.

Each working drawing and calculation sheet shall be signed by an engineer who is registered as a Mechanical Engineer in the State of California.

Complete working drawings shall be submitted to the Engineer. After complete working drawings are received by the Engineer, the Contractor shall allow the Engineer 30 working days to review the submittal. No construction of heating and ventilation of tunnel ancillary spaces shall begin until complete working drawings are reviewed and approved, in writing, by the Engineer.

Field test reports.--The Contractor shall submit to the Engineer field test reports indicating and interpreting test results relative to compliance with specified requirements.

QUALITY ASSURANCE

Ventilation fan units and components shall be designed, fabricated, and installed in conformance with the requirements in NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."

Central-station air-handling units and their components shall be factory tested in conformance with the requirements in ARI 430, "Central-Station Air-Handling Units".

Electrical components, devices, and accessories shall be listed and labeled in conformance with requirements in NFPA 70, Article 100, by UL, and marked for intended use.

The Contractor shall provide AMCA certified fan and damper performance ratings. Components and installation shall conform to the requirements in NFPA 70.

DELIVERY, STORAGE, AND HANDLING

Central-station air handling units and tubular centrifugal fans shall be delivered as factory-assembled modules with protective crating and covering. Units shall be lifted and supported with manufacturer's designated lifting or supporting points.

INLINE PRESSURIZATION FANS

In-line pressurization fans shall be factory assembled units. Each unit shall consist of a centrifugal belt drive fan assembly in a tubular housing which is mounted in-line with the inlet and outlet duct. The assembled unit shall bear the AMCA certified ratings seal for both the sound and air performance.

The fan housing shall be constructed of continuously welded heavy gage steel and square duct mounting collars. Housing shall include removable, gasket-lined access panel located perpendicular to the motor mounting panel. The access panels shall permit access to all interior components.

The fan wheel shall be centrifugal backward inclined, constructed of aluminum and shall include a wheel cone carefully matched to the inlet cone for precise running tolerances. Wheels shall be statically and dynamically balanced at the factory.

Motors shall be TEFC type with heavy duty ball bearings matched to the fan load.

Belt drives shall be sized for a minimum of 150 percent of the driven power. Pulleys shall be fully machined cast iron construction keyed to the wheel and motor shafts. The pulley on the motor shall be adjustable for final system balancing. Motors and drives shall be mounted out of the airstream.

Shafts shall be precision ground and polished and shall be mounted in permanently sealed and lubricated pillow block bearings. Bearings shall be selected for a minimum (L10) life in excess of 80,000 hours at maximum operating speed.

The entire inside and outside of the fan housing shall include a factory applied two part polyamide resin (epoxy) coating.

Each unit shall be furnished with companion duct flanges on each end, belt guard, motor cover, spring isolation hangers, and inspection door on fan.

ELECTRIC CHAMBER HEATING AND VENTILATION UNITS

Electric chamber heating and ventilation units shall be factory assembled and shall, consist of fans, motor and drive assembly, electric heating coils, plenums, filters, and mixing dampers.

The arrangement shall be draw-through with top front upblast, or top horizontal front discharge, and right-hand or left-hand fan arrangement to provide access as shown on the plans. Access doors and panels to allow periodic maintenance and inspections.

Materials shall include formed and reinforced galvanized steel panels, fabricated to allow removal for access to internal parts and components, with joints between sections sealed, and the following:

A. Outside casing: pre-painted galvanized steel, 1.0 mm thickness, capable of withstanding Federal Test Method Standard No. 141 (Method 6061) 500 hour salt spray test. Casing panels shall be removable for easy access to the unit. All panels shall be gasketed to ensure a tight seal.
B. Floor plate: galvanized steel, 3.5 mm thickness.

Insulation shall be coated, dual density glass-fiber insulation, 24 kg/m^3 density, in conformance with the requirements for insulation in NFPA 90A, "Installation of Air

Conditioning and Ventilating Systems." Insulation shall be 25 mm thickness and factory applied with waterproof adhesive and mechanical fasteners to the internal surface of all section panels.

Access panels and doors shall be double wall with 24 kg/m^3 density fiberglass insulation between galvanized steel panels, using the same materials and finishes as the casing and complete with hinges, latches, handles, and gaskets.

The fan section shall include belt-driven centrifugal fans, consisting of housing, wheel, fan shaft, bearings, motor and disconnect switch, drive assembly, and support structure, equipped with formed-steel channel base for integral mounting of fan, motor, and casing panels. The fan scroll, wheel, shaft, bearings, and motor shall be on a structural-steel frame, to be rigidly mounted to the base unit. Construction of the fan section shall include the following:

A. Housings: fabricate from formed- and reinforced-steel panels to form curved scroll housings with shaped cutoff, spun-metal inlet bell, and access doors or panels to allow entry to internal parts and components.
B. Fan wheel assemblies: statically and dynamically balanced and designed for continuous operation at maximum rated fan speed and motor power. Fan wheel shall be double-width, double-inlet type with forward-curved blades.
C. Forward curved: bonderized steel painted with baked enamel or galvanized steel, and having an inlet flange, back plate, shallow blades with inlet and tip curved forward in direction of airflow, and steel hub. Fan wheels and shaft shall be selected to operate at least 25 percent below the first critical speed.
D. Shafts: hot-rolled steel; turned, ground, and polished, and having keyway to secure to fan wheel hub.
E. Shaft bearings: prelubricated and sealed, self-aligning, pillow-block-type ball or roller bearings with the rated bearing life: ABMA 9 or ABMA 11, L-50 of 200,000 hours.
F. Belt drives shall be factory mounted, with final alignment and belt adjustment made after installation. Belt drive shall including the following:

    1. Service factor based on fan motor nameplate power: 1.3.
    2. Pulleys: cast iron or steel with split, tapered bushing, dynamically balanced at factory.
    3. Motor pulleys: adjustable pitch, selected so pitch adjustment is at middle of adjustment range at fan design conditions.
    4. Belts: oil resistant, nonsparking, and nonstatic; matched set for multiple belt drives.
    5. Motor mount: adjustable for belt tensioning. Fan motor shall be mounted within the fan section casing on slide rails having 2 adjusting screws.

The following factory tests shall be performed for the fan section:

A. Sound power level ratings shall conform to AMCA 301, "Methods for Calculating Fan Sound Ratings from Laboratory Test Data." Test fans shall conform to AMCA 300, "Reverberant Room Method for Sound Testing of Fans." Fans shall bear AMCA-certified sound ratings seal.
B. Factory test fan performance for flow rate, pressure, power, air density, rotation speed, and efficiency. Ratings shall be established in conformance with AMCA 210, "Laboratory Methods of Testing Fans for Rating."

Motors shall conform to the following requirements:

A. Torque characteristics: sufficient to accelerate driven loads satisfactorily.

B. Motor sizes: minimum size as indicated on the schedule or large enough so driven load will not require motor to operate in service factor range.
C. Temperature rating: 45°C maximum temperature rise at 40°C ambient for continuous duty at full load (Class A insulation.)
D. Service factor: 1.15.
E. Motor construction: NEMA MG-1, general purpose, continuous duty, Design B, with adjustable bases, and suitable for inverter duty and be specifically matched for operation with the variable frequency drives (VFD's) specified herein.
F. Bearings: ball or roller bearings with inner and outer shaft seals, grease lubricated, designed to resist thrust loading where belt drives or other drives produce lateral or axial thrust in motor.
G. Enclosure type: TEFC Motor
H. Overload protection: built-in, automatic reset, thermal overload protection.
I. Noise rating: quiet.
J. Efficiency: energy-efficient motors shall have a minimum efficiency as scheduled according to IEEE 112, Test Method B. If efficiency is not specified, motors shall have a higher efficiency than "average standard industry motors" according to IEEE 112, Test Method B.
K. Nameplate: indicate full identification of manufacturer, ratings, characteristics, construction, and special features.
L. Power wiring: power wiring and connections to the VFD shall conform to requirements specified in Section 10-4, "Tunnel Electrical," of these special provisions.

Electric-resistance coils shall be open-wire type, 80 percent nickel, 20 percent chromium elements, uniformly distributed and supported in aluminized or galvanized steel frame with vertical support brackets and insulated with floating ceramic bushings. Bushings shall be recessed into embossed openings and stacked into supporting brackets spaced not more than 100 mm on center.

Control panel shall be a NEMA 250, Type 1 enclosure, with thermal cutouts, primary and secondary controls, staging contactors, back-up contactors, circuit fusing, airflow switch, and fused control transformer, and shall include integral primary automatic and secondary manual reset thermal-protection devices and airflow switches.

Controls shall include circuitry for six stages of heating. All stages shall be phase balanced. A pre-wired terminal block shall be furnished for connection of the low voltage wires from the DDC system.

The leakage rate of dampers shall conform with AMCA 500, "Test Methods for Louvers, Dampers and Shutters," and shall not exceed 2 percent of air quantity at 10 m/s face velocity through damper and 1000 Pa pressure differential. Damper operators shall be electrically operated.

Electric or electronic actuators shall conform to the following requirements:

A. Provide for all motor operated dampers sufficient size and type, matched to application.
B. Provide with solid state positioner to stop automatically at end of travel.
C. Complete with permanently lubricated gear train.
D. Provide analog, current proportional or 2-position actuators with visual position indication.
E. Provide with spring return to normally-open or normally closed on loss of control power.
F. Power return type actuators shall not be acceptable.

G. Calculate damper torque requirements and include documentation of sufficient actuator power.
H. Power requirements: 24 V, single phase, 60 Hz, with interface module providing current or voltage control 4-20 mA and 2-10 V(dc) with adjustable zero and span.

Combination filter and mixing box shall include parallel-blade galvanized steel damper blades mechanically fastened to steel operating rod rotating in nylon bushings and mounted in rigid galvanized steel frames. Operating rods shall be connected with common linkage and interconnect linkages so dampers operate simultaneously. Cabinet support members shall hold 50 mm thick pleated throwaway filters. Filters shall be arranged in an angled pattern for increased area for airflow. Hinged access doors shall be provided to allow removal of filters from both sides of unit.

VARIABLE FREQUENCY DRIVES (VFD) WITH ELECTRONIC BYPASS

Variable frequency drives (VFD) with electronic bypass shall conform to the following requirements:

A. Description: NEMA ICS 7.0, pulse-width-modulated, variable-frequency controller; listed and labeled as a complete unit and arranged to provide variable speed of a NEMA MG 1, Design B, 3-phase, induction motor by adjusting output voltage and frequency.
B. Design and rating: match the load type such as fans, blowers, and pumps, and the type of connection used between motor and load such as direct or through a power-transmission connection.
C. Output rating: 3-phase, 6 to 60 Hz, with voltage proportional to frequency throughout voltage range.
D. Starting torque: 100 percent of the rated torque or as shown on the plans.
E. Speed regulation: plus or minus one percent.
F. ambient temperature: -25°C to +40°C.
G. Efficiency: 95 percent minimum at full load and 60 Hz.
H. Minimum displacement power factor at input terminals: 95 percent.
I. Isolated control interface shall allow controller to follow control signal over an 11:1 speed range.
J. Inputs and outputs: two programmable analog inputs (current or voltage), two programmable analog outputs (4 to 20 mA at 24 V), six programmable digital inputs, and three programmable digital Form-C relay outputs.
K. Electrical signal: input signal will be preset in the field to operate fan at two discrete speeds. The Contractor's attention is directed to "Tunnel Control Systems" of these special provisions for description of operating sequence and connection to DDC System.
L. Internal adjustability: include the following internal adjustment capabilities:

    1. Minimum speed: 10 to 25 percent of maximum rpm.
    2. Maximum speed: 80 to 100 percent of maximum rpm.
    3. Acceleration: 2 to 22 seconds
    4. Deceleration: 2 to 22 seconds
    5. Current limit: 50 to 110 percent of maximum rating.

M. Multiple-motor capability: controller suitable for service to a single motor and have a separate overload relay and protection for the controlled motor. Overload relay shall shut off the controller and motors served by it when overload relay is tripped.

N. Self-protection and reliability features shall include the following:

1. Input transient protection by means of surge suppressors.
2. Snubber networks to protect against malfunction due to system voltage transients.
3. Motor overload relay: adjustable and capable of NEMA 250, Class 10 performance.
4. Notch filter to prevent operation of the controller-motor-load combination at a natural frequency of the combination.
5. Instantaneous overcurrent trip.
6. Loss-of-phase protection.
7. Reverse-phase protection.
8. Under- and overvoltage trips.
9. Overtemperature trip.
10. Short-circuit protection.

O. Automatic reset and restart: attempt three restarts after controller fault or on return of power after an interruption and before shutting down for manual reset or fault correction. Restarting during deceleration shall not damage controller, motor, or load.

P. Power-interruption protection: prevents motor from re-energizing after a power interruption until motor has stopped.

Q. Input signal protection: The VFD shall hold at the last input signal received and signal an alarm.

R. Panel-mounted operator station: the operator station shall include a keypad with a backlit LCD display, and shall provide for bypass-hand-off-auto selections and manual speed control. All applicable operating values shall be capable of being displayed in engineering units. The operator station shall have a built-in time clock with a 10-year battery backup. The clock shall be programmable to control start and stop functions, constant speeds, PID parameter sets and output relays. A digital input shall allow the time clock to be overridden. In addition, door-mounted LED indicators shall indicate the following conditions:

1. Power On.
2. Run.
3. Overvoltage.
4. Line fault.
5. Overcurrent.
6. External fault.

S. Electronic bypass: factory wired and tested bypass system shall consist of an output contactor and bypass contactor. Overload protection and shall be provided in both drive and bypass modes.

T. Integral disconnecting means: NEMA AB 1, instantaneous-trip circuit breaker, AB 1, molded-case switch with lockable handle.

OUTSIDE AIR AND RELIEF AIR BURIED DUCTS

The round ducts buried in the cut and cover areas and embedded in the concrete structure at the north and south equipment chambers shall be fiberglass reinforced plastic. Duct and fittings shall conform to the requirements of Uniform Mechanical Code, Chapter 6, and shall be listed with the California State Fire Marshall for direct burial installation. The duct shall have a UL listed Class 1 inner liner. The structural layer of the duct shall be filament wound of resin and

glass. The resin shall be an isophthalic polyester or ester. The duct shall be capable of withstanding the soil pressure and duct working pressure at the burial depths indicated. As a minimum, the vertical buried duct shall be designed to withstand 144 kPa lateral soil pressure at a depth of 8 meters. The duct shall be rated for minimum operating pressures of positive 2.47 kPa and negative 1.19 kPa. The minimum duct wall thickness shall be 8 mm.

Fitting connectors shall be watertight, bell and spigot type with 150-mm bell, combined with manufacturer's standard couplings. The bell and spigot joint shall be sealed with a resin putty. Couplings shall consist of waterproof flexible collar with an adhesive on one side. The collar shall be wrapped around the bell and spigot joint and secured to the duct using stainless steel straps, and wrapped again.

Fittings shall be fabricated from straight duct and have the same working pressure with bell ends or plain-end.

MISCELLANEOUS ACCESSORIES

Miscellaneous accessories consisting of piping and drains shall conform to the following requirements:

A. Buried cast iron soil piping: hub-and-spigot pipe and fittings: ASTM A74, Service and Extra-Heavy classes. Gaskets: ASTM C564, rubber.
B. Embedded and indoor steel drain piping: ASTM A53, Type E or S, Grade A or B, Schedule 40, galvanized. Include ends matching joining method, with the following:

    1. Steel pipe nipples: ASTM A733, made of ASTM A53 or ASTM A106, Schedule 40, galvanized, seamless steel pipe. Include ends matching joining method.
    2. Malleable-iron unions: ASME B16.39; Class 150; hexagonal-stock body with ball-and-socket, metal-to-metal, bronze seating surface; and female threaded ends.
    3. Cast-iron, threaded, drainage fittings: ASME B16.12 galvanized.
    4. Flanges: ASTM A105 for material, ASTM B16.5 for dimensions, faced to match mating equipment. Provide 1.5 mm thick red rubber gasket.

C. Embedded and indoor copper DWV tube: ASTM B306, drainage tube, drawn temper. Copper drainage fittings: ASME B16.23, cast copper or ASME B16.29, wrought copper, solder-joint fittings.
D. Floor drain (FD-1): where plumbing specialties of this designation are indicated, provide products, of size as shown on the plans and complying with the following:

    1. Applicable standard: ASME A112.3.1.
    2. Body material: cast iron.
    3. Seepage flange: required.
    4. Clamping device: not required.
    5. Outlet: bottom.
    6. Top or strainer material: cast iron.
    7. Top shape: dome.
    8. Dimensions of top or strainer: 200 mm.
    9. Top loading classification: light duty.
    10. Funnel: not required.

INSTALLATION

Heating and Ventilation Units.--

Ventilation fans shall be installed level and plumb, according to manufacturer's written instructions. Ventilation units in the cross passages shall be suspended from the concrete ceiling using embedded inserts, threaded steel rods and vibration isolation.

Central-station air-handling units shall be installed level and plumb, according to manufacturer's written instructions. Installation of units shall be arranged to provide access space around air-handling units for service and maintenance. Final duct connections shall be made with flexible connections.

All electric chamber HVAC systems shall be monitored and controlled by the DDC system specified in "Tunnel Control Systems" of these special provisions.

After completing installation, the Contractor shall inspect the exposed finish, remove burrs, dirt, and construction debris, and repair damaged finishes including chips, scratches, and abrasions. Fan interiors shall be cleaned to remove foreign material and construction dirt and dust. Fan wheels, cabinets, and coils entering air face shall be vacuumed clean. Temporary filters shall be installed as directed by the Engineer during construction prior to commissioning. The Contractor shall vacuum clean and inspect each section of fresh air duct prior to installing the next section, and vacuum clean the complete embedded duct using an industrial grade duct cleaning system compatible and non corrosive to fiberglass resins to remove all obstructions and loose items. The duct shall be completely dried if moisture or standing water is present.

Buried Duct

Thermoset FRP ducts and fittings shall be installed in conformance with the requirements in NFPA 91.

Buried duct excavation, bedding and backfilling shall be coordinated with tunnel north and south portal cut and cover work. The Contractor shall provide for excavation, bedding, and backfilling for FRP ducts in accordance with duct manufacturers recommended installation instructions. For horizontal ducts, installation shall be coordinated such that the structure backfill is completed to the designed elevation, and then the duct trench is installed. For vertical ducts, sheet metal casings shall be provided to protect the FRP duct from structure backfill. Mechanical compaction shall not be used around ducts. Water shall be removed from the trench to maintain a reasonable dry condition until the duct has been installed and enough backfill placed to prevent any flotation of the duct.

Ducts shall be installed with the fewest joints possible. Ducts shall be installed vertically and horizontally, unless otherwise shown on the plans. Horizontal runs shall be pitched at 0.5 percent slope to the ventilation structure.

Drain Piping

Drain piping categories shall be as follows:

A. Embedded and indoor drainage piping in tunnel equipment chambers and fire pump room:

   1. 32 and 40 mm nominal size: steel pipe galvanized with cast iron galvanized drainage fittings and threaded joints, or copper DWV tube, copper drainage fittings and soldered joints.
   2. 50 to 100 mm nominal size: steel pipe galvanized with cast iron galvanized drainage fittings threaded on flanged joints, or copper DWV tube, copper drainage fittings and soldered joints.

B. Buried drainage piping at north and south tunnel portals consisting of service class, cast-iron soil pipe and fittings, gaskets, and gasketed joints.

Drain piping shall conform to the following requirements:

A. Attention is directed to "Mechanical Materials and Methods" of these special provisions for basic piping installation and joint construction.
B. Install soil and waste drainage and vent piping at the following minimum slopes, unless otherwise indicated: horizontal drainage piping: 2 percent downward in direction of flow.
C. Install cast-iron soil piping in conformance with CISPI's "Cast Iron Soil Pipe and Fittings Handbook," Chapter IV, "Installation of Cast Iron Soil Pipe and Fittings."
D. Make changes in direction for cast iron soil piping using appropriate branches, bends, and long-sweep bends. Direction of flow shall not be changed for more than 90 degrees. Use proper size of standard increasers and reducers if pipe of different sizes are connected. Reducing size of drainage piping in direction of flow will not be permitted.
E. Install buried piping true to grades and alignment indicated, with unbroken continuity of invert. Place hub ends of piping upstream. Install required gaskets according to manufacturer's written instruction for use of lubricants, cements, and other installation requirements. Maintain swab in piping and pull past each joint as completed.
F. The Contractor shall not enclose, cover, or put piping into operation until it is inspected and approved by the Engineer.
G. Attention is directed to "Hangers and Supports" of these special provisions for pipe hanger and support devices. Install the following:

    1. Vertical piping: MSS Type 8 or Type 42, clamps.
    2. Individual, straight, horizontal piping runs: 30 m and less: MSS Type 1, adjustable, steel clevis hangers.
    3. Base of vertical piping: MSS Type 52, spring hangers.

J. Support vertical piping and tubing at base and at each floor, and install supports for vertical steel piping every 4.5 m.
K. Install hangers for steel piping with the following maximum horizontal spacing and minimum rod diameters:

    1. 32 mm pipe: 2100 mm with 10 mm rod.
    2. 40 mm pipe: 2700 mm with 10 mm rod.
    3. 50 mm pipe: 3 m with 10 mm rod.
    4. 65 mm pipe: 3.4 m with 13 mm rod.
    5. 80 mm pipe: 3.7 m with 13 mm rod.
    6. Rod diameter may be reduced one size for double-rod hangers, with 10 mm minimum rods.

L. Piping and tubing shall be supported in conformance with MSS SP-69 and manufacturer's written instructions.
M. Protect drains during remainder of construction period to avoid clogging with dirt and debris and to prevent damage from traffic and construction work.
N. Place plugs in ends of uncompleted piping at end of day and when work stops.

Floor Drains

Floor drains shall be installed in conformance with manufacturer's written instructions, at low points of surface areas to be drained. Grates of drains shall be set flush with finished floor as shown on the plans. Size of outlets shall conform to the details shown on the plans. Traps shall not be provided for floor drains.

COMMISSIONING

A factory-authorized service representative shall perform the following duties:

A. Inspect field assembly of components and installation of central-station air-handling units including piping, ductwork, and electrical connections.
B. Prepare a written report on findings and recommended corrective actions.

The following final checks shall be performed before startup:

A. Verify that shipping, blocking, and bracing are removed.
B. Verify that unit is secure on mountings and supporting devices and that connections for piping, ductwork, and electrical are complete. Verify that proper thermal overload protection is installed in motors, starters, and disconnects.
C. Perform cleaning and adjusting.
D. Disconnect fan drive from motor, verify proper motor rotation direction, and verify free fan wheel rotation and smooth bearings operations. Reconnect fan drive system, align belts, and install belt guards.
E. Lubricate bearings, pulleys, belts, and other moving parts with factory-recommended lubricants.
F. Set outside-air and return-air mixing dampers to minimum outside-air setting.
G. Install clean filters.
H. Verify that manual and automatic volume control, and fire and smoke dampers in connected ductwork systems are in fully open position.

Starting procedures for central-station air-handling units shall include the following:

A. Energize motor; verify proper operation of motor, drive system, and fan wheel. Adjust fan to indicated rpm.
B. Replace fan and motor pulleys as required to achieve design conditions at 60 Hz operation with the VFD.
C. Measure and record motor electrical values for voltage and amperage.
D. Manually operate dampers from fully closed to fully open position and record fan performance.

Attention is directed to "Testing, Adjusting, and Balancing" of these special provisions for air-handling system testing, adjusting, and balancing.

MEASUREMENT

Heating and ventilation of tunnel ancillary spaces will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for heating and ventilation of tunnel ancillary spaces shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for performing all the work involved in furnishing and installing the heating and ventilation system, complete in place, including drain piping, hangers, supports, and commissioning, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-5.__ METAL DUCTS

GENERAL

SUMMARY

Scope.--Metal ducts, consisting of rectangular, round, and flat-oval metal ducts and plenums for heating, ventilating, and air-conditioning systems in pressure classes from -500 to +2490 Pa, shall conform to the provisions in Section 75 "Miscellaneous Metal" of the Standard Specifications and these special provisions.

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data of sealing materials and sheet metal materials.

Working Drawings.--The Contractor shall submit working drawings that include compete details, information and equipment selection criteria for the metal duct equipment as shown on the plans and as specified in these special provisions:

A. Record drawings drawn to a minimum 1:100 scale indicating actual routing, fitting details, reinforcement, support, and installed accessories and devices. Record drawings shall show clearances to building structure and other mechanical and electrical equipment.

DELIVERY, STORAGE, AND HANDLING

Sealant and fire-stopping materials shall be delivered to the site in original unopened containers or bundles with labels indicating manufacturer, product name and designation, color, expiration period for use, pot life, curing time, and mixing instructions for multi-component materials. Sealant and fire-stopping materials shall be stored and handled according to manufacturer's written recommendations.

Stainless steel sheets shall be delivered and stored with mill-applied adhesive protective paper that is maintained through fabrication and installation.

PRODUCTS

Sheet Metal.--Sheet metal shall conform to the following requirements:

A. Galvanized, sheet steel: lock-forming quality; ASTM A 653/A 653M, Z275 coating designation; mill-phosphatized finish for surfaces of ducts exposed to view.
B. Reinforcement shapes and plates: galvanized steel reinforcement where installed on galvanized, sheet metal ducts; compatible materials for aluminum and stainless-steel ducts.

C. Tie rods: galvanized steel, 6 mm minimum diameter for 900 mm length or less; 10 mm minimum diameter for lengths longer than 900 mm.

Sealant materials.--Sealant materials shall conform to the following requirements:

A. The term "sealant" is not limited to materials of adhesive or mastic nature but includes tapes and combinations of open-weave fabric strips and mastics.
B. Joint and seam sealant: one-part, non-sag, solvent-release-curing, polymerized butyl sealant, formulated with a minimum of 75 percent solids.
C. Flanged joint mastics: one-part, acid-curing, silicone, elastomeric joint sealants, complying with ASTM C 920, Type S, Grade NS, Class 25, Use O.

Hangers and supports.--Hangers and supports shall conform to the following requirements:

A. Building attachments: concrete inserts, powder-actuated fasteners, or structural-steel fasteners appropriate for building materials. Use powder-actuated concrete fasteners for standard-weight aggregate concretes or for slabs more than 100 mm thick. Contractor shall not use powder-actuated concrete fasteners for lightweight-aggregate concretes or for slabs less than 100 mm thick.
B. Hanger materials: round, threaded steel rod:

    1. Hangers installed in corrosive atmospheres: electro-galvanized, all-thread rod or galvanized rods with threads painted after installation.
    2. Rod sizes: comply with SMACNA's "HVAC Duct Construction Standards—Metal and Flexible" for sheet steel width and thickness and for steel rod diameters.
    3. Sheet metal straps: not allowed.

C. Duct attachments: sheet metal screws, blind rivets, or self-tapping metal screws; compatible with duct materials.
D. Trapeze and riser supports: steel shapes complying with ASTM A 36/A 36M:

    1. Supports for galvanized-steel ducts: galvanized steel shapes and plates.
    2. Supports for stainless-steel ducts: stainless-steel support materials.

Rectangular Duct Fabrication.--Ducts, elbows, transitions, offsets, branch connections, and other construction shall be fabricated with galvanized, sheet steel, in conformance with the requirements in SMACNA's "HVAC Duct Construction Standards—Metal and Flexible." Comply with requirements for metal thickness, reinforcing types and intervals, tie-rod applications, and joint types and intervals, and the following:

A. Lengths: fabricate rectangular ducts in lengths appropriate to reinforcement and rigidity class required for pressure classification.
B. Materials: free from visual imperfections such as pitting, seam marks, roller marks, stains, and discolorations.
C. Static-pressure classifications: unless otherwise indicated, construct ducts to the following:

    1. Supply ducts: 1480 Pa.
    2. Return ducts and outside air ducts: 1000 Pa, negative pressure.

3. Exhaust and relief ducts: 500 Pa, negative pressure.

D. Cross breaking or cross beading: cross break or cross bead duct sides 480 mm and larger and 0.9-mm thick or less.

INSTALLATION

Ducts shall be installed in conformance with the requirements in NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

Each duct system shall be constructed and installed for the specific duct pressure classification indicated, and in conformance with the following requirements

A. Install ducts with fewest possible joints.
B. Install fabricated fittings for changes in directions, changes in size and shape, and connections.
C. Install couplings tight to duct wall surface with a minimum of projections into duct.
D. Install ducts, unless otherwise indicated, vertically and horizontally, parallel and perpendicular to building lines; avoid diagonal runs.
E. Install ducts close to walls, overhead construction, columns, and other structural and permanent enclosure elements of building.
F. Install ducts with a clearance of 25 mm, plus allowance for insulation thickness.
G. Conceal ducts from view in finished spaces. Contractor shall not encase horizontal runs in solid partitions, unless specifically indicated.
H. Coordinate layout with ceiling structural elements, fire- and smoke-control dampers, lighting and conduit layouts, and similar finished work.
I. Electrical equipment spaces: route ductwork to avoid passing through transformer vaults and over electrical equipment spaces and enclosures.
J. Non-fire-rated partition penetrations: where ducts pass through interior partitions and exterior walls, and are exposed to view, conceal space between construction opening and duct or duct insulation with sheet metal flanges of same metal thickness as duct. Overlap opening on four sides by at least 38 mm.
K. Contractor shall not install duct liner in the ductwork.

Seam And Joint Sealing.--Duct seams and joints shall be sealed according to the duct pressure class indicated and as described in SMACNA's "HVAC Duct Construction Standards—Metal and Flexible." Transverse joints shall be sealed for ducts with pressure classification less than 500 Pa. Externally insulated ducts shall be sealed before insulation installation.

Hanging And Supporting.--Rigid round, rectangular, and flat-oval metal ducts shall be installed with support systems in conformance with the requirements in SMACNA's "HVAC Duct Construction Standards—Metal and Flexible." Sheet metal straps shall not be used to hang exposed ducts. Horizontal ducts shall be supported within 600 mm of each elbow and within 1200 mm of each branch intersection. Vertical ducts shall be supported at a maximum interval of 5 m and at each floor.

Upper attachments to structures shall be installed with an allowable load not exceeding one fourth of the failure-proof test load.

Concrete inserts shall be installed before placing concrete. Powder-actuated concrete fasteners shall be installed after concrete is placed and completely cured.

Connections.--Equipment shall be connected with flexible connectors in conformance with the provisions in "Duct Accessories" of these special provisions. Branch, outlet and inlet, and terminal unit connections shall conform to the requirements in SMACNA's "HVAC Duct Construction Standards—Metal and Flexible."

Cleaning.--After completing system installation, including outlet fittings and devices, the Contractor shall inspect the system and vacuum ducts to remove dust and debris.

FIELD QUALITY CONTROL

The Contractor shall submit field test reports indicating and interpreting test results for conformance with performance requirements.

MEASUREMENT AND PAYMENT

Full compensation for metal ducts shall be considered as included in the contract lump sum price paid for heating and ventilation ancillary spaces and no additional compensation will be allowed therefor.

10-5.__ DUCT ACCESSORIES

GENERAL

SUMMARY

Scope.--Duct accessories, including manual-volume dampers, turning vanes, duct-mounted access doors and panels, flexible connectors and duct accessory hardware, shall conform to the provisions in Section 75 "Miscellaneous Metal" of the Standard Specifications and these special provisions.

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data of backdraft dampers, duct-mounted access doors and panels, fire dampers, modulating combination fire/smoke dampers, volume control dampers, electric damper actuators, flexible connectors, turning vanes and duct smoke detectors sealing materials and sheet metal materials. In addition, product certificates with certified test data on airflow performance, static-pressure loss, dimensions, and weights for duct accessories shall be submitted.

Working Drawings.--The Contractor shall submit working drawings that include compete details, information and equipment selection criteria for the duct accessories as shown on the plans and as specified in these special provisions:

A. Drawings detailing equipment assemblies and indicating dimensions, weights, loadings, required clearances, method of field assembly, components, location, and size of each field connection. Detail and show exact locations for combination fire- and smoke-damper installations, including sleeves and duct-mounted access doors and panels.

PRODUCTS

Manual-volume dampers.--Manual-volume dampers shall conform to the following requirements:

A. Factory fabricated with required hardware and accessories. Stiffen damper blades for stability. Include locking device to hold single-blade dampers in a fixed position without vibration. Close duct penetrations for damper components to seal duct consistent with pressure class.
B. Construct dampers with pressure classifications of 750 Pa or higher with end bearings or other seals for ducts with axles full length of damper blades and bearings at both ends of operating shaft.
C. Construct standard volume dampers with multiple- or single-blade, parallel- or opposed-blade design as shown on the plans and specified in these special provisions, standard leakage rating, with linkage outside airstream, and designed for horizontal or vertical applications.
D. Construct steel frames with hat-shaped, galvanized, sheet steel channels, minimum of 1.62 mm thick, with mitered and welded corners; frames with flanges where shown on the plans and specified in these special provisions for attaching to walls; and flangeless frames where shown on the plans and specified in these special provisions for installing in ducts.
E. Construct roll-formed steel blades with 1.62-mm- thick, galvanized, sheet steel.
F. Construct blade axles with nonferrous or galvanized steel.
G. Construct tie bars and brackets with galvanized steel.
H. Construct jackshaft with 25 mm diameter, galvanized steel pipe rotating within a pipe-bearing assembly mounted on supports at each mullion and at each end of multiple-damper assemblies.
I. Construct length and number of mountings with appropriate configuration to connect linkage of each damper of a multiple-damper assembly.
J. Construct damper hardware with zinc-plated, die-cast core with dial and handle made of 2.4 mm thick zinc-plated steel, and a 19 mm hexagon locking nut. Include center hole to suit damper operating-rod size. Include elevated platform for insulated duct mounting.

Combination fire/smoke dampers.--Combination fire/smoke dampers shall conform to the following requirements:

A. Combination fire/smoke dampers shall be labeled to UL 555 "Standard for Fire Damper" for 1-1/2 or 3-hour fire damper for use in a dynamic system. Dampers shall be labeled to UL 555S "Standard for Leakage Rated Dampers for use in Smoke Control Systems". Open and close under operating conditions up to 100 mm w.g. in closed position and 1200 meters/minute in open position. Class I leakage rating. Automatic remote reset after test, smoke detection or power failure. Maximum air pressure drop across damper shall not exceed 7 mm w.g.
B. Combination fire/smoke damper shall have UL listed fire rating of 1-1/2 and 3 hours.
C. Fusible link included with combination fire/smoke damper shall be replaceable, 75°C rated unless specifically shown on the plans or specified in these special provisions 100°C or 140°C.
D. Frame shall be constructed of minimum 1.6 mm thick, galvanized, sheet steel.
E. Blades shall be constructed with minimum 1.9 mm thick single piece airfoil construction. Opposed blade action, unless shown on the plans or specified in these special provisions specifically parallel. Blades shall include stainless steel bearings. Flexible stainless steel compression type joints seals. Blades shall include silicone blade edge seals, capable of withstanding 175°C.

F. Mounting sleeve shall be factory-installed, minimum 1.0 mm thick, galvanized, sheet steel; length to suit wall or floor application.
G. Blade position indicator switch shall provide blade position two-position indicator switch for remote monitoring of blade position.
H. Damper actuator shall be electric actuators with actuator and linkage located out of air stream.
I. Damper motors shall provide for modulating action for modulation fire/smoke dampers (MFS) or two-position action for fire/smoke dampers (FS) as shown on the plans:

1. Permanent-split-capacitor or shaded-pole motors designed with oil-immersed and sealed gear trains.
2. Spring-return motors shall include an integral spiral-spring mechanism where shown on the plans or specified in these special provisions. Enclose entire spring mechanism in a removable housing designed for service or adjustments. Size motor for running torque rating of 17 N.m and breakaway torque rating of 17 N.m.
3. Nonspring-return motors shall be installed for dampers larger than 2.3 m2, size motor for running torque rating of 17 N.m and breakaway torque rating of 34 N.m.
4. Two-position motor shall be designed as 115 V, single phase, 60 Hz.
5. Modulating, spring-return motor shall be designed as 115 V, single phase, 60 Hz, with interface module providing current or voltage control 4-20 mA and 2-10 V DC with adjustable zero and span.

Control Dampers.--Low leakage control dampers shall be provided where not furnished with package units. Damper leakage rate shall not exceed 0.5 percent of damper based on 600 meters/minute duct velocity when closed against 100 mm water gage static pressure. Control dampers shall be complete with extruded aluminum, stainless steel or zinc-coated steel blades, with extruded vinyl or rubber edge seals. Blade ends shall be sealed with aluminum or stainless steel "arc" seals. An external frame of heavy gage welded steel with 6 mm plate bearing bars and bronze insert bearings shall be provided.

Actuators shall be provided for all motor operated dampers of sufficient size and type, matched to the application. Electric or electronic actuators shall be provided with solid state positioners to stop automatically at end of travel, complete with permanently lubricated gear train. Analog, current proportional or 2-position actuators shall be provided with visual position indication. Actuators shall be provided with spring return to normally-open or normally closed on loss of control power. Power return type actuators shall not be acceptable. The Contractor shall calculate damper torque requirements and include documentation of sufficient actuator power. Power requirements: 24 V, single phase, 60 Hz, with interface module providing current or voltage control 4-20 mA and 2-10 V(dc) with adjustable zero and span.

Static Pressure Relief Dampers.--Relief dampers shall conform to the following requirements:

A. Description: Static pressure relief dampers shall be constructed as multiple-blade, parallel action gravity balanced, with blades of minimum 1.8 mm thickness, with extruded vinyl edge seals mechanically locked into blade edge, assembled in rattle-free manner with 90-degree stop, steel ball bearings, and axles; adjustment device to permit setting for varying differential static pressure.
B. Frame: 3.2 mm thick extruded aluminum, with galvanized steel braces at all corners.
E. Blade Axles: Stainless steel.

F. Tie Bars and Brackets: 13 mm.
G. Static Pressure Adjustment Device: Field-adjustable control to maintain pressure in ranges from 0.062 kPa to 0.185 kPa.

Turning vanes.--Turning vanes shall be fabricated in conformance with the requirements in SMACNA's "HVAC Duct Construction Standards—Metal and Flexible."

Manufactured turning vanes shall be fabricated of 38 mm width curved blades set 19 mm on center, and supported with bars perpendicular to blades set 50 mm on center, and set into side strips designed for mounting in ducts.

Acoustic turning vanes shall be fabricated of airfoil-shaped aluminum extrusions with perforated faces and fibrous-glass fill.

Duct Mounted Access Doors and Panels.--Doors and panels shall be airtight and designed for duct pressure class as shown on the plans or specified in these special provisions, and conform to the following requirements:

A. Frame: galvanized, sheet steel, with bend-over tabs and foam gaskets.
B. Door: double-wall, galvanized, sheet metal construction with insulation fill and thickness, and number of hinges and locks as shown on the plans or specified in these special provisions for duct pressure class. Include vision panel where shown on the plans or specified in these special provisions. Include 25 by 25 mm butt or piano hinge and cam latches.
C. Seal around frame attachment to duct and door to frame with neoprene or foam rubber.
D. Insulation: 25 mm thick, fibrous-glass board.

Flexible connectors.--Flexible connectors shall be flame-retarded or noncombustible fabrics, coatings, and adhesives conforming to the requirements in UL 181, Class 1, and the following requirements:

A. Standard metal-edged connectors: Connectors shall be factory fabricated with a strip of fabric 89 mm wide attached to two strips of 70 mm wide, 0.7-mm thick, galvanized, sheet steel or 0.8-mm aluminum sheets. Select metal compatible with connected ducts.
B. Conventional, indoor system flexible connector fabric: Glass fabric shall be double coated with polychloroprene. Minimum Weight: 880 g/m^2. Tensile Strength: 84 N/mm in the warp, and 63 N/mm in the fill.

Accessory Hardware.--Accessories shall include the following:

A. Instrument test holes: Test holes shall be cast iron or cast aluminum to suit duct material, including screw cap and gasket. Size to allow insertion of pitot tube and other testing instruments, and length to suit duct insulation thickness.
B. Splitter damper accessories: Accessories shall include zinc-plated damper blade bracket; 6 mm, zinc-plated operating rod; and a duct-mounted, ball-joint bracket with flat rubber gasket and square-head set screw.
C. Adhesives: Adhesives shall be high strength, quick setting, neoprene based, waterproof, and resistant to gasoline and grease.

Duct Type Smoke Detectors.--Duct smoke detectors shall be analog addressable type. Detector housing shall be UL listed and conform to the requirements in UL 268A for specific use

in air handling systems. Photoelectric units shall operate at 90 to 1200 meters/minute, while ionization units shall operate at 300 to 1200 meters/minute.

It shall be possible to view the address of the detector without having to disassemble the duct housing.

Two sets of form C relay contacts shall be provided within the duct housing.

INSTALLATION

Installation shall conform to the requirements in the following NFPA standards:

A. NFPA 90A, "Installation of Air Conditioning and Ventilating Systems."
B. NFPA 90B, "Installation of Warm Air Heating and Air Conditioning Systems."

Duct accessories shall be installed in conformance with applicable details shown in SMACNA's "HVAC Duct Construction Standards—Metal and Flexible" for metal ducts, and the following requirements:

A. Provide test holes at fan inlet and outlet and elsewhere as shown on the plans.
B. Install duct access panels for access to both sides of duct coils. Install duct access panels downstream from volume dampers, fire dampers, turning vanes, and equipment.
C. Install duct access panels to allow access to interior of ducts for cleaning, inspecting, adjusting, and maintaining accessories and terminal units.
D. Install access panels on side of duct where adequate clearance is available.
E. Label access doors in conformance with the provisions in "Mechanical Identification" of these special provisions.
F. Adjust duct accessories for proper settings, with final positioning of manual-volume dampers in conformance with the provisions in "Testing, Adjusting and Balancing" of these special provisions.
G. Conform to the requirements in NFPA 72 and NFPA 90A. Install sampling tubes so they extend the full width of the duct.
H. Install fire and smoke dampers, with fusible links, in accordance with to manufacturer's UL-approved written instructions.

MEASUREMENT AND PAYMENT

Full compensation for duct accessories will be considered as included in the contract lump sum price paid for heating and ventilation of tunnel ancillary spaces and no additional compensation will be allowed therefor.

10-5.__ DIFFUSERS, REGISTERS, AND GRILLES

GENERAL

SUMMARY

Scope.--Diffusers, registers, and grilles shall conform to the provisions in Section 75 "Miscellaneous Metal" of the Standard Specifications and these special provisions.

Diffusers, registers, and grilles shall have been tested for performance in accordance with ASHRAE 70, "Method of Testing for Rating the Performance of Air Outlets and Inlets."

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data for each type of air outlet and inlet, and accessory furnished, indicating construction, finish, and mounting details In addition, brochures or other information describing performance data including throw and drop, static-pressure drop, and noise ratings for each type of air outlet and inlet shall be included.

Working Drawings.--The Contractor shall submit working drawings that include compete details, information and equipment selection criteria for diffusers, registers and grilles as shown on the plans and as specified in these special provisions:

A. Schedule of diffusers, registers, and grilles indicating drawing designation, room location, quantity, model number, size, and accessories furnished.
B. Assembly drawings for each type of air outlet and inlet, indicating materials and methods of assembly of components.

DEFINITIONS

A. Diffuser: circular, square, or rectangular air distribution outlet, generally located in the ceiling and comprised of deflecting members discharging supply air in various directions and planes and arranged to promote mixing of primary air with secondary room air.
B. Grille: a louvered or perforated covering for an opening in an air passage, which can be located in a sidewall, ceiling, or floor.
C. Register: a combination grille and damper assembly over an air opening.

PRODUCTS

INSTALLATION

Diffusers, registers, and grilles shall be installed in conformance with the requirements in NFPA 90A, "Standard for the Installation of Air-Conditioning and Ventilating Systems."

Prior to installation the Contractor shall examine areas where diffusers, registers, and grilles are to be installed for conformance with requirements for installation tolerances and other conditions affecting performance of equipment.

Diffusers, registers, and grilles shall be installed level and plumb, in accordance with manufacturer's written instructions, coordination drawings, original design, and referenced standards.

Plans show general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been shown on the plans to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Final locations shall be made where shown on the plans, as much as practicable. Where architectural features or other items conflict with installation, the Contractor shall notify the Engineer for a determination of final location.

Diffusers, registers, and grilles shall be installed with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

After installation, the Contractor shall adjust diffusers, registers, and grilles to the air patterns shown on the plans, or as directed by the Engineer, before starting air balancing.

After installation of diffusers, registers, and grilles, the Contractor shall inspect the exposed finish, and shall clean exposed surfaces to remove burrs, dirt, and smudges. The Contractor shall replace diffusers, registers, and grilles that have damaged finishes, at no additional cost to the State.

PAYMENT

Full compensation for diffusers, registers, and grilles will be considered as included in the contract lump sum price paid for heating and ventilation of tunnel ancillary spaces and no additional compensation will be allowed therefor.

10-5.__ DUCT INSULATION

GENERAL

SUMMARY

Duct insulation for tunnel chamber heating and ventilation system outside air ducts, consisting of semi-rigid and flexible duct, plenum, and breeching insulation, insulating cements, field-applied jackets, accessories, attachments, and sealing compounds, shall conform to these special provisions.

SUBMITTALS

Product Data.--The Contractor shall submit manufacturer's technical data identifying thermal conductivity, thickness, and jackets (both factory and field applied, if any), for each type of product indicated.

Working Drawings.--The Contractor shall submit working drawings that include compete details, information and equipment selection criteria for duct insulation as shown on the plans and as specified in these special provisions:

A. Drawings showing fabrication and installation details for the following:

1. Removable insulation sections at access panels.
2. Application of field-applied jackets.
3. Applications at linkages for control devices.

QUALITY ASSURANCE

Fire test response characteristics shall be determined by testing materials identical to those specified in these special provisions according to ASTM E 84, by a testing and inspecting agency acceptable to authorities having jurisdiction. Insulation and jacket materials and sealer and cement material containers shall be factory labeled with appropriate markings of applicable testing and inspecting agency.

Insulation installed indoors shall have a flame-spread rating of 25 or less, and smoke-developed rating of 50 or less.

DELIVERY, STORAGE, AND HANDLING

Insulation materials shall be shipped in containers marked by manufacturer with appropriate ASTM specification designation, type and grade, and maximum use temperature.

SEQUENCING AND SCHEDULING

Insulation application shall be scheduled after testing duct systems. Insulation application may begin on segments of ducts that have satisfactory test results.

PRODUCTS

Insulation materials.--Insulation materials shall conform to the following:

A. Mineral-fiber board thermal insulation: glass fibers bonded with a thermosetting resin. Comply with ASTM C 612, Type IB, without facing and with all-service jacket manufactured from kraft paper, reinforcing scrim, aluminum foil, and vinyl film.
B. Adhesive: Class 2, Grade A for bonding glass fiber insulation to metal surfaces.

Field-applied jackets.--Field-applied jackets shall conform to the following:

A. ASTM C 921, Type 1, unless otherwise indicated.
B. A properly sealed foil, scrim, kraft-paper (FSK) jacket, common with most forms of factory-applied jackets for mineral-fiber insulation, meets vapor-retarder requirements of ASTM C 921, Type I.

Accessories and Attachments.--

A. Glass cloth and tape: comply with MIL-C-20079H, Type I for cloth and Type II for tape. Woven glass-fiber fabrics, plain weave, presized a minimum of 270 g/sq. m. Tape Width: 100 mm.
B. Bands: 19 mm wide, in one of the following materials compatible with jacket:

    1. Stainless steel: ASTM A 666, Type 304; 0.5-mm thick.
    2. Galvanized steel: 0.13-mm thick.
    3. Aluminum: 0.18-mm thick.

C. Wire: 2.0 mm, nickel-copper alloy or 1.6 mm, soft-annealed, stainless steel.
D. Adhesive-attached anchor pins and speed washers:

    1. Galvanized steel plate, pin, and washer manufactured for attachment to duct and plenum with adhesive. Pin length sufficient for insulation thickness indicated.
    2. Adhesive: recommended by the anchor pin manufacturer as appropriate for surface temperatures of ducts, plenums, and breechings; and to achieve a holding capacity of 45 kg for direct pull perpendicular to the adhered surface.

Vapor Retarders.--Mastics shall be materials recommended by insulation material manufacturer that are compatible with insulation materials, jackets, and substrates.

INSTALLATION

Preparation.--Substrates and conditions shall be examined for conformance with requirements for installation and other conditions affecting performance of insulation application. Installation shall proceed only after unsatisfactory conditions have been corrected.

Surfaces shall be clean and dry to receive insulation. Materials that will adversely affect insulation application shall be removed.

General Application Requirements.--Duct insulation shall be applied as follows:

A. Apply insulation materials, accessories, and finishes according to the manufacturer's written instructions; with smooth, straight, and even surfaces; and free of voids throughout the length of ducts and fittings.
B. Refer to schedules at the end of this Section for materials, forms, jackets, and thicknesses required for each duct system.
C. Use accessories compatible with insulation materials and suitable for the service. Use accessories that do not corrode, soften, or otherwise attack insulation or jacket in either wet or dry state.
D. Apply multiple layers of insulation with longitudinal and end seams staggered.
E. Seal joints and seams with vapor-retarder mastic on insulation indicated to receive a vapor retarder.
F. Keep insulation materials dry during application and finishing.
G. Apply insulation with tight longitudinal seams and end joints. Bond seams and joints with adhesive recommended by the insulation material manufacturer.
H. Apply insulation with the least number of joints practical.
I. Apply insulation over fittings and specialties, with continuous thermal and vapor-retarder integrity, unless otherwise indicated.
J. Hangers and anchors: where vapor retarder is indicated, seal penetrations in insulation at hangers, supports, anchors, and other projections with vapor-retarder mastic. Apply insulation continuously through hangers and around anchor attachments.
K. Insulation terminations: for insulation application where vapor retarders are indicated, seal ends with a compound recommended by the insulation material manufacturer to maintain vapor retarder.
L. Apply insulation with integral jackets as follows:

    1. Pull jacket tight and smooth.
    2. Joints and seams: cover with tape and vapor retarder as recommended by insulation material manufacturer to maintain vapor seal.
    3. Vapor-retarder mastics: where vapor retarders are indicated, apply mastic on seams and joints and at ends adjacent to duct flanges and fittings.

M. Cut insulation according to manufacturer's written instructions to prevent compressing insulation to less than 75 percent of its nominal thickness.
N. Install vapor-retarder mastic on ducts and plenums scheduled to receive vapor retarders. Overlap insulation facing at seams and seal with vapor-retarder mastic and pressure-sensitive tape having same facing as insulation. Repair punctures, tears, and penetrations with tape or mastic to maintain vapor-retarder seal.
O. Interior wall and partition penetrations: apply insulation continuously through walls and partitions, except fire-rated walls and partitions.
P. Fire-rated wall and partition penetrations: terminate insulation at fire/smoke damper sleeves for fire-rated wall and partition penetrations.

Mineral Fiber Insulation Application.--Board applications for ducts and plenums shall conform to the following:

A. Secure board insulation with adhesive and anchor pins and speed washers.
B. Apply adhesives according to manufacturer's recommended coverage rates per square meter, for 100 percent coverage of duct and plenum surfaces.

C. Apply adhesive to entire circumference of ducts and to all surfaces of fittings and transitions.
D. Install anchor pins and speed washers on sides and bottom of horizontal ducts and sides of vertical ducts as follows:

   1. On duct sides with dimensions 450 mm and smaller, along longitudinal centerline of duct. Space 75 mm maximum from insulation end joints, and 400 mm on center.
   2. On duct sides with dimensions larger than 450 mm. Space 400 mm on center each way, and 75 mm maximum from insulation joints. Apply additional pins and clips to hold insulation tightly against surface at cross bracing.
   3. Anchor pins may be omitted from top surface of horizontal, rectangular ducts and plenums.
   4. Do not overcompress insulation during installation.

E. Impale insulation over anchors and attach speed washers.
F. Cut excess portion of pins extending beyond speed washers or bend parallel with insulation surface. Cover exposed pins and washers with tape matching insulation facing.
G. Create a facing lap for longitudinal seams and end joints with insulation by removing 50 mm from one edge and one end of insulation segment. Secure laps to adjacent insulation segment with 13 mm staples, 25 mm on center, and cover with pressure-sensitive tape having same facing as insulation.
H. Apply insulation on rectangular duct elbows and transitions with a full insulation segment for each surface. Apply insulation on round and flat-oval duct elbows with individually mitered gores cut to fit the elbow.
I. Insulate duct stiffeners, hangers, and flanges that protrude beyond the insulation surface with 150 mm wide strips of the same material used to insulate duct. Secure on alternating sides of stiffener, hanger, and flange with anchor pins spaced 150 mm on center.
J. Apply vapor-retarder mastic to open joints, breaks, and punctures for insulation indicated to receive vapor retarder.

Field Applied Jacket Application.--Apply glass-cloth jacket, where indicated on inside ducts and on all outside ductwork, directly over bare insulation or insulation with factory-applied jackets, as follows:

A. Apply jacket smooth and tight to surface with 50 mm overlap at seams and joints.
B. Embed glass cloth between two 1.6 mm thick coats of jacket manufacturer's recommended adhesive.
C. Completely encapsulate insulation with jacket, leaving no exposed raw insulation.

Duct System Applications.--Insulate indoor exposed outside air ductwork. Unless otherwise indicated, do not apply insulation to the following systems, materials, and equipment:

A. Fibrous-glass ducts.
B. Factory-insulated round and oval ducts.
C. Factory-insulated plenums, casings, terminal boxes, and filter boxes and sections.
D. Flexible connectors.
E. Vibration-control devices.
F. Testing agency labels and stamps.

G. Nameplates and data plates.
H. Access panels and doors in air-distribution systems.

Indoor Duct and Plenum Application Schedule.--Insulation shall be applied to the ducts and plenums in conformance with the following schedule:

Service	Material	Thickness	Number of Layers	Field Applied Jacket	Vapor Retarder Required
Rectangular, supply-air ducts, exposed	None				
Rectangular, return-air ducts, exposed	None				
Rectangular, outside-air ducts, exposed.	Mineral Fiber Board	25 mm	1	Glass cloth	Yes

PAYMENT

Full compensation for furnishing all labor, materials, tools, equipment and incidentals and for performing all the work involved in furnishing and installing duct insulation will be considered as included in the contract lump sum price paid for heating and ventilation of tunnel ancillary spaces and no additional compensation will be allowed therefor.

10-5.__ TESTING, ADJUSTING, AND BALANCING

GENERAL

SUMMARY

Testing, adjusting, and balancing of heating, ventilating and air conditioning (HVAC) systems shall conform to these special provisions, and shall include the following:

A. Balancing airflow within distribution systems, including submains, branches, and terminals, to indicated quantities according to specified tolerances.
B. Adjusting total HVAC systems to provide indicated quantities.
C. Measuring electrical performance of HVAC equipment.
D. Setting quantitative performance of HVAC equipment.
E. Verifying that automatic control devices are functioning properly.
F. Measuring sound and vibration.
G. Reporting results of the activities and procedures specified in these special provisions.

Testing and adjusting requirements unique to particular systems and equipment, are included in the sections that specify those systems and equipment, such as "Storm Water Pumps," "Fire Pumps," "Leach Water System" and "Tunnel Jet Fans" of these special provisions.

SUBMITTALS

Testing Documents.--The Contractor shall submit testing adjusting and balancing support documentation as shown on the plans and as specified in these special provisions:

A. Quality-assurance submittals: within 30 days after approval of the contract, submit 2 copies of evidence that the testing, adjusting, and balancing Agent and this project's testing, adjusting, and balancing team members meet the qualifications specified in these special provisions.
B. Contract documents examination report: within 45 days after approval of the contract, submit 2 copies of the contract documents review report as specified in these special provisions.
C. Strategies and procedures plan: within 60 days after approval of the contract, submit 2 copies of the testing, adjusting, and balancing strategies and step-by-step procedures as specified in these special provisions. Include a complete set of report forms intended for use on this project.
D. Certified testing, adjusting, and balancing reports: submit 2 copies of reports prepared, as specified in these special provisions, on approved forms certified by the testing, adjusting, and balancing Agent.
E. Sample report forms: submit 2 sets of sample testing, adjusting, and balancing report forms.
F. Warranty: submit 2 copies of the special warranty specified in these special provisions.

QUALITY ASSURANCE

The Contractor shall engage a testing, adjusting, and balancing agent certified by either AABC or NEBB.

A testing, adjusting, and balancing conference shall be held, where the Contractor shall meet with the Department's representatives, on approval of the testing, adjusting, and balancing strategies and procedures plan, to develop a mutual understanding of the details. The conference shall include the participation of testing, adjusting, and balancing team members, equipment manufacturers' certified service representatives, tunnel control system installer, and other support personnel. The Contractor shall provide 7 days advance notice of scheduled meeting time and location. Agenda items shall include at least the following:

A. Submittal distribution requirements.
B. Contract documents examination report.
C. Testing, adjusting, and balancing plan.
D. Work schedule and project site access requirements.
E. Coordination and cooperation of trades and subcontractors.
F. Coordination of documentation and communication flow.

The Contractor shall certify the testing, adjusting, and balancing field data reports. This certification shall include the following:

A. Review field data reports to validate accuracy of data and to prepare certified testing, adjusting, and balancing reports.
B. Certify that the testing, adjusting, and balancing team complied with the approved testing, adjusting, and balancing plan and the procedures specified and referenced in these special provisions.

Testing, adjusting, and balancing reports shall use standard forms from AABC's "National Standards for Testing, Adjusting, and Balancing." or standard forms from NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems."

Instrumentation type, quantity, and accuracy shall conform to the requirements in NEBB's "Procedural Standards for Testing, Adjusting, and Balancing of Environmental Systems," Section II, "Required Instrumentation for NEBB Certification."

Instruments shall be calibrated at least every 6 months or more frequently if required by the instrument manufacturer.

WARRANTY

The national project performance guarantee specified herein shall not deprive the State of other rights the State may have under other provisions of the contract documents and shall be in addition to, and run concurrent with, other warranties made by the Contractor under requirements of the contract documents.

The Contractor shall provide a special guarantee on NEBB forms stating that NEBB will assist in completing the requirements of the contract documents if the testing, adjusting, and balancing Agent fails to comply with the contract documents. The guarantee shall include the following provisions:

A. The certified Agent has tested and balanced systems according to the contract documents.
B. Systems are balanced to optimum performance capabilities within design and installation limits.

DEFINITIONS

A. Adjust: to regulate fluid flow rate and air patterns at the terminal equipment, such as to reduce fan speed or adjust a damper.
B. Balance: to proportion flows within the distribution system, including submains, branches, and terminals, according to design quantities.
C. Draft: a current of air, when referring to localized effect caused by one or more factors of high air velocity, low ambient temperature, or direction of airflow, whereby more heat is withdrawn from a person's skin than is normally dissipated.
D. Procedure: an approach to and execution of a sequence of work operations to yield repeatable results.
E. Report forms: test data sheets for recording test data in logical order.
F. Static head: the pressure due to the weight of the fluid above the point of measurement. In a closed system, static head is equal on both sides of the pump.
G. Suction head: the height of fluid surface above the centerline of the pump on the suction side.
H. System effect: a phenomenon that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system.
I. System effect factors: allowances used to calculate a reduction of the performance ratings of a fan when installed under conditions different from those presented when the fan was performance tested.
J. Terminal: a point where the controlled medium, such as fluid or energy, enters or leaves the distribution system.
K. Test: a procedure to determine quantitative performance of a system or equipment.
L. Testing, Adjusting, and Balancing Agent: the entity responsible for performing and reporting the testing, adjusting, and balancing procedures.
M. AABC: Associated Air Balance Council.
N. AMCA: Air Movement and Control Association.
O. NEBB: National Environmental Balancing Bureau.

TESTING

Examination.--The Contractor shall examine the systems and equipment in conformance with the following requirements:

A. Examine contract documents to become familiar with project requirements and to discover conditions in systems' designs that may preclude proper testing, adjusting, and balancing of systems and equipment. See "Tunnel Control System" of these special provisions for control of HVAC equipment.
B. Verify that balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices and manual volume dampers are required by the contract documents. Verify that quantities and locations of these balancing devices are accessible and appropriate for effective balancing and for efficient system and equipment operation.
C. Examine approved submittal data of HVAC systems and equipment and project record documents.
D. Examine Engineer's design data, including HVAC system descriptions, statements of design assumptions for environmental conditions and systems' output, and statements of philosophies and assumptions about HVAC system and equipment controls.
E. Examine equipment performance data, including fan and pump curves. Relate performance data to project conditions and requirements, including system effects that can create undesired or unpredicted conditions that cause reduced capacities in all or part of a system. Calculate system effect factors to reduce the performance ratings of HVAC equipment when installed under conditions different from those presented when the equipment was performance tested at the factory. To calculate system effects for air systems, use tables and charts found in AMCA 201, "Fans and Systems," Sections 7 through 10; or in SMACNA's "HVAC Systems—Duct Design," Sections 5 and 6. Compare this data with the design data and installed conditions.
F. Examine system and equipment installations to verify that they are complete and that testing, cleaning, adjusting, and commissioning specified in individual sections of the special provisions have been performed.
G. Examine system and equipment test reports.
H. Examine HVAC system and equipment installations to verify that indicated balancing devices, such as test ports, gage cocks, thermometer wells, flow-control devices and manual volume dampers are properly installed, and their locations are accessible and appropriate for effective balancing and for efficient system and equipment operation.
I. Examine systems for functional deficiencies that cannot be corrected by adjusting and balancing.
J. Examine air-handling equipment to ensure clean filters have been installed, bearings are greased, belts are aligned and tight, and equipment with functioning controls is ready for operation.
K. Examine electric heating coils for correct connections and for clean and straight elements.
L. Examine equipment for installation and for properly operating safety interlocks and controls.
M. Examine automatic temperature system components to verify the following:

    1. Dampers, valves, and other controlled devices operate by the intended controller.
    2. Dampers and valves are in the position indicated by the controller.
    3. Integrity of valves and dampers for free and full operation and for tightness of fully closed and fully open positions.

4. Thermostats and are located to avoid adverse effects of sunlight, drafts, and cold walls.
5. Sensors are located to sense only the intended conditions.
6. Sequence of operation for control modes is according to the contract documents.
7. Controller set points are set at design values. Observe and record system reactions to changes in conditions. Record default set points if different from design values.
8. Interlocked systems are operating.
9. Changeover from heating to cooling mode occurs according to design values.

N. Report deficiencies discovered before and during performance of testing, adjusting, and balancing procedures.

Preparation.--The Contractor shall prepare a testing, adjusting, and balancing plan that includes strategies and step-by-step procedures, and shall complete system readiness checks and prepare system readiness reports. The Contractor shall verify the following:

A. Permanent electrical power wiring is complete.
B. Automatic temperature-control systems are operational.
C. Equipment and duct access doors are securely closed.
D. VFD's where applicable are enabled and functioning.
E. Balance, smoke and fire dampers are open.
F. Windows and doors can be closed so design conditions for system operations can be met.

The Contractor shall provide 7 days advance notice for each test, with scheduled test dates and times. Testing, adjusting, and balancing shall be performed after leakage and pressure tests on air and water distribution systems have been satisfactorily completed.

General Testing and Balancing Procedures.--Perform testing and balancing procedures on each system according to the procedures contained in AABC national standards or the procedures contained in NEEB's "Procedural Standards for Testing, Adjusting and Balancing" and the procedures included in these special provisions.

Insulation, ducts, pipes, and equipment cabinets shall be cut for installation of test probes to the minimum extent necessary to allow adequate performance of procedures. After testing and balancing, the Contractor shall close probe holes and patch insulation with new materials identical to those removed. Vapor barriers and finishes shall be restored according to the special provisions for insulation.

Equipment settings shall be marked with paint or other suitable, permanent identification material, including damper-control positions, valve indicators, fan-speed-control devices, and similar controls and devices, to show final settings.

Fundamental Air Systems' Balancing Procedures.--Balancing procedures for air systems shall include the following:

A. Prepare test reports for both fans and outlets. Obtain manufacturer's outlet factors and recommended testing procedures. Crosscheck the summation of required outlet volumes with required fan volumes.
B. Prepare schematic diagrams of systems' as-built duct layouts.
C. Simulate both summer and winter operating conditions.

D. Determine the best locations in main and branch ducts for accurate duct airflow measurements.
E. Check the airflow patterns from the outside-air louvers and dampers and the return- and exhaust-air dampers, through the supply-fan discharge and mixing dampers.
F. Locate start-stop and disconnect switches, electrical interlocks, motor starters and variable frequency drives.
G. Verify that motor starters are equipped with properly sized thermal protection.
H. Check dampers for proper position to achieve desired airflow path.
I. Check for airflow blockages.
J. Check for proper sealing of air-handling unit components.

Constant Volume Air Systems' Balancing Procedures.--The procedures in this section apply to constant-volume supply-, return-, and exhaust-air systems. Fans shall be adjusted to deliver total design airflows within the maximum allowable rpm listed by the fan manufacturer. Balancing procedures shall include the following:

A. Measure fan static pressures to determine actual static pressure as follows:

    1. Measure outlet static pressure as far downstream from the fan as practicable and upstream from restrictions in ducts such as elbows and transitions.
    2. Measure static pressure directly at the fan outlet or through the flexible connection.
    3. Measure inlet static pressure of single-inlet fans in the inlet duct as near the fan as possible, upstream from flexible connection and downstream from duct restrictions.
    4. Measure inlet static pressure of double-inlet fans through the wall of the plenum that houses the fan.

B. Measure static pressure across each air-handling unit component. Simulate dirty filter operation and record the point at which maintenance personnel must change filters.
C. Compare design data with installed conditions to determine variations in design static pressures versus actual static pressures. Compare actual system effect factors with calculated system effect factors to identify where variations occur. Recommend corrective action to align design and actual conditions.
D. Adjust fan speed higher or lower than design with the approval of the Engineer. Make required adjustments to pulley sizes and VFD set points, motor sizes, and electrical connections to accommodate fan-speed changes.
E. Do not make fan-speed adjustments that result in motor overload. Consult equipment manufacturers about fan-speed safety factors. Modulate dampers and measure fan-motor amperage to ensure no overload will occur. Measure amperage in full ventilation or cooling, full heating, and economizer modes to determine the maximum required brake power.
F. Adjust volume dampers for main duct, submain ducts, and major branch ducts to design airflows within specified tolerances:

    1. Measure static pressure at a point downstream from the balancing damper and adjust volume dampers until the proper static pressure is achieved.
    2. Where sufficient space in submains and branch ducts is unavailable for Pitot-tube traverse measurements, measure airflow at terminal outlets and inlets and calculate the total airflow for that zone.

3. Remeasure each submain and branch duct after all have been adjusted. Continue to adjust submains and branch ducts to design airflows within specified tolerances.

G. Measure terminal outlets and inlets without making adjustments. Measure terminal outlets using a direct-reading hood or the outlet manufacturer's written instructions and calculating factors.
H. Adjust terminal outlets and inlets for each space to conform to design air-flows within specified tolerances. Make adjustments in branch ducts using volume dampers rather than extractors or the dampers at the air terminals. Adjust each outlet in the same room or space to within specified tolerances of design quantities without generating noise levels above the limitations prescribed by the contract documents. Adjust patterns of adjustable outlets for proper distribution without drafts.

Procedures for Space Pressurization Measurements and Adjustment.--Before testing for space pressurization, observe the space to verify the integrity of the space boundaries. Verify that windows and doors are closed and applicable safing, gaskets, and sealants are installed. Report deficiencies and postpone testing until after the reported deficiencies are corrected.

Measure, adjust, and record the pressurization of each cross passage, the south, center, and north equipment chambers, and the fire pump room, by adjusting the supply, return, and exhaust airflows to achieve the indicated conditions.

Measure space pressure differential where pressure is used as the design criteria, and measure airflow differential where differential airflow is used as the design criteria for space pressurization:

A. For pressure measurements, measure and record the pressure difference between the intended spaces at the door with all doors in the space closed. Record the high-pressure side, low-pressure side, and pressure difference between each adjacent space.

To achieve indicated pressurization, set the supply airflow to the indicated conditions and adjust the exhaust and return airflow to achieve the indicated pressure or airflow difference. For spaces with pressurization being monitored and controlled automatically, observe and adjust the controls to achieve the desired set point:

A. Compare the values of the measurements taken to the measured values of the control system instruments and report findings.
B. Check the repeatability of the controls by successive tests designed to temporarily alter the ability to achieve space pressurization. Test overpressurization and underpressurization, and observe and report on the system's ability to revert to the set point.

In spaces that employ multiple modes of operation, such as normal mode and emergency mode or occupied mode and unoccupied mode, measure, adjust, and record data for each operating mode.

Record indicated conditions and corresponding initial and final measurements. Report deficiencies.

Motor.--Motors 0.37-kW and larger shall be tested at final balanced conditions and the following data recorded:

A. Manufacturer, model, and serial numbers.
B. Motor power rating.
C. Motor rpm.
D. Efficiency rating if high-efficiency motor.
E. Nameplate and measured voltage, each phase.
F. Nameplate and measured amperage, each phase.
G. Starter thermal-protection-element rating.

Motors that are driven by variable-frequency controllers shall be tested for proper operation at speeds varying from minimum to maximum. The manual bypass for the controller shall be tested to prove proper operation. All the settings at the two discrete speeds of operation shall be recorded. Observations, including controller manufacturer, model and serial numbers, and nameplate data shall be recorded.

Temperature Testing.--During testing, adjusting, and balancing, need for adjustment in temperature regulation within the automatic temperature-control system shall be reported.

The indoor wet- and dry-bulb temperatures shall be measured every other hour for a period of 2 successive 8-hour days, in each separately controlled zone, to prove correctness of final temperature settings. Measurement shall be when the building or zone is occupied. This may be done using the monitoring capabilities of the DDC system if it is functional at the time of this test. The outside-air, wet- and dry-bulb temperatures shall also be measured and recorded.

Temperature Control Verification.--Verification of temperature control shall include the following procedures:

A. Verify that controllers are calibrated and commissioned.
B. Check transmitter and controller locations and note conditions that would adversely affect control functions.
C. Record controller settings and note variances between set points and actual measurements.
D. Verify operation of limiting controllers (i.e., high- and low-temperature controllers.)
E. Verify free travel and proper operation of control devices such as damper operators.
F. Verify sequence of operation of control devices. Note air pressures and device positions and correlate with airflow measurements. Note the speed of response to input changes.
G. Confirm interaction of electrically operated switch transducers.
H. Confirm interaction of interlock and lockout systems.
I. Record voltages of power supply and controller output. Determine if the system operates on a grounded or non-grounded power supply.
J. Note operation of electric actuators using spring return for proper fail-safe operations.

Tolerances.--The HVAC system airflow rates shall be set within the following tolerances:

A. Supply, return, and exhaust fans: plus 5 to plus 10 percent.
B. Air outlets and inlets: zero to minus 10 percent.

Reporting.--Based on examination of the contract documents as specified in these special provisions, the Contractor shall prepare an initial construction-phase report on the adequacy of design for systems' balancing devices. The report shall recommend changes and additions to systems' balancing devices to facilitate proper performance measuring and balancing, and shall

recommend changes and additions to HVAC systems and general construction to allow access for performance measuring and balancing devices.

As work progresses, the Contractor shall prepare status reports to describe completed procedures, procedures in progress, and scheduled procedures, including a list of deficiencies and problems found in systems being tested and balanced. A separate report shall be prepared for each system.

Final Report.--The final report shall be typewritten, or computer printout in letter-quality font, on standard bond paper, in a 3-ring binder, tabulated and divided into sections by tested and balanced systems, and including a certification sheet in front of the binder signed and sealed by the certified testing and balancing engineer. Reports shall include a list of the instruments used for procedures, along with proof of calibration.

Final Report Contents.--In addition to the certified field report data, the final report shall include the following:

A. Fan curves.
B. Manufacturers' test data.
C. Field test reports prepared by system and equipment installers.
D. Other information relative to equipment performance, but do not include approved working drawings and manufacturers' technical data.

General Report Data.--In addition to the form titles and entries, the final report shall include the following data, as applicable:

A. Title page.
B. Name and address of testing, adjusting, and balancing Agent.
C. Project name.
D. Project location.
E. Architect's name and address.
F. Engineer's name and address.
G. Contractor's name and address.
H. Report date.
I. Signature of testing, adjusting, and balancing Agent who certifies the report.
J. Summary of contents, including the following:

    1. Design versus final performance.
    2. Notable characteristics of systems.
    3. Description of system operation sequence if it varies from the contract documents.

K. Nomenclature sheets for each item of equipment.
L. Data for terminal units, including manufacturer, type size, and fittings.
M. Notes to explain why certain final data in the body of reports vary from design values.
N. Test conditions for fans performance forms, including the following:

    1. Settings for outside-, return-, and exhaust-air dampers.
    2. Conditions of filters.
    3. Fan drive settings, including settings and percentage of maximum pitch diameter.
    4. Settings for supply-air or the room static-pressure controller.

5. Other system operating conditions that affect performance.

O. Settings for the variable frequency drives where applicable.

System Diagrams.--The final report shall include schematic layouts of air distribution systems, presented with single-line diagrams, and including the following:

A. Quantities of outside, supply, return, and exhaust airflows.
B. Duct, outlet, and inlet sizes.
C. Balancing stations.

Air-Handling Unit Test Reports.--For air-handling units with electric heating coils, the final report shall include the following:

A. Unit identification.
B. Location.
C. Make and type.
D. Model number and unit size.
E. Manufacturer's serial number.
F. Unit arrangement and class.
G. Discharge arrangement.
H. Sheave make, size in mm, and bore.
I. Sheave dimensions, center-to-center and amount of adjustments in mm.
J. Number of belts, make, and size.
K. Number of filters, type, and size.
L. Motor and VFD data: include the following:

1. Make and frame type and size.
2. Power in kW and rpm.
3. Volts, phase, and hertz.
4. Full-load amperage and service factor.
5. Sheave make, size in mm, and bore.
6. Sheave dimensions, center-to-center and amount of adjustments in mm.

M. Test data: include design and actual values for the following:

1. Total airflow rate in L/s.
2. Total system static pressure in Pa.
3. Fan rpm for both summer and winter conditions.
4. Discharge static pressure in Pa.
5. Filter static-pressure differential in Pa.
6. Heating coil static-pressure differential in Pa.
7. Outside airflow in L/s.
8. Return airflow in L/s.
9. Outside-air damper position.
10. Return-air damper position.
11. VFD amperes at each discreet speed.
12. VFD amperes in bypass mode.

Electric-Coil Test Reports.--For duct coils, and electric coils installed in central-station air-handling units, the final report shall include the following:

A. System identification.
B. Location.
C. Coil identification.
D. Capacity in kW.
E. Number of stages.
F. Connected volts, phase, and hertz.
G. Rated amperage.
H. Airflow rate in L/s.
I. Face area in m^2.
J. Minimum face velocity in m/s.
K. Test data: include design and actual values at each stage for the following:

1. Heat output in kW.
2. Airflow rate in L/s.
3. Air velocity in m/s.
4. Entering-air temperature in °C.
5. Leaving-air temperature in °C.
6. Voltage at each connection.
7. Amperage for each phase.

Fan Test Reports.--For supply, return, and exhaust fans, the final report shall include the following:

A. System identification.
B. Location.
C. Make and type.
D. Model number and size.
E. Manufacturer's serial number.
F. Arrangement and class.
G. Sheave make, size in mm, and bore.
H. Sheave dimensions, center-to-center and amount of adjustments in mm.
I. Motor data: include the following:

1. Make and frame type and size.
2. Power and rpm.
3. Volts, phase, and hertz.
4. Full-load amperage and service factor.
5. Sheave make, size in mm, and bore.
6. Sheave dimensions, center-to-center and amount of adjustments in mm.
7. Number of belts, make, and size.

J. Test data: include design and actual values for the following:

1. Total airflow rate in L/s.
2. Total system static pressure in Pa.
3. Fan rpm.

4. Discharge static pressure in Pa.
5. Suction static pressure in Pa.

Round, Flat-Oval, and Rectangular Duct Traverse Reports.--The final report shall include a diagram with a grid representing the duct cross-section and record the following:

A. System and air-handling unit number.
B. Location and zone.
C. Traverse air temperature in °C.
D. Duct static pressure in Pa.
E. Duct size in mm.
F. Duct area in m^2.
G. Design airflow rate in L/s.
H. Design velocity in m/s.
I. Actual airflow rate in L/s.
J. Actual average velocity in m/s.
K. Barometric pressure in Pa.

Air-Terminal-Device Reports.--For terminal units, the final report shall include the following:

A. System and air-handling unit identification.
B. Location and zone.
C. Test apparatus used.
D. Area served.
E. Air-terminal-device make.
F. Air-terminal-device number from system diagram.
G. Air-terminal-device type and model number.
H. Air-terminal-device size.
I. Air-terminal-device effective area in m^2.
J. Test data: include design and actual values for the following:

1. Airflow rate in L/s.
2. Air velocity in m/s.
3. Preliminary airflow rate as needed in L/s.
4. Preliminary velocity as needed in m/s.
5. Final airflow rate in L/s.
6. Final velocity in m/s.
7. Space temperature in °C.

Instrument Calibration Reports.--For instrument calibration, the final report shall include the following:

A. Instrument type and make.
B. Serial number.
C. Application.
D. Dates of use.
E. Dates of calibration.

Additional Tests.--Within 90 days of completing testing, adjusting, and balancing, the Contractor shall perform additional testing and balancing to verify that balanced conditions are being maintained throughout and to correct unusual conditions.

If initial testing, adjusting, and balancing procedures were not performed during near-peak summer and winter conditions, the Contractor shall perform additional inspections, testing, and adjusting during near-peak summer and winter conditions.

PAYMENT

Full compensation for testing, adjusting, and balancing HVAC systems will be considered as included in the contract lump sum price paid for heating and ventilation of tunnel ancillary spaces and no additional compensation will be allowed therefor.

10-5.__ TUNNEL JET FANS

GENERAL

SUMMARY

Scope.--This work shall consist of furnishing, installing and testing the tunnel jet fans including the motor units, sound attenuators, hangers, supports, fan starters, controls, accessories, and associated work in conformance with the details shown on the plans and to the requirements specified in these special provisions.

SUBMITTALS

Product data.--The Contractor shall submit manufacturer's technical data of fans, motors, sound attenuators, supports, vibration isolators, flow switches, vibration and temperature sensors and hardware. In addition, brochures or other information describing the materials, construction methods and the general characteristics of the fans, motors and sound attenuators shall be submitted.

Working drawings.--

Working drawings for the jet fan assembly shall include complete details, information, and drawings for the jet fans, jet fan housings, and supports as shown on the plans and as specified in these special provisions:

A. The dimensioned drawings of tunnel jet fans shall be submitted showing sound attenuator assembly layout, supports, and other appurtenances required for installation. The working drawings shall show point loads at each support point including summary of dead loads, live loads, axial loads and thrust loads, and complete installation details. The fan supports shall be designed in accordance with the details and scheduled information on shown on the plans and the requirements of these special provisions.
B. The structural support design calculations shall be stamped and signed by an Engineer who is registered as a Civil Engineer in the State of California. Additional supports or bracing to the structure shall be provided to conform to Seismic Zone 4 requirements.
C. Motor performance curves shall be submitted that are either derived from actual performance tests or analytical data.
D. The working drawings and the test procedures shall be submitted for the pre-production units.

E. The narrative test reports for factory and field tests shall be submitted, including the raw data as recorded during each test.
F. The working drawings for the fan housing shall be submitted showing the maximum and minimum clearances at the two extreme temperature conditions as specified elsewhere in these special provisions.

Certificates of Compliance.—The Contractor shall provide certificates for the materials and components required in conformance with the requirements specified in these special provisions.

Operation and maintenance manuals.--The printed and loose leaf bound manuals furnished shall contain operation and maintenance procedures, preventative maintenance schedules, and detailed lubrication instructions for the jet fan assemblies accompanied by photographs, schematics, wiring and assembly diagrams. The manuals shall include equipment removal and replacement procedures, equipment assembly and disassembly procedures and a list of special tools and test equipment required to perform the maintenance tasks. The manuals shall include operating instructions, troubleshooting and fault isolation procedures, manufacturer's descriptive literature, catalog cuts, as-built drawings, fan and motor performance curves, and the name and address of suppliers. The operating and maintenance instructions for the jet fan cradle shall be included. Programming and set point information for the motor manager, and the vibration and temperature monitors shall be included.

WARRANTIES AND GUARANTEES

The fan manufacturer shall furnish to the State any guarantee or warranty furnished as a normal trade practice in connection with the purchase of any components used on the fans.

The fan manufacturer shall guarantee all material, work or equipment furnished for a period of six months from the date of written acceptance of the installation and field testing of all the jet fans. Any material, work or equipment found (during this guarantee period) defective, unsatisfactory or failing to meet the specification as to quality or performance, shall be repaired or replaced by the manufacturer without additional cost to the State. Repaired or replaced parts shall be warranted for an additional six month period.

Operation of equipment does not constitute an acceptance of work. The final acceptance will be made after the fan manufacturer has repaired or replaced defective work, adjusted equipment, demonstrated that it conforms to the plans and these special provisions and has furnished all required certificates without additional cost to the State.

Defects shall be corrected in less than 30 calendar days after notification by the Engineer that defects in the work exist.

QUALITY ASSURANCE

Codes and standards.--The following codes, regulations, reference standards and specifications shall apply:

A. Anti-Friction Bearing Manufacturer's Association (AFBMA):
   1. 99 Load Rating and Fatigue Life for Ball Bearings
   2. 11 Load Rating and Fatigue Life for Roller Bearings
B. American Iron and Steel Institute (AISI):
   1. 316 Stainless and Heat Resisting Steel
   2. S12.36 Survey Methods for Determination of Sound Power Levels of Noise Sources
C. Air Movement and Control Association, Inc. (AMCA):
   1. 250 Methods of Testing Jet Fans for Rating

D. American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE):
   1. 51 Laboratory Methods of Testing Fans for Rating
E. American Society for Testing and Materials (ASTM):
   1. E84 Surface Burning Characteristics of Building Materials
   2. A36 Specification for Carbon Structural Steel
F. American Welding Society (AWS):
   1. D1.1 - Structural Welding Code, Steel
   2. D1.3 - Structural Welding Code, Sheet Steel
   3. D14.6 - Welding of Rotating elements of Equipment
G. Institute of Electrical and Electronic Engineers (IEEE):
   1. 85 - Standard Test Procedure for airborne Sound Measurements on Rotating electric Machinery.
H. National Electrical Manufacturers Association (NEMA):
   1. ICS - Industrial controls and Systems
   2. ISI.1 - Enclosures for controls and systems
   3. MG1 - Motors and Generators
   4. MG1-12.43 -Temperature Rise for Medium Single phase and Polyphase Induction Motors
   5. MG1-12.54- Efficiency
   6. 4 Rain Tight Indoor/Outdoor
   7. 4X Non-Metallic FRP
I. Steel Structures Painting Council (SSPC):
   1. SP-1 - Solvent Cleaning
   2. SP-2 - Hand Tool Cleaning
   3. SP-3 - Power Tool Cleaning
   4. SP-6 - Commercial Blast Cleaning
   5. SP-10 - Near White Blast Cleaning
   6. PA-1 - Shop, Field, and Maintenance and Painting
   7. PA-2 - Method for Measurement of Dry Paint Thickness with Magnetic Gage
J. Underwriters Laboratories (UL)
   1. UL 508 Industrial Control Equipment (ANSI)
   2. 723 UL Standard for Safety Test for Surface Burning Characteristics of Building Materials
K. Institute of Electrical and Electronic Engineers (IEEE):
   1. Standard Test Procedure for Polyphase Induction Motors and Generators
L. National Fire Protection Association (NFPA):
   1. Standard Method of Test of Surface Burning Characteristics of Building Materials
M. International Standards Organization (ISO):
   1. TC117.WG6 Methods of Testing the Performance of Jet Tunnel Fans

Jet Fan Shop Tests.--A test facility shall be provided at the fan manufacturers shop or an independent testing laboratory. The motor test shall be performed at the motor manufacturer's facility. All testing standards and procedures shall be submitted to the Engineer for approval, prior to proceeding with any of the tests. The Contractor shall notify the Engineer in writing of shop test dates, not less than 14 days prior to the test.

Test procedures and reports shall conform to the following:

A. Details and duration of tests, including sample test report forms shall be submitted to the Engineer for approval prior to testing.
B. The test report shall identify the name of manufacturer, model numbers, serial numbers. The testing instruments shall be calibrated within nine months prior to the tests.
C. The test report shall include a list of attendees.
D. Certified test results for fans shall be submitted within 30 days after the completion of each test. No equipment shall be released for shipment until certified test data is accepted by the Engineer. Copies of test procedures, raw data, calculations and data derived from tests shall be included as part of report. The test report shall be indexed and cross-referenced.
E. After completion of the witnessed performance test on one pre-production jet fan assembly, submit the performance test results to the Engineer.
F. The submitted test results shall include a tabulation showing the static thrust, exit jet velocity, power input and sound power level of the jet fan assembly at the design point blade angle setting and at three additional settings, in 2 degree increments, above and below the design point. The fan manufacturer shall identify the possibility of fan stalling if it exists within the fan performance region covered by 10 percent above and below the design thrust as specified.

Motor Test.--Each pre-production motor shall be tested in accordance with the procedures specified in ANSI/IEEE publication 112.

The Contractor shall arrange for factory testing of each fan motor. Tests shall be witnessed and un-witnessed.

Witnessed Tests: The motor to be used in the fan performance test, also known as the pre-production unit, shall be independently tested in the presence of the Engineer. Witnessed tests shall be as follows:

A. Tests to obtain actual fan motor performance curves verifying the theoretical fan motor performance curves and additional data submitted.
B. Tests to obtain values for the following electrical and mechanical characteristics with rated voltage and frequency applied to motor terminals:

    1. Full load current in amperes.
    2. No load current in amperes.
    3. Full load input in kilowatts.
    4. No load input in kilowatts.
    5. Locked rotor current in amperes.
    6. Locked rotor input in kilovolt amperes.
    7. Locked rotor torque in Newton-meters.
    8. Rotational moment of inertia of rotor in Newton-meters squared.
    9. Displacement power factor in percent at full load amperes in locked rotor amperes.

C. The following additional witnessed tests shall be performed:

    1. Performance speed-current and speed-torque tests.
    2. Temperature test, full load.
    3. Insulation resistance-temperature test shall be taken following heat run, readings being taken in degrees Celsius at one hour intervals for a period of four hours. Temperature shall be determined by the resistance method.

4. Cold and hot resistance measurement.
5. Dielectric Test: Voltage to be applied shall be based on the voltage rating of insulation plus 1000 V.
6. Noise test in accordance with IEEE 85 with results expressed in decibels of sound pressure and power on the A scale.
7. Winding resistance.
8. Losses, no load and full load.
9. Visual bearing inspection.

Un-witnessed Tests: Each of the remaining motors shall be tested at its rated synchronous speed un-witnessed.

A. Winding resistance.
B. No load current in amperes.
C. Dielectric tests.
D. No load speed.
E. Locked rotor current in amperes.
F. Bearing inspection.
G. Running-no load current.
H. Cold resistance measurement.
I. Insulation resistance and winding temperature at time taking insulation resistance.
J. Vibration check.

Test data shall be recorded for the performance curves continuously at the rated voltages and frequency of the motor over the speed range from standstill to rated rotational speed.

Motors shall be assembled into fan-motor units after the test reports and performance curves have been approved by the Engineer.

Fan Tests.--Testing of jet fans shall conform to the following requirements:

A. The following tests shall apply to the pre-production model only:

1. One pre-production jet fan assembly shall be operated continuously for 24 hours. The pre-production fan shall have successfully passed the spin tests and vibration checks specified herein.
2. The pre-production jet fan assembly shall be performance tested in accordance with the requirement of AMCA 210/ASHRAE 51. Jet fan assembly thrust shall be measured in accordance with the requirements of AMCA 250. The jet fan assembly shall be tested in the forward and the reverse direction of air flow to determine the thrust developed, air flow, exit jet velocity and motor input power. All electrical information shall be recorded during each test such as volts, amperes and power factor. The angle of fan blades shall be changed and test repeated as required until the specified requirements are satisfied. If the maximum power listed on the schedule is exceeded when delivering the specified thrust, the jet fan shall be redesigned to meet the maximum power requirements.
3. This reversing test shall be coordinated with motor control center settings similar to that which will be used in the field. The test shall demonstrate the fans are capable of completing full rotational reversal within 45 seconds without overloading the motor or tripping any protective devices in the motor controller.

4. The pre-production jet fan assembly shall be noise tested in accordance with the requirements of ISO/TC 117 WG6 to obtain sound pressure data at eight-octave band center frequencies from 63 Hz to 8000 Hz. The measured data shall be presented for each octave band and in the A-weighted dBA scale.
5. A second pre-production base fan-motor unit complete with sound attenuators shall be subjected to a test to verify the unit is capable of operating for one hour when the airflow passing through and around the fan-motor unit is at a temperature of 250°C. The unit shall remain the property of the manufacturer after testing.

B. Each impeller shall be statically and dynamically balanced at the rated operating rpm. Each impeller shall be tested at 125 percent of design rpm for a period of not less than five minutes. The impeller shall be inspected for loose blades and additional damage. Defective parts shall be replaced and impeller shall be re-tested.
C. Each fan shall be vibration tested. Defective bearings shall be replaced and fan shall be re-tested. Vibration test shall be measured front and rear in two radial planes 90 degrees apart, and in the axial direction. The measured vibration levels shall be compared with the acceptable vibration limits specified. If the measured vibration exceeds the specified limits, the Contractor shall correct and re-test the fan.

DELIVERY, STORAGE AND HANDLING

Ventilation equipment components shall be delivered wrapped in opaque water-resistant covers and fastened to substantial pallet type shipping supports. Components shall be packed with padding materials of sufficient quantity and thickness to prevent damage to painted surfaces and to prevent other damage.

Ventilation equipment components shall be stored under cover in dry areas protected from the weather and other hazards. Jet fans shall be protected from vibrations to avoid the brinelling of the motor bearings. If the fans are stored for more that a month, the impellers shall be rotated as required by the fan manufacturer, to circulate the bearing lubricants. Storage shall be in environments with ambient temperatures at or above 13°C if temporary power for the space heaters cannot be provided. Jet fan assemblies or components shall not be stored in contact with the ground.

The Contractor shall schedule installation of jet fans with availability of permanent power to prevent condensation in the motors of the fans installed in place.

Ventilation equipment components shall be handled to prevent damage to painted surfaces and to prevent other damage. Damaged painted surfaces shall be repaired with a filler compatible with the paint system specified in "Painting and Finishing" of these special provisions, and repainted with the three coat paint system specified herein.

Protective coverings shall be left in place during installation and erection of components. After installation temporary protective coverings shall be provided to protect against work by others in the tunnel structure.

A protective coating consisting of a coating of an anti-corrosion compound shall be provided on machined surfaces not requiring painting, including shaft ends.

DEFINITIONS

The following definitions shall apply to this section:

A. Fan: the terms fan, jet fan, tunnel ventilation fan, and fan assembly are synonymous and are deemed to mean a jet fan complete with sound attenuators and directly-connected reversible motor.

B. Forward flow: airflow generated by the fan in the same direction as the normal traffic flow in the specific tube of the tunnel.
C. Reverse flow: airflow generated by the fan in a direction opposite to the normal traffic flow in that specific tube of the tunnel.
D. Pitch: the angle formed by the chord line of a fan blade root cross-section and a line parallel to the direction of rotation.
E. Manufacturer's Representative: a representative from the firm of the manufacturer for each and every category of equipment furnished under this special provision.

JET FAN FEATURES

Jet Fan.--Fans shall be of the axial-flow type, direct-driven by internally mounted single speed motors which are capable of delivering air in the forward and reverse direction. The forward and reverse direction of airflow shall be permanently marked in a conspicuous location on the exterior of the fan housing. In selecting equipment, interchangeability of parts shall be provided.

Fans shall be operated manually or automatically, locally from the motor control centers in the equipment chambers or remotely from the operation and maintenance control center. The operating procedures will require any number of fans to be operated either individually or simultaneously.

Operating Environment.--For normal operation, the entire fan motor and sound attenuator assembly shall be industrial protection rating of IP 55 and capable of withstanding low pressure jets of water. The jet fan assembly shall be equipped with a drainage system.

For emergency operation, the fan motor and sound attenuator assembly including hangers, supports, monitoring sensors and cables shall be constructed such that no mechanical, electrical or structural failure will occur when operating at full capacity in an ambient air temperature of 250ºC for a minimum period of one hour.

Performance Requirements.--The fan performance requirements are specified in the schedule as shown on the plans. The static thrust and maximum exit jet velocity requirements shown shall apply to fan operation with the standard air density of 1.2 kg/m^3.

Fan motors shall be capable of starting and operating in an ambient air temperature of 0ºC and operating satisfactorily for not less than one hour in 250ºC ambient air.

Fans shall be capable of withstanding the effect of all stresses and loads under starting, operating and reversing conditions.

Fans shall be capable of developing static thrust and exit jet velocity, in both directions of motor rotation, not less than that shown on the plans and with a brake power less than the nameplate rating of the motor at the selected design point and at blade angle settings of 2 degrees above and below the design point when operating at maximum air density conditions.

Fans shall be shop performance tested with the safety screens in place. A maximum reduction in thrust of 5 percent below that shown in the schedule shall be deemed acceptable.

Fans shall be capable of accelerating to full speed in 15 seconds or less and capable of starting three times, consisting of one cold and two hot starts, during any one hour of continuous operation in 250ºC ambient air.

Fan motor units shall have an efficiency of not less than 60 percent when operating in either direction of airflow at the specified nominal static thrust and exit jet velocity.

The maximum acceptable sound power level of the jet fan assembly shall not exceed that shown in the schedule on the plans for each octave band. The maximum vibration amplitude of

the jet fan assembly shall not exceed the peak-to-peak amplitude of 0.025 mm at the nominal operating speed of 1750 rpm.

Fan Components and Materials.--Impeller hub and blades shall be cast aluminum-alloy.

The impeller shall be fastened to the motor shaft by means of positive locking device. The impeller shall be designed and constructed to withstand stresses and loads created by over speed testing to 125 percent of the nominal operating speed.

The impeller and hub shall be designed and constructed such that the pitch of blades can be manually adjusted without removing the impeller. The blades and hubs shall have index marks that show the design operating blade setting and a minimum of three increments of stagger angle larger and three increments smaller than the design operating blade setting, and shall clearly indicate the maximum blade angle beyond which the motor will overload.

The fan housing, motor mounts and supports and housing supports shall be fabricated of hot rolled steel. The fan housing shall be continuously welded construction and of thickness not less than 4 mm. Welds located in air stream shall be ground smooth.

The fan housing shall be formed to a true-round, concentric, cylindrical shape providing uniform clearance between the tips of the impeller blades and the housing. Adequate clearance shall be provided between blade tips and the housing at all points to allow for expansion and contraction over a temperature range from 0ºC to 250ºC without developing interference.

End flanges for the housing shall be the same thickness as the housing or thicker. Flanges may be rolled integrally or continuously welded to the outer periphery of the fan housing. Flanges shall have sufficient width and punched or drilled holes to allow sound attenuators to be rigidly bolted to the housing.

Motor mounts and motor supports shall be designed and constructed to make the motor axis and fan-housing axis concentric. Motor mounts and motor supports shall be in sufficient number and shall be designed to support the entire weight of the impeller and the motor and the loads developed by the fan operation.

Access doors shall be of adequate size in the fan housing for inspection of blade locking devices to facilitate blade angle adjustment and for access to vibration and test instrumentation. Access doors shall be steel construction with AISI Type 316 stainless steel hardware and minimum 3.18 mm thick silicone base gasket to make an air-tight construction. The silicone gasket material shall be designed for use in 0ºC to 250ºC ambient air temperature.

The fan housing shall be of sufficient length to totally enclose the fan impeller and motor within the housing. The ends of the fan housing shall be straight and smooth to receive sound attenuators at both ends. The connection between fan and sound attenuators shall facilitate assembly and disassembly of jet fan and sound attenuators in the field.

Lifting lugs of steel construction shall be welded on the exterior of the fan housing and sound attenuator to facilitate lifting and transport of the fan as a single assembly.

Welding.--Welded components of jet fans shall conform to the following requirements:

A. Welding shall conform to the requirements of AWS D1.1 and AWS D1.3, and AWS D14.6.
B. Welders shall be qualified in accordance with the requirements of AWS D1.1, Section 5, "Qualification."
C. The welding process shall be the shielded metal arc, in accordance with AWS D1.1 and D14.6.

MOTORS

General Requirements.--Motors for all tunnel ventilation fans shall be supplied by a single manufacturer. Motors shall conform to the requirements in all applicable ANSI, IEEE, and NEMA or approved equivalent ISO standards and shall be NEMA Design B, designed for continuous operation for a minimum period of one hour in an ambient temperature of at least 250ºC.

Motors shall have embedded 100-ohm Resistance Temperature Detectors (RTDs) in the windings, minimum of two per phase, wired to a NEMA 4X terminal box mounted on the outside of the fan housing. The terminal box shall be common for all monitoring devices specified in these special provisions. The RTDs shall be compatible with the temperature monitor or motor manager in the motor control centers.

Motors shall be totally enclosed, high efficiency, air-over, all cast iron or high grade silicone steel frame, induction type. Motors shall be wound for 460 V, three-phase, 60 Hz alternating current. Motors shall be wired for full voltage starting. Motors shall have a 1.15 service factor rating.

Motor Performance Requirements.--Motors shall be capable of accelerating the fan impeller from standstill to the design rotational speed in not more than 15 seconds when connected to terminal voltage of 85 percent of the nominal supply voltage.

Motors shall be capable of starting, and operating continuously, under full load conditions, for a minimum period of one hour in ambient temperature of at least 250ºC. Motors shall be capable of going from full forward flow to full reverse flow or vice versa in a maximum of 45 seconds without overloading. Motors shall be capable of a minimum of three starts during a sixty minute period with 250ºC air flowing through the fan.

Motors shall conform to the requirements in NEMA standards for the locked-rotor input (Kilovolt-amperes per kW) required to meet the indicated acceleration performance. Motors shall have a minimum of Class H insulation and rated for Class F temperature rise, when tested at the 1.15 service factor load.

Motors shall be capable of operating continuously at rated torque at any terminal voltage between 85 percent and 110 percent of the nominal supply voltage.

Motor Components and Construction.--Motor shafts shall be steel construction, designed to support and drive fan impeller under all specified operating conditions. Each motor shall have lifting lugs in sufficient numbers.

To prevent condensation during the off cycle, The motor windings shall be heated by 460 V, single phase power supplied to heaters in the motors to prevent condensation during the off cycle. The heaters shall be pre-wired in rigid steel conduit to an auxiliary conduit box on the outside of the fan housing.

Motor leads shall be insulated copper, wired to an oversized weatherproof conduit box mounted on the exterior of the fan housing. The conduit box shall have screw-type or bolt down pressure terminals and exterior mounting lugs. Lead wires shall be protected from the air stream by enclosing them in an airtight, high tensile strength, seamless metal rigid conduit. The conduit box shall be the next larger size than the NEMA standard size for the number of wires shown on the plans. The conduit box shall be oriented to receive feeder conduit from the direction shown on the plans.

The motor bearings shall be designed and constructed for the maximum radial and thrust loads anticipated during starting, and operating conditions. Bearings shall have a minimum L-10 life rating equal to 40,000 hours as defined by the Anti-Friction Bearing Manufacturers Association (AFBMA).

Lubrication lines shall be brought from motor bearings to the exterior of the fan housing and terminated in straight lubrication fittings. Grease relief lines, if used, shall be terminated in spring loaded relief fittings. Grease fittings shall have covers to exclude water and dust. Bearing lubricant shall be capable of providing the lubrication properties specified by the bearing manufacturer under conditions of operation for one hour in ambient air at a temperature of 250ºC.

Lubrication lines for motor bearings shall be high strength, seamless stainless steel tubing without kinks or sharp bends. Lubrication lines shall be secured to the housing to prevent vibration of the lines and the leakage.

Motor bearings shall have a vibration monitoring system, complete with velocity pick-up transducer, for each motor bearing. The monitoring system shall trigger remote alarms for two levels of vibrations: "Alert" and "Alarm." The alert level is to trigger an alarm when general wear and minor defects have increased motor vibration to a level where maintenance is needed. The alarm level is to safeguard the motor against dangerous vibration caused by damage or sudden out of balance conditions. The measuring range shall include 1 to 25 mm/s RMS maximum for alert and alarm. The transducers shall be wired to the common control terminal box mounted on the exterior of the fan housing.

SOUND ATTENUATORS

General Requirements.--Sound attenuators for tunnel ventilation fans shall be selected by the fan manufacturer to meet all the operating conditions specified.

Cylindrical (tubular) sound attenuators shall be provided, one mounted directly on each end of the fan housing. The inside diameter of the sound attenuator shall match the inside diameter of the fan. An inner bullet, if required, shall be of aerodynamic design. The exterior diameter of the bullet shall match the diameter of motor and hub.

Sound attenuators shall be the minimum length required, but not less than two fan diameter length each side.

Sound attenuators shall be provided with safety screens mounted to the bellmouth ends. Screens shall be fabricated of minimum 10 gage galvanized or stainless steel wire.

Performance Requirements.--Sound attenuators shall be designed so that jet fan assemblies do not exceed the acceptable maximum sound power or sound pressure levels shown in the schedule on the plans.

Sound Attenuator Construction.--The materials and methods used to fabricate sound attenuators shall be such that they will be operational for minimum period of one hour in ambient air temperature 250°C, without any mechanical or a structural failure.

The exterior casing shall be not less than 1.3 mm thick, hot dipped galvanized steel, internally lined with inorganic mineral wool or glass fiber acoustic in fill covered with not less than 0.75 mm thick stainless steel perforated sheets.

A drain hole of 12 mm minimum diameter shall be provided in the exterior casing of each sound attenuator, to drain water that may enter into fan assembly during tunnel washing operations.

The acoustic in-fill material shall be vermin free and moisture resistant. The facing on the in-fill shall prevent erosion of the fibrous particles by the air stream under all conditions of operation specified. The acoustic fill material shall have a combustion rating not more than the following when tested in accordance with ASTM Designation: E 84, NFPA 255, or UL 723:

A. Flame spread classification: 25

B. Smoke developed rating: 5
C. Fuel contribution rating: 20

MISCELLANEOUS APPURTENANCES

Fan Supports.--Fan supports and the suspension system shall be designed and constructed to provide adequate support as required against the fluctuating loads imposed by fan operations and moving traffic, and designed per the Specification for Structural Steel Buildings, Allowable Stress Design Method, June 1, 1989 by the American Institute of Steel Construction. AISI Type 316 stainless steel bolts and hot dip galvanized or stainless steel support members shall be used, with rubber isolating material providing adequate isolation in the pre-engineered support components. The support system shall facilitate easy dismantling and reinstallation of fan assembly for maintenance.

The fan supports shall be hot dip galvanized or stainless steel. Supports shall be bolted to the fan housing and cross braced to provide rigidity and to absorb all axial loads. Supports shall be designed in the field for attachment to the tunnel structure and the space constraints as shown on the plans. Calculations for the supporting structures shall be provided in conformance with the requirements specified herein.

All bolts, nuts, washers, and lock washers shall be AISI Type 316 stainless steel. Bolts and nuts shall be consistent with the tunnel embedded inserts where applicable.

Lifting lugs or eyes shall be in sufficient numbers as specified in these special provisions.

Nameplates.--A nameplate shall be furnished for each fan assembly. Each nameplate shall show the name and address of the fan manufacturer, serial number of the fan, the maximum safe rotational speed of the fan in revolutions per minute and the design operating conditions of the fan. An additional nameplate shall be furnished for each fan which shows, in characters 75 mm high, the number of the fan as shown on the plans or as directed by the Engineer. Nameplates shall be riveted or screwed to the fan housings.

Two identical nameplates shall be furnished for each motor. Each nameplate shall show the name and address of the motor manufacturer, the motor model number and serial number, motor speed in revolutions per minute, nominal power in kW, voltage, phase, frequency, no-load, full-load, and locked-rotor currents, NEMA code-letter designation, NEMA frame size, service factor, and the terminal connection chart for the motor. One of the two nameplates shall be securely fastened to the motor housing; the other shall be riveted or screwed to the fan housing adjacent to the fan nameplates. Nameplates shall be stainless steel. The specified data shall be permanently marked on the nameplates.

Airflow Indicating Devices.--Each fan assembly shall be furnished with two differential pressure switches capable of detecting a difference in air pressure between the intake and discharge sides of the fan to provide positive indication of airflow generated by the fan.

Differential pressure switches shall be diaphragm operated to actuate a single pole double throw snap action switch. Motion of the diaphragm shall be restrained by a calibrated spring that can be adjusted to set the exact pressure differential at which the electrical switch will be actuated. Motion of the diaphragm shall be transmitted to the switch button by means of a direct mechanical linkage. Set point adjustment shall be screw type with set point indicated on a visual scale.

Housing to contain each pressure switches shall be Nema 4 rated weatherproof, and made of 16 gauge zinc plated steel with gasketed cover. Housing shall be complete with bulk head fittings to accept the 3.2 mm stainless steel tubing from the probes. Housings shall be mounted in an accessible location as shown on the plans.

Electrical rating for the switches shall be 15 A, 120 V, 60 Hz. Switches shall operate in a temperature range of -28ºC to +80ºC.

Operating range shall be 5 mm wg to 25 mm wg or as otherwise recommended by the fan manufacturer.

Cradle.--The jet fan manufacturer shall design and furnish a cradle fabricated from carbon steel. The cradle shall be used by the Contractor to install the fans in place. The cradle shall be designed for a static load of 115 percent of the weight of the jet fan assembly and shall be designed to allow removal and replacement of jet fans in the future without interference with or damage to the adjacent tunnel light fixtures. After completion of the work the cradle shall become the property of the State.

PAINTING AND FINISHING

Fan housings, attenuator outside casings, supports and all other steel components shall be hot dipped having an electric-deposited zinc coating in conformance with the GS165 standard or equivalent.

All surfaces of fan housings, sound attenuators, supports, and exterior surfaces of motors, except the items that are fabricated of either aluminum or stainless steel, shall be factory painted to the appropriate finish in accordance with these special provisions. Primer and paint materials shall have a design life of minimum 10 years in the environmental conditions normally encountered in a vehicular tunnel, and capable of withstanding a temperature of at least 250ºC for a minimum period of one hour without emitting smoke or toxic fumes. The color of the finish coat shall be black.

All paint material shall be provided from one source and shall be volatile organic content (VOC) compliant in accordance with California state regulations, and shall conform to the following requirements:

A. Primer paint material for bare carbon or alloy steel materials shall be a solvent based, high solids, inorganic zinc rich primer, and shall meet requirements for ASTM Designation: A 490, Class B slip co-efficient and creep test, ASTM Designation: B 117 salt spray test, ASTM Designation: D 3363 film hardness by pencil test, and AASHTO standard M300. Solids content shall be 89 percent minimum, by weight. The zinc content shall be 82 percent minimum, by weight, in dry film. Primer paint material for galvanized surfaces shall be a tie bond epoxy penetrating sealer.
B. Intermediate paint material shall be a high solids, high build, cycloaliphatic amine epoxy. The solids content shall be 73 percent minimum, by volume.
C. Topcoat paint material shall be a high gloss, high solids aliphatic acrylic polyurethane, and shall meet SSPC Paint 36 for a level 3 urethane. Solids content shall be 68 percent minimum, by volume.

Surface preparation shall be as follows:

A. Bare carbon steel surfaces, except surfaces of motors, to receive primer paint material shall be prepared in accordance with the requirements of SSPC SP 6. The minimum height of profile after completion of blast cleaning shall be 0.04 mm.
B. Surfaces of motors to receive primer paint material shall be prepared in accordance with the requirements of SSPC SP 3.

Surfaces specified to receive paint shall receive one coat of primer paint material, one coat of intermediate paint material and one coat of topcoat paint material. The dry film thicknesses shall be as follows:

A. The dry film thickness of the primer coat shall be 0.05 mm to 0.075 mm.
B. The dry film thickness of the intermediate coat shall be 0.10 mm to 0.15 mm.
C. The dry film thickness of the topcoat shall be 0.05 mm to 0.075 mm.

Primer, intermediate and topcoat paint materials shall be applied in accordance with the requirements of the paint material manufacturer's printed paint application instructions and in accordance with the applicable non conflicting requirements of SSPC PA 1.

The applied and cured paint film shall be tested to determine the dry film thickness. Measurement of dry film thickness shall be in accordance with the requirements of SSPC PA 2.

Surfaces which are found to be deficient shall be re-cleaned, re-primed and re-painted until the specified coating requirements have been met.

EXECUTION

The jet fan shall be mounted without encroaching in to the clearance envelope of the tunnels as shown on the plans.

The Contractor shall coordinate with the finish lining work in the placement of the embedded struts, and shall provide temporary supports and bracing as required during handling and erection.

INSTALLATION

The fan manufacturer shall provide the services of a qualified field representative who is experienced with the work involved in the installation of ventilation equipment of this type. The fan manufacturers representative shall be present on site during the installation of the fans and shall also direct the activities specified in "Field Quality Control" of these special provisions.

The jet fan assemblies shall be installed in the space provided with access panel and junction boxes oriented in such manner as to allow the fan motor and blades to be serviceable. The Contractor shall verify and coordinate location and type of inserts in the finish concrete and required bracing of the fan to the concrete and other installation provisions prior to fabrication of hangers and other structural steel supports.

Supports for fans and sound attenuators shall be adjusted such that they align accurately on the same horizontal plane. The Contractor shall attach sound attenuators to each end of the fan housing prior to lifting the jet fan assembly to the tunnel ceiling for installation.

Jet fan assemblies shall be installed as recommended by the fan manufacturer, using vibration isolators of adequate strength and deflection to minimize transmission of high frequency vibration to the structure.

Airflow indicating devices shall be installed. Differential pressure switch enclosures shall be installed on the tunnel ceiling or the fan housing as shown on the plans. Stainless steel tubing shall be provided from fittings on the sound attenuator housing to the low and high pressure connections on each switch. Stainless tubes with a diameter of 3.2 mm shall be used for the static pressure probes. Tubes shall be inserted through sound attenuators and liner and extend into the air stream approximately 50 mm.

FIELD QUALITY CONTROL

Testing.--Field tests of jet fans shall conform to the following requirements:

A. Vibration tests shall measure the amplitude and frequency of vibration levels to verify specified acceptance levels. If specified acceptance levels are exceeded, the impeller shall be balanced and vibration level measured until the specified requirement is obtained.
B. The fans shall be operated in the required direction of air flow. The fans shall be continuously operated for one hour. For each jet fan motor, starting current, starting voltage, full load voltage and power factor shall be measured and recorded. Operating current and applied voltage shall be measured and recorded with all fans in a specific tube operating together.
C. Each fan shall be operated four times fifteen minutes apart. The starts shall occur immediately following a de-energizing and spin down.
D. Each fan shall be independently run in the reverse direction for a period of at least 10 minutes and then initiate the forward direction of operation. Forward and reverse operation shall be controlled from the local tunnel control system in the respective equipment chamber. Record motor current and winding temperature during this test and show that motor will not overheat or stall during reversal.
E. Jet fans shall be tested for performance after installation. The direction and magnitude of the natural wind velocity in the tunnel shall be measured and recorded immediately prior to starting each jet fan for this test. The exit jet velocity and air volume generated by the jet fan assembly shall be measured in the desired direction of air flow. The thrust developed by the fan based on the measured value of velocity and volume shall be calculated. The jet fan operating in the reverse direction shall be tested. If the calculated thrust is at least 90 percent of, or more than, the specified value, no further testing is required. If the calculated thrust is less than 90 percent of the specified value, the fan blade angle shall be adjusted to increase the air flow. The Engineer shall be notified prior to adjusting the fan blade angle. The exit jet velocity and air volume shall be re-measured until the calculated thrust is at least 90 percent of the specified value. The new running current and power input in the jet fan shall be recorded.
F. The natural airflow and its direction in the tunnel shall be measured and recorded as follows:

    1. Two adjacent rows of fans, a total of 4 fans, shall operate in the direction opposing the natural air flow direction through the tunnel. Air flow through the tunnel shall be stabilized for 15 minutes. The air flow rate shall be measured at a minimum of 2 locations. This test shall be repeated with each incremental group of adjacent rows, a total of 4 fans per group.
    2. The final measurement shall be made with a total of 7 rows, a total of 14 fans, operating.

G. Sound pressure levels for each fan operating alone shall be measured and recorded. Sound pressure levels 1.5 m above the roadway surface under the fan and at 4.5 m and 9 m from both ends of the fan shall be measured. Before the fan is started and after the fan is turned off, ambient sound levels shall be measured. With all the fans in the tunnel operating simultaneously, sound level at locations, as determined by the Engineer, shall be measured.

H. After successful completion and acceptance of the jet fan tests, the Contractor shall test the coordinated operation of the tunnel ventilation system under the DDC system manually, automatically, locally and remotely for both normal and emergency conditions. The description of the operation under the DDC Control is described in "Tunnel Control System" of these special provisions. While the fans are operating in the forward emergency mode, test operation of the "Reversing Switch" located in the control room at the operation and maintenance building. Normal mode automatic operation of fans shall be tested by manually simulating high Carbon Monoxide (CO) conditions in step sequence.

MEASUREMENT

The tunnel jet fans will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for tunnel jet fans shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the tunnel jet fans, complete in place including testing, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

ELECTRICAL

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SECTION 10-2. (BLANK)

SECTION 10-3. SIGNALS, LIGHTING AND ELECTRICAL SYSTEMS

10-4.01 DESCRIPTION

Installing flashing beacons lighting Roadway Warning Lights and sign illumination Electrical systems, including power, lighting, systems and instrumentation, shall conform to the provisions in Section 86, "Signals, Lighting and Electrical Systems," of the Standard Specifications and these special provisions.

Unless shown otherwise, locations of cabinets, standards, foundations, lighting fixtures, conduits, pull boxes, appurtenances and other similar electrical equipment are approximate and may be changed to suit field conditions or as directed by the Engineer.

10-4.__ COST BREAK-DOWN

Cost break-downs shall conform to the provisions in Section 86-1.03, "Cost Break-Down," of the Standard Specifications and these special provisions.

The Engineer shall be furnished a cost break-down for each contract lump sum item of work described in this Section 10-3.

The cost break-down shall be submitted to the Engineer for approval within 30 days after the contract has been approved. The cost break-down shall be approved, in writing, by the Engineer before any partial payment for the items of electrical work will be made.

10-4.__ BASIC ELECTRICAL MATERIALS AND METHODS

GENERAL

Basic electrical materials and methods shall conform to these special provisions, and shall include the following:

A. Operation and maintenance (O&M) manual requirements.
B. Tunnel materials.
C. Concrete equipment bases.
D. Touch-up painting.
E. Training

SUMMARY

Scope.--Electrical work shall be furnished, installed and tested in conformance to these special provisions.

QUALITY ASSURANCE

Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. All device and component installations shall comply with the requirements of NFPA 70 and NFPA 502. All electrical materials and components shall be UL Listed.

OPERATION AND MAINTENANCE MANUAL

The Contractor shall provide O&M manuals including documentation for every major piece of electrical equipment having specific operating procedures, or that would require maintenance, inspection or adjustment. The Contractor shall provide O&M manuals for each item of equipment as specified elsewhere in these special provisions. The Contractor shall submit three copies, each bound in hardback binders. One complete manual shall be submitted to the Engineer for review 3 months prior to commencement of systems or equipment tests. The Contractor shall submit the remaining manuals with as-constructed installation, start-up, and test data, including project specific equipment and component settings, prior to contract completion. Each O&M manual shall include the names, addresses, and telephone numbers of each subcontractor installing the system or equipment and the local representatives for the system or equipment. Each O&M manual shall include a table of contents referencing individually tabbed sections and the manual shall be assembled to conform to the included table of contents. Tab sheets shall be used to separate information pertaining to each system or item of equipment. The instructions shall be typewritten and legible, with any included large drawings sheets neatly folded in.

The following identification shall be inscribed on the cover:

A. The words "OPERATION AND MAINTENANCE MANUAL."
B. The name and location of the system, equipment, building, name of responsible Contractor, and contract number.

Each O&M manual shall include the following documentation:

A. Internal and interconnecting wiring and control diagrams with data to explain detailed operation and control of the system or equipment.
B. Description of the function of each principal item of equipment including, a control sequence describing normal startup, operation, and shutdown, and emergency procedures.
C. Installation and maintenance instructions.
D. Safety precautions.
E. Diagrams and illustrations.
F. Testing methods.
G. Performance data and settings "as installed."
H. Cleaning and lubrication schedule including type, grade, temperature range, and frequency.
I. Recommended spare parts list. The list shall indicate sources of supply, recommended spare parts, and name of servicing organization. The spare parts list shall include pictorial diagrams identifying part numbers, when available from the manufacturer.
J. Appendix: list qualified permanent servicing organizations for support of the equipment, including addresses, telephone numbers and certified qualifications.

POSTED OPERATING INSTRUCTIONS

The Contractor shall furnish approved operating instructions for all systems and equipment listed in the technical sections for use by operation and maintenance personnel. The operating instructions shall include wiring diagrams, control diagrams, and control sequence for each principal system and equipment. The operating instructions shall be engraved in laminated plastic. The operating instructions shall be posted adjacent to each principal system and equipment including startup, proper adjustment, operating, lubrication, shutdown, safety precautions, procedure in the event of equipment failure, and other items of instruction as

recommended by the manufacturer of each system or equipment. Operating instructions that may be exposed to the weather shall be provided on weather resistant materials. Operating instructions shall not fade when exposed to sunlight and shall be secured to prevent easy removal.

DEMONSTRATION AND TRAINING

The Contractor shall demonstrate and instruct the Department's designated operating, maintenance, and training personnel in the adjustment, operation, and maintenance of systems and equipment, including pertinent safety requirements. Each instructor shall be familiar with all parts of the installation and shall be trained and certified in operating theory and practical operation and maintenance work. The training shall start after the Contractor has completed start-up of the electrical systems, but before final acceptance tests. The field instruction shall cover all of the items contained in the operating and maintenance manuals, and shall include demonstrations of routine maintenance and servicing operations. The Contractor shall submit to the Engineer for approval, at least 15 days prior to the proposed date and time, proposals for the following:

A. The location of a training site within a 50km radius of the project site.
B. Topics to be covered during the instruction.
C. Training schedule including dates and times.
D. Other logistics related to training tasks.

Training requirements.--The instruction shall include the following:

A. Description of each basic electrical system including startup, normal operation, normal shutdown, emergency startup, emergency shutdown, normal testing and trouble-shooting conditions.
B. Explain identification system.
C. Describe interfaces with mechanical equipment including interlocks, sequencing, start-up, shut-down, emergency, safety, system failure, security and other provisions.
D. Outline basic maintenance procedures including adjustments to optimize output and efficiency of electrical systems.
E. Display and conduct a "thumb-through" explanation of the maintenance manuals, record drawings, spare parts inventory, metering and other service items.
F. Conduct a detailed review of preventative maintenance measures.
G. Review trouble modes and remedies.

Training documentation.--A lesson plan and training manuals for the training phases including types of training shall be provided with lists of reference materials and sections of O&M manual to be addressed.

Training audio-video recordings.-- The Contractor shall provide all equipment, materials and qualified personnel to visually and audibly record all training sessions. Video recordings shall be produced in DVD-R_format. Each system or piece of equipment covered shall be recorded as a single program and correlated with the O&M manuals. An identification label shall be affixed to the DVD and be shown on the first two minutes of recording. The label shall identify the project and contract number, equipment or system discussed, length of recording, and reference O&M manual.

Training sessions.--The Contractor shall conduct training sessions on the equipment items and systems as specified in these special provisions, and shall provide training materials for up to six (6) persons per session (shift).

COORDINATION

The Contractor shall coordinate chases, slots, inserts, sleeves, and openings with general construction work and arrange these features within the associated structures during progress of construction to facilitate subsequent electrical installations.

Inserts, embedded strut, and sleeves shall be set in poured-in-place concrete, masonry work, and other structural components as they are constructed.

The Contractor shall arrange, coordinate, and integrate the installation of electrical materials and equipment for efficient flow of the work. The installation of large equipment requiring positioning shall be performed before closing in the building.

The Contractor shall coordinate electrical service connections to components furnished or required by utility companies:

A. Coordinate installation and connection of permanent exterior underground and temporary overhead utilities and services, including electricity-metering components.
B. Comply with requirements mandated by authorities having jurisdiction (as defined in NFPA 70, Article 100) and by the utility company providing electrical power and other services.

TUNNEL MATERIALS

Materials installed in the tunnel shall be selected to comply with NFPA 502, Paragraph 8-3, "Materials" as follows:

A. Materials for use as conduits, raceways, ducts, cabinets, and equipment enclosures and their surface finish shall be capable of being subjected to temperatures up to 316°C for one hour without supporting combustion.
B. Electrical systems that are installed within confined spaces shall not use materials that produce toxic by-products during electrical circuit failure or when subjected to an external fire. PVC conduit and vinyl-insulated or jacketed conductors or cables, and exposed PVC conduit and PVC-coated metal conduit, shall not be used in tunnels.

Jet fan motor connection lead material installed in the tunnel shall be selected in conformance with NFPA 502, paragraph 7-7.1 as follows:

A. Tunnel ventilation fan motors and all related components that are exposed to the ventilation airflow shall be designed to remain operational for a minimum of one hour in an air stream temperature of 250°C.
B. Wiring in concrete embedded raceways and junction boxes shall not be considered to be exposed to the elevated temperature air stream.

CONCRETE BASES

All direct floor mounted equipment shall be installed on raised concrete bases with the sizes shown on the plans. Concrete bases shall be constructed as shown on the plans and as specified in these special provisions, but shall not be less than 102 mm larger, in both directions, than supported unit.

Unless otherwise shown on the plans, the Contractor shall follow supported equipment manufacturer's anchorage recommendations and setting templates for anchor-bolt and tie locations.

TOUCHUP PAINT

Equipment manufacturer's paint shall be selected to match installed equipment finish. The Contractor shall use zinc-rich paint on galvanized surfaces as recommended by the equipment manufacturer.

ELECTRICAL EQUIPMENT INSTALLATION

The Contractor shall arrange and install components and equipment to provide the maximum possible headroom.

Unless otherwise specified, all materials and components shall be installed level, plumb, and parallel and perpendicular to other building systems and components.

The Contractor shall install equipment to facilitate service, maintenance, and repair or replacement of components. The Contractor shall connect equipment for ease of disconnecting, with minimum interference with other installations.

Right of way shall be given to raceways and piping systems requiring installation at a required slope.

All equipment shall be anchored and braced securely to resist seismic and dynamic wind forces.

UTILITY COMPANY ELECTRICITY-METERING EQUIPMENT

The Contractor shall install equipment according to utility company's written requirements. The Contractor shall provide grounding and empty raceways as required by utility company.

FIRESTOPPING

Fire-stopping shall be applied to cable and raceway penetrations of fire-rated floor and wall assemblies to achieve fire-resistance rating of the assembly, in conformance with these special provisions.

CUTTING AND PATCHING

The Contractor shall cut, channel, chase, and drill floors, walls, partitions, ceilings, and other surfaces required to permit electrical installations. The Contractor shall repair and refinish disturbed finish materials and other surfaces to match adjacent undisturbed surfaces. New fire-proofing shall be installed where existing fire-stopping has been disturbed.

FIELD QUALITY CONTROL

The Contractor shall inspect installed components for damage and faulty work, including the following:

A. Electricity-metering components.
B. Concrete bases.
C. Cutting and patching for electrical construction.
D. Touchup painting.

REFINISHING AND TOUCH-UP PAINTING

The Contractor shall clean any damaged or disturbed structural elements, equipment, or components and then apply primer, intermediate, and finish coats to suit the degree of damage at each location. The Contractor shall follow paint manufacturer's written instructions for surface preparation and for timing and application of successive coats.

The Contractor shall repair damage to galvanized finishes with zinc-rich paint recommended by manufacturer. Damage to PVC or paint finishes shall be repaired with matching touchup coating systems, in conformance with manufacturer recommendations.

CLEANING AND PROTECTION

The Contractor shall inspect exposed finish on completion of installation, including outlets, fittings, and devices. The Contractor shall remove burrs, dirt, paint spots, and construction debris.

The Contractor shall protect equipment and installations and maintain conditions to ensure that coatings, finishes, and cabinets are without damage or deterioration at completion.

PAYMENT

Full compensation for basic electrical materials and methods shall be considered as included in the contract lump sum prices paid for various items of work involved and no additional compensation will be allowed therefor.

10-4.__ SYSTEMS STUDIES AND FIELD TESTING

The work shall include furnishing labor and material to perform the followings tasks.

A. Engineering services for the electrical systems studies including short-circuit analysis and protective device coordination.
B. Independent field protective device setting and testing services for all electrical equipment and systems.
C. Commissioning assistance for final coordinated systems.

SHORT-CIRCUIT AND PROTECTIVE DEVICE COORDINATION STUDIES

Short-circuit and protective device coordination shall include the following:

A. Complete single-line diagram of system studied with all buses identified to report data.
B. Short-circuit study including the maximum and minimum values of short-circuit currents at major buses extended down to system buses where currents are equal to 10,000 A symmetrical (assume 8,000 A symmetrical with X/R=8 at the primary 12.47 kV service switchgear buses) fully coordinated composite time-current characteristic curves including recommended ratings and settings of all protective devices in tabulated form; and associated calculations to demonstrate that the power system protection will be selectively coordinated by the use of devices or equipment submitted. Situations where system coordination is not achievable due to device limitations along with inadequate interrupting ratings shall be noted. The studies shall consider operation during normal conditions, alternate operations, and during emergency power conditions, and shall include ground fault protective device settings. The registered Professional Engineer shall perform these studies.

C. Data consisting of manufacturer's time-current characteristic curves for individual protective devices, recommended settings of adjustable protective devices, and recommended ratings of non-adjustable protective devices.
D. Submit the power systems study within 30 days after the electrical equipment submittals have been received for review by the engineer. The electrical submittals will be reviewed but will not be approved until the power systems studies have been received and reviewed. Submit 3 copies of the power systems study.

Engineer's Qualifications

Contractor shall verify experience and license number, of a registered Professional Engineer with at least five years of current experience in the design of coordinated power system protection. Experience data shall include at least five references for work of a magnitude comparable to his contract. Engineer must perform items required by this section to be performed by a registered Professional Engineer.

FIELD TESTING

Where testing is called for in this Section 10-4, the test shall be performed by an independent subcontractor which is a recognized electrical testing firm. The Contractor shall furnish all test instruments, materials and labor necessary to perform the following tests. All tests shall be performed in the presence of the Engineer. All instruments shall have been calibrated within a period of two years preceding testing. Calibrations shall be traceable to applicable industry recognized standards. Testing shall conform to the following:

A. All protective devices with field adjustable settings shall be set and testing in the field after installation. This work shall be performed as a part of the testing requirements specified in the individual specification sections, and shall be conducted by the approved independent testing agency.
B. All testing requirements specified in the individual specification sections shall be performed per an approved test plan. The proposed test plan shall be submitted and approved prior to field tests: Plan shall consist of complete field test procedure including inspections and tests to be performed, test equipment required, and tolerance limits, including complete testing and verification of protective device setting, ground fault and motor protection equipment, where used.
C. Performance test reports: reports shall be in booklet form showing all field tests performed to adjust each component and all field tests performed to prove compliance with the specified performance criteria, upon completion and testing of the installed system. Each test report shall indicate the final positions of controls and a summary of the test results.
D. Suitability of test equipment, test instrument calibration, and test reports shall comply, as a minimum, with NETA ATS, Section 5, latest edition.
E. Certificates: certificates certifying that all devices and equipment meet the requirements of the contract documents.

Testing Agency Qualifications

A. Testing agency shall be a member company of the International Electrical Testing Association and is acceptable to authorities having jurisdiction.

B. Testing agency's field supervisor: A person currently certified by the International Electrical Testing Association or National Institute for Certification in Engineering Technologies to supervise on-site testing specified in these special provisions.

Systems Commissioning Assistance

Upon completion of all equipment field testing and protective device setting, the electrical contractor shall supply qualified manpower to assist in the complete mechanical and electrical system commissioning conducted by the general contractor. The electrical contractor shall also make available the testing agency for commissioning problems which may occur.

QUALITY ASSURANCE

The study shall be in accordance with applicable ANSI and IEEE Standards.

Field testing shall be performed per NETA ATS specifications, manufacturer's recommendations, and these special provisions.

EXECUTION

Examine utilization equipment nameplates and installation instructions. Install fuses of sizes and with characteristics appropriate for each piece of equipment. Evaluate ambient temperatures to determine if fuse rating adjustment factors must be applied to fuse ratings.

Proceed with installation only after unsatisfactory conditions have been corrected.

Perform field testing as specified in these special provisions.

MEASUREMENT AND PAYMENT

Full compensation for systems studies and field testing shall be considered as included in the contract prices paid for the various items of work involved and no additional compensation will be allowed therefor.

10-4.__ GROUNDING AND BONDING

GENERAL

The work shall consist of furnishing labor and material for grounding of electrical systems and equipment and basic grounding requirements for protection of life, equipment, circuits and systems.

SUMMARY

Scope.--Grounding and bonding shall be furnished and install for all equipment, manholes, handholes and systems.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for grounding and bonding system as shown on the plans and as specified in these special provisions.

The Contractor shall submit written field test reports including the following:

A. Test procedures used.
B. Test results that comply with requirements.
C. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

QUALITY ASSURANCE

Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100.

Grounding and bonding work shall be in conformance with UL 467.

GROUNDING CONDUCTORS

Grounding conductors shall conform to the following requirements.

A. Insulated conductors, shall be in compliance with "Conductors and Cables" of these special provisions.
B. Equipment grounding conductors in raceway shall be insulated with green-colored insulation.
C. Grounding electrode conductors shall be stranded copper conductor.
D. Underground conductors shall be bare, tinned, stranded, copper.
E. Bare copper conductors shall conform to the following requirements:

    1. Solid conductors shall be in conformance with ASTM B 3.
    2. Assembly of stranded conductors shall be in conformance with ASTM B 8.
    3. Tinned conductors shall be in conformance with ASTM B 33.

F. Copper bonding conductors shall meet the following requirements:

    1. Bonding cable shall be 28 kcmil, 14 strands of No. 17 AWG copper conductor, 6 mm in diameter.
    2. Bonding conductor shall be No. 4 or No. 6 AWG, stranded copper conductor.
    3. Bonding jumper shall be bare copper tape, or braided bare copper conductors, terminated with copper ferrules; 41 mm wide and 2 mm thick.

Grounding bus shall be bare, annealed copper bars of rectangular cross section, sizes as shown on the plans.

Ground bus shall be installed on insulated spacers 25mm away from wall and 360 mm above finished floor.

CONNECTOR PRODUCTS

Connectors shall conform to the following requirements:

A. Products for connectors shall be in conformance with IEEE 837 and UL 467.
B. Bolted connectors shall be pressure-type, or compression type.
C. Welded connectors shall be exothermic-welded type.

GROUNDING ELECTRODES

Grounding electrodes shall be copper-clad steel and shall be 19 mm in diameter by 3048 mm in length.

APPLICATION

Grounding and bonding shall conform to the following requirements:

A. The Contractor shall use exothermic-welded connections for connections to structural steel and for underground connections.
B. The Contractor shall use bolted pressure clamps for equipment grounding termination.
C. The Contractor shall install grounding bus in electrical and telephone equipment rooms.
D. The Contractor shall install ground rod in all manholes and handholes as shown on the plans. Ground rod shall be connected to the ground loop in manholes.

EQUIPMENT GROUNDING CONDUCTORS

Equipment grounding conductors shall conform to the following requirements:

A. The Contractor shall install equipment grounding conductors in all feeders and circuits.
B. For signal and communication systems (telephone, alarm, voice and data, and other communication systems) the Contractor shall install No. 4 AWG minimum insulated grounding conductor in raceways from grounding electrode to each service location, terminal cabinet, and central equipment location:

COUNTERPOISE

Tunnel chambers.--The Contractor shall construct an earth counterpoise comprised of a continuous loop of copper cable exothermically welded and embedded in concrete outside of the weatherproof barrier.

OMC building.--The Contractor shall construct an earth counterpoise comprised of a continuous loop of copper cable exothermically welded to driven ground rods and building steel. The cable shall be bare, No. 2/0 AWG stranded copper cable buried at least 610 mm below grade. Ground rods shall be located 610 to 1524 mm outside the foundation or exterior footing of the structure with their tops 610 mm below grade.

INSTALLATION

The Contractor shall ground the OMC building roof beams by bonding them together with No. 2/0 AWG stranded copper conductor and connect to the counterpoise on opposite sides of the building. Exothermically weld the conductors to the structural steel and counterpoise.

The Contractor shall route grounding conductors along the shortest path.

The Contractor shall install bonding straps and jumpers to equipment subject to vibration.

The Contractor shall provide insulated copper grounding conductors, in conduit, from the building's main electrical service equipment, or grounding bus, to main metal water service entrances to building. Where a dielectric main water fitting is installed, the Contractor shall connect the grounding conductor to the street side of fitting. The contractor shall bond grounding conductor and conduit or sleeve at each end.

CONNECTIONS

The Contractor shall make connections to minimize galvanic action or electrolysis.

A. The Contractor shall use electroplated or hot-tin-coated materials to ensure high conductivity.
B. The Contractor shall make aluminum-to-steel connections with stainless-steel separators and mechanical clamps.
C. The Contractor shall make aluminum-to-galvanized steel connections with tin-plated copper jumpers and mechanical clamps.
D. The Contractor shall coat and seal connections having dissimilar metals with inert material.

Exothermic-welded connections shall in accordance with manufacturer's written instructions. Welds that are puffed up or that show convex surfaces indicating improper cleaning will not be permitted.

The Contractor shall use pressure-type grounding lug for No. 8 AWG and larger conductor, and winged pressure-type connectors for No. 10 AWG and smaller conductors terminations.

The Contractor shall tighten screws and bolts for grounding and bonding connectors and terminals according to manufacturer's published torque-tightening values or use those specified in UL 486A.

FIELD QUALITY CONTROL

The following field quality-control testing shall be performed by a testing agency:

A. Maximum grounding resistance shall be tested and shall conform to the following values.

   1. Equipment rated 500 KVA and less shall have 10 ohms.
   2. Pad mounted equipment shall have 5 ohms.

B. The Contractor shall megger test the grounding system at each electrical room ground bus and at each service disconnect enclosure grounding terminal and at ground rods. The Contractor shall measure ground resistance not less than two days after the last trace of precipitation, and without the soil being moistened by other than natural drainage or seepage and without chemical treatment or other artificial means of reducing natural ground resistance. The Contractor shall perform tests, by the fall-of-potential method according to IEEE 81.
C. The Contractor shall provide drawings locating each ground rod and ground rod assembly and other grounding electrodes, identifying each by letter in alphabetical order, and key to the record of tests and observations. The contractor shall include the number of rods driven and their depth at each location and include observations of weather and other phenomena that may affect test results. The contractor shall describe measures taken to improve test results. Ground bus and service equipment shall be in conformance at values of 5 ohms.
D. The Contractor shall notify the Engineer if resistance to ground exceeds specified values, and the Contractor shall include recommendations to reduce ground resistance.

MEASUREMENT

Grounding and bonding will be measured as a lump sum.

PAYMENT

The contract lump sum price paid for grounding and bonding shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in grounding and bonding electrical systems and equipment (except for equipment ground conductors installed inside raceways), including testing, and as shown on the plans, and as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

Full compensation for equipment ground conductors installed inside raceways shall be considered as included in the contract lump sum price paid for conductors and cables and no additional compensation will be allowed therefor.

10-4.__ SEISMIC CONTROLS FOR ELECTRICAL WORK

Seismic controls for electrical work shall conform to the provisions in these special provisions, and include mounting and seismic restraints and other damage-reduction measures for electrical components.

DEFINITIONS

A. CBC: California Building Code.
B. Seismic restraint: a fixed device (a seismic brace, an anchor bolt or stud, or a fastening assembly) used to prevent vertical or horizontal movement, or both vertical and horizontal movement, of an electrical system component during an earthquake.
C. Mobile structural element: a part of the building structure such as a slab, floor structure, roof structure, or wall that may move independent of other mobile structural elements during an earthquake.

SUBMITTALS

The Contractor shall submit the following:

A. Product Data:

    1. Submit scaled dimensioned drawings of strut and accessories including clamps, brackets, hanger rods, and fittings.
    2. Submit manufacturer's product data on strut channels including, but not limited to, types, materials, finishes, gauge thickness, and hole patterns. For each different strut cross section, submit cross sectional properties including section modulus (Sx) and moment of inertia (Ix).
    3. Anchor bolts and studs: tabulate types and sizes, complete with report numbers and rated strength in tension and shear as evaluated by ICBO Evaluation Service.

B. Working drawings: for anchorage and bracing. Indicate materials, and show designs and calculations signed and sealed by a professional engineer:

    1. Design analysis: to support selection and arrangement of seismic restraints. Include calculations of combined tensile and shear loads.
    2. Details: detail fabrication and arrangement of all typical tunnel luminaire and raceway systems. Detail luminaire, raceway and box mounting and attachment with code compliant raceway support member spacing and clamps. Detail attachment of

restraints to both structural and restrained items. Show attachment locations, methods, and spacing, identifying components and listing their strengths. Indicate direction and value of forces transmitted to the structure during seismic events.

3. Pre-approval and evaluation documentation: by California Office of Statewide Health Planning and Development (OSHPD), showing maximum ratings of restraints and the basis for approval (tests or calculations).

C. Coordination drawings: plans and sections of equipment drawn to scale and coordinating supports and seismic bracing for electrical components with other systems and equipment, including other seismic restraints, in the vicinity.
D. Qualification data: for firms and persons specified in "Quality Assurance" of this special provision section.

QUALITY ASSURANCE

Comply with seismic restraint requirements in California Building Code/Code of Regulations of OSHPD, unless requirements in this Section are more stringent.

Professional engineer qualifications: a professional engineer who is experienced in providing seismic engineering services, including the design of seismic restraints, that are similar to those indicated for this Project.

Testing agency qualifications: an independent testing agency with the experience and capability to conduct the testing indicated.

PROJECT CONDITIONS

A. Project Seismic Zone and Zone Factor as defined in CBC: Zone 4, Zone Factor 0.40.
B. Occupancy Category as defined in UBC: IV.
C. Acceleration Factor: 1.0G.

COORDINATION

Coordinate layout and installation of seismic bracing with tunnel and building structural systems and architectural features, and with mechanical, fire-protection, electrical, and other building features in the vicinity.

Coordinate concrete bases with building structural system.

MATERIALS

Use the following materials for mounting and restraints:

A. Indoor dry locations: steel, zinc plated.
B. Outdoors and damp locations: galvanized steel.
C. Roadway tunnel locations: AISI Type 316 stainless steel.

ANCHORAGE AND STRUCTURAL ATTACHMENT COMPONENTS

Strength: defined in reports by ICBO Evaluation. Structural safety factor: strength in tension and shear of components used shall be at least two times the maximum seismic forces to which they will be subjected.

Concrete and Masonry Anchor Bolts and Studs

A. Dry locations: zinc plated steel-expansion wedge type.

B. Tunnel anchor bolts: anchor bolts supporting strut and conduit supports shall be AISI Type 304 stainless steel mechanical anchor type or epoxy anchor bolts. Both types shall be rated for dynamic loading.

1. Mechanical anchor bolts shall be stainless steel hexagon head finished bolt with a longitudinally tapered threaded end and a spring loaded multi-part conforming threaded zinc expander nut. Anchor shall meet Federal Spec FF-S-325, Group II, Type 4 Class I, be heat treated to SAE Grade 5 and zinc plated in accordance with ASTM B633-78, Type III, Class Fe/Zn 5, SC-I. Anchors shall be Taper Bolt.
2. Epoxy anchor bolts shall be stainless steel all-thread, encapsulated epoxy type with embedment length and drilled hole diameter per the manufacturer's recommendations. Polyester and vinyl resin is not acceptable.

Other connection components:

C. Through bolts shall be structural type, hex head, high strength. compliance with ASTM A 325.
D. Toggle bolts shall be all-steel springhead type.
E. Beam clamps for steel beams and joists shall be double-sided. Single-sided type is not acceptable.
F. Pipe sleeves: shall be ASTM A 53, Type E, Grade A, Schedule 40, galvanized steel, plain ends.
G. Raceway and cable supports shall be manufactured clevis hangers, riser clamps, straps, threaded C-clamps with retainers, ceiling trapeze hangers, and wall brackets.

MOUNTING AND SEISMIC BRACING COMPONENTS

Steel channel (not in roadway tunnel) shall be 41 mm by 41 mm cross section, formed from 12 gauge steel, if over 610 mm long.:

A. Materials for channel shall comply with ASTM A 570, GR 33.
B. Materials for fittings and accessories shall comply with ASTM A 575, ASTM A 576, or ASTM A 36.
C. Fittings and accessories shall be the products of the same manufacturer as channels and designed for use with that product.
D. Use electro-plated zinc for interior use and hot-dip galvanized after fabrication for exterior use.

Tunnel Strut Support System

The bolted stainless steel strut and attachments shall be installed as shown on the plans, and as may be additionally required by the seismic analysis, and design required by this section. The trapeze supports, drop rods, strut side rails, and splice plates, shall be capable of supporting the light fixtures, conduit, conductors, and junction boxes. Strut, fastening and attachment systems shall be off-the-shelf type.

The strut shall be AISI Type 316 stainless steel. All nuts, bolts, screws, clamps, brackets and miscellaneous hardware shall be stainless steel. If a particular part is not available in stainless steel, then the part shall be galvanized steel. Contractor shall identify which components are non-stainless steel in submittals. Non-stainless steel parts shall not be used on the project without prior Engineer's approval.

Conform to ASTM 167, MFMA and AISI for material properties requirements:

A. ASTM A167- Standard specification for Stainless and Chromium-Nickel steel Plate, Sheet and Strip.
B. MFMA- Metal Framing Standards Publication, MFMA-1 1984
C. AISI- American Iron and Steel Institute

Material requirements:

A. All materials shall be of standard off-the-shelf type, new and brought to the site in manufacturers original package. Underwriter's Laboratories shall list all equipment whenever UL has published a standard for that item of equipment.
B. Bolted framing channels and fittings shall have the manufacturer's name, part number, and material heat code identification number stamped in the part itself for identification.
C. A material designator shall be stamped into the bolted framing parts to identify the material to maintain tractability of the product. Material certification sheets and test reports must be made available by the manufacturer upon request.
D. Strut shall be 41 mm wide in varying heights and welded combinations as required to meet load capacities and designs indicated on the plans. Use clamps and fittings designed for use with the strut system
E. Strut channels shall be 12 gauge material thickness as required to meet the strength requirements of the application. Factory punched slotted holes, 14 mm x 22 mm on 51 mm centers, designed for use with 13 mm diameter hardware to provide adjustment and eliminate drilling.
F. Fabricated pieces shall be in accordance with the plans. Drilling, punching and cutting shall be carefully and accurately performed to prevent any possibility of irregularities occurring which might introduce difficulty in the erection of the raceway or result in straining or distortion of the parts thereof. All material shall be clean and straight. No straightening or flattening shall be allowed. All members shall be free from kinks, twists, or bends.
G. Firms regularly engaged in the manufacture of bolted metal framing of the types required, whose products have been in satisfactory use in similar service for not less than 5 years.

Channel-type bracing assemblies shall be slotted steel channel, with 14 mm by 22 mm slots at a maximum of 51 mm on center spacing in webs, and flange edges turned toward web and with adjustable hinged steel brackets and bolts.

INSTALLATION

Install mounting materials and seismic restraints according to manufacturer's recommended practices, applicable codes and regulations and as approved by authorities having jurisdiction, unless more stringent requirements are indicated. The plans provide typical installation details, that may require adaptation to actual field conditions, and in all cases, require qualification by certified calculation.

STRUCTURAL ATTACHMENTS

A. Use bolted connections with steel brackets, slotted channel, and slotted-channel fittings to spread structural loads and reduce stresses.
B. Attachments to concrete shall use expansion anchors, unless otherwise indicated.
C. Holes for expansion anchors in concretshall be drill at locations and to depths that avoid reinforcing bars.

D. Attachments to solid concrete masonry unit walls shall use expansion anchors.
E. Attachments to hollow walls: bolt to slotted steel channels fastened to wall with expansion anchors.
F. Attachments to wood structural members: install bolts through members.
G. Attachments to steel: bolt to clamps on flanges of beams or on upper truss chords of bar joists.

ELECTRICAL EQUIPMENT ANCHORAGE

Anchor rigidly to a single mobile structural element or to a concrete base that is structurally tied to a single mobile structural element.

Anchor any free-standing equipment, panelboards, motor-control centers, motor controls, switchboards, transformers, power-circuit devices, transfer switches, battery racks, static un-interruptible power units, communication system components, and electronic signal processing, control, and distribution units as follows:

A. Size concrete bases so expansion anchors will be a minimum of 10 bolt diameters from the edge of the concrete base.
B. Torque bolts and nuts on studs to values recommended by equipment manufacturer.

MOUNTING STRUT AND SEISMIC BRACING INSTALLATION

A. Install mounting supports bracing according to spacing and strengths indicated by plans and approved analysis.
B. Expansion and contraction: install to allow for thermal movement of braced components.
C. Cable braces shall be installed with maximum cable slack recommended by manufacturer.
D. Attachment to structure: if specific attachment is not indicated, anchor bracing to the structure at flanges of beams, upper truss chords of bar joists, or at concrete members.
E. Tunnel strut system:

1. Locate the strut to position the luminaires as indicated in the plans.
2. All nuts and bolts shall be tightened to the following values:

Bolt Size	Torque N.m
6.35 mm	8
7.94 mm	15
9.52 mm	26
19 mm	68

ACCOMMODATION OF DIFFERENTIAL MOTION

Make flexible connections in raceways, and cables, where they cross expansion and seismic control joints, where adjacent sections or branches are supported by different structural elements, and where they terminate at electrical equipment anchored to a different mobile structural element from the one supporting them.

FIELD QUALITY CONTROL

Testing agency: Contractor shall engage a qualified testing agency to perform the following field quality-control testing.

Test pull-out resistance of seismic anchorage devices: Contractor shall

A. Provide test equipment required for reliable testing.
B. Provide evidence of recent calibration of test equipment by a testing agency acceptable to authorities having jurisdiction.
C. Schedule test with Department, through Engineer, before connecting anchorage device to restrained component (unless post-connection testing has been approved), and with at least seven days advance notice.
D. Obtain Engineer's approval before transmitting test loads to the structure. Provide temporary load-spreading members.
E. Test at least four of each type and size of installed anchors and fasteners selected by Engineer.
F. Test to 90 percent of rated proof load of device.
G. If a device fails the test, modify all installations of same type and retest until satisfactory results are achieved.
H. Record test results.

MEASUREMENT AND PAYMENT

Full compensation for seismic controls for electrical work shall be considered as included in the contract prices paid for the various items of work involved and no additional compensation will be allowed therefor.

10-4.__ ELECTRICAL IDENTIFICATION

GENERAL

Electrical identification materials and devices shall conform to ANSI C2, NFPA 70, OSHA standards, and to these special provisions.

SUMMARY

Scope.--Identification materials shall be provided for electrical and systems materials and devices in conformance with these special provisions.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the electrical identification components as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Manufacturer's technical data for each type of product specified, indicating dimensions, performance characteristics, electrical characteristics, finishes of materials, and installation instructions.

QUALITY ASSURANCE

Electrical identification components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. All device and component installations shall comply with

NFPA 70 and NFPA 502. All electrical identification devices and components shall be UL Listed.

SYSTEM COMPONENTS

Raceway, Junction Box, and Pull Box Labels.--Labels shall be provided to identify all circuits within medium voltage systems in conformance with the following requirements:

A. Legend: indicate circuit and voltage.
B. Install on all exposed conduit runs at maximum of 10 meter intervals and on all junction boxes:

   1. 32 mm high black letters on clear background.
   2. Black letters on orange field.
   3. Adhesive raceway labels: preprinted, flexible, self-adhesive vinyl with legend, weather-and chemical-resistant.

C. Install on all concrete manhole lids: recessed stainless steel plate with black paint filled, engraved text. Minimum 16 mm letter height.
D. Install on all metal manhole lids: engraved with black paint filled or welded. Minimum 16 mm letter height.

The Contractor shall install safety signs on exposed conduit and junction boxes for medium voltage systems in conformance with the following requirements:

A. Adhesive raceway labels: preprinted, flexible, self-adhesive vinyl with legend, weather- and chemical-resistant.
B. Legend: "DANGER—HIGH VOLTAGE".
C. 50 mm high letters with color code conforming to "Nameplates and Signs" of these special provisions.

The Contractor shall provide circuit identification for all surface-mounted and embedded pull and junction boxes for 600-volt tunnel lighting and power systems in conformance with the following requirements:

A. 75 mm wide by 50 mm high stainless steel plate with engraved black paint filled letters on metal background.
B. Attached with stainless steel, self-tapping screws as shown on plans.
C. Legend: as shown on the plans.

Cable and Conductor Labels.--Colored adhesive tape shall be used for phase marking on cables. Self-adhesive vinyl tape shall be not less than 0.075 mm thick by 25 mm to 50 mm wide.

Cable and wire markers shall be furnished and installed for control and multi-conductor cable used for branch and control circuits:

A. Flexible, self-adhesive polyester or vinyl tape with legend.
B. Self laminating wrap around design with weather- and chemical-resistant coating.
C. White print area and preprinted black text.
D. Rated for –18°C to +135°C for indoor and outdoor applications.

Medium voltage power-circuit identification shall consist of plastic or fiberglass tags in conformance with the following requirements:

A. Legend: 6.4 mm letter and number embossing with legend corresponding to:

   1. Circuit designation.
   2. Phase designation.

B. Tag fasteners: nylon cable ties.

Identification for primary and secondary service, feeder, and branch-circuit conductors shall be color-coded throughout the electrical system. The color-code for medium voltage and 208/120 V systems shall be as follows:

A. Phase A: black.
B. Phase B: red.
C. Phase C: blue.
D. Neutral: white.
E. Ground: green.

The color-code for 480/277 V systems shall be as follows:

A. Phase A: brown.
B. Phase B: orange.
C. Phase C: yellow.
D. Neutral: white with a colored stripe or gray.
E. Ground: green.

Color shall be factory applied the entire length of conductors for conductors No. 8 AWG and smaller. For wire sizes larger than No. 8 AWG, pressure-sensitive colored plastic tape shall be field applied in half-lapped turns for a distance of 152 mm from terminal points and in boxes where splices or taps are made. The last two turns of tape shall be applied with no tension to prevent possible unwinding. Marking tape shall be 25 mm width in the colors specified. The location of applied tape bands shall be adjusted to avoid obscuring cable identification markings.

Underground-line warning tape shall be permanent, bright-colored, continuous-printed, vinyl tape in conformance with the following requirements:

A. Not less than 152 mm wide by 0.1-mm thick.
B. Compounded for permanent direct-burial service.
C. Embedded continuous metallic strip or core.
D. Printed legend indicating type of underground line.

Nameplates and Signs.--Engraved plastic nameplates and signs shall be furnished and installed in conformance with the following requirements:

A. Engraving stock, melamine plastic laminate, minimum 2 mm thick for signs up to 129 cm^2 and minimum 3 mm thick for larger sizes.
B. Punched or drilled for mechanical fasteners.

C. Fasteners for nameplates and signs: self-tapping, stainless steel screws or No. 10/32, stainless steel machine screws with nuts and flat and lock washers.

Warning, caution, and instruction signs shall be installed as follows:

A. Warnings, cautions, and instructions: install to ensure safe operation and maintenance of electrical systems and of items to which they connect. Instruction signs, with legends, shall be installed to detail system and equipment operation sequences, procedures, and related interlocks.
B. Emergency operation: install engraved laminated signs with minimum 10 mm high lettering for emergency instructions on power transfer, load shedding, and other emergency operations.

Safety signs shall comply with 29 CFR, Chapter XVII, Part 1910.145 and shall conform to the following requirements:

A. Danger signs shall have a predominately red background with black and white text.
B. Caution signs shall have a predominately yellow background with black text or yellow text on a black panel.
C. Warning signs shall have a predominately orange background with black text or orange text on a black panel.
D. Safety instruction signs shall have a predominately white background with black text or white text on a green panel.

Equipment identification labels shall conform to the following requirements:

A. Engraved legend in 13 mm high letters, except control push-button stations use 6.4 mm high letters:

    1. Normal and stand-by power: white letters on black face.
    2. Emergency power: white letters on red face.
    3. Medium voltage (MV) power: black letters on orange face.

B. Label shall include the following:

    1. Distribution equipment: equipment ID, source type, and voltage. (Suggested format: "PNS1-12, 14, 16", "Stand-by", "480 Volts", on three lines.)
    2. Individual cubicles: cubicle ID, load equipment ID, and load description. (Suggested format: "CUBICLE 2G, JF-29, JET FAN NO. 29" on three lines.
    3. Individually mounted equipment: equipment ID, voltage, and load equipment description.
    4. Control stations: equipment ID and system or control description.
    5. Source of power for panelboards: (Suggested format: "FED FROM SWDB-SND")

C. Apply labels for each unit of the following categories of equipment using mechanical fasteners:

    1. Panelboards, electrical cabinets, and enclosures.
    2. Access doors and panels for concealed electrical items.

3. Electrical switchboards, multiple service locations labeled per NEC 230-2(e).
4. Emergency system boxes and enclosures.
5. Motor-control centers.
6. Disconnect switches.
7. Enclosed circuit breakers.
8. Motor starters.
9. Push-button stations.
10. Power transfer equipment.
11. Contactors.
12. Remote-controlled switches.
13. Receptacles.
14. Control devices.
15. Transformers.
16. Inverters.
17. Telephone equipment.
18. CCTV equipment.
19. Fire alarm system.
20. Security systems.
21. Emergency power system.

Receptacle Labels.--Embossed plastic adhesive tape shall be furnished and installed at receptacle locations and shall conform to the following requirements:

A. Embossed legend in 6.4 mm high letters.

1. Normal and stand-by power: white letters on black face.
2. Emergency power: white letters on red face.

B. Label shall include panelboard ID and circuit number.

INSTALLATION

Identification materials and devices shall be installed at locations that provide unobstructed viewing without interfering with operation and maintenance of equipment.

The Contractor shall coordinate names, abbreviations, colors, and other designations with corresponding designations shown on the plans and specified in these special provisions. Consistent designations shall be used throughout the project.

Identification shall be applied to surfaces after completing all required finish work.

The Contractor shall clean surface of material prior to installation of self-adhesive identification products with solvent.

For all exterior underground power, control, signal, and communication conductor and raceway runs, both direct-buried and installed in raceway, the Contractor shall install, during trench backfilling, continuous underground plastic line marker located directly above the run at 152 to 203 mm below finished grade. Where the width of multiple runs installed in a common trench or concrete envelope does not exceed 406 mm overall, a single line marker shall be used.

PAYMENT

Full compensation for electrical identification shall be considered as included in the contract lump sum prices paid for various items of work involved and no additional compensation will be allowed therefor.

10-4.__ CONDUCTORS AND CABLES

GENERAL

Conductors and cables, consisting of building and tunnel wires and cables and associated connectors, splices, and terminations for wiring systems rated 600 V and less, shall conform to ANSI C2, NFPA 70, OSHA standards, the details shown on the plans, and to these special provisions. Conductors and cables shall apply to all field installed conductors and cables used throughout the tunnel and adjacent approach roadways, up to the boundary of the OMC building.

SUMMARY

Scope.--Conductors and cables shall be furnished, installed, and tested as shown on the plans and as specified in these special provisions.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product Data.--The following shall be submitted to the Engineer:

A. Cable pulling records.
B. Field test reports: indicate and interpret test results for compliance with performance requirements.
C. Manufacturer's technical data for signal system conductors and cable and optical fiber connectors.
D. Operation and Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

QUALITY ASSURANCE

All cable of each type shall be obtained through one source from a single manufacturer. Products shall be listed and labeled as defined in NFPA 70, Article 100. All conductor and cable installation methods and practices shall comply with NFPA 70 and NFPA 502.

DELIVERY, STORAGE, AND HANDLING

The Contractor shall deliver wires and cables in accordance with NEMA WC 26.

BUILDING AND TUNNELS WIRES AND CABLES

Wire and cable shall conform to the following requirements:

A. UL-listed building wires and cables with conductor material, insulation type, cable construction, and rating as specified in these special provisions.
B. Rubber insulation material: comply with NEMA WC 3.
C. Thermoplastic insulation material: comply with NEMA WC 5.
D. Cross-linked polyethylene insulation material: comply with NEMA WC 7.

E. Teflon impregnated glass braid (TGGT): UL listed (Style 5251) for tunnel jet fan connections.
F. Conductor material: copper.
G. Stranding:

1. Stranded for all power and lighting circuits, except solid conductor for No. 10 AWG and smaller used for equipment chamber lighting and convenience receptacles only.
2. Stranded for all control circuits, unless otherwise shown on the plans.

WIRE AND INSULATION APPLICATIONS

Wire and insulation applications for power and lighting circuits shall conform to the following requirements:

A. Equipment chamber and OMC feeders and branch circuits: type THHN/THWN, 90°C, in raceway.
B. Tunnel power branch circuits: type XHHW-2, 90°C, in embedded raceway.
C. Tunnel jet fan connections (from embedded junction box to tunnel jet fan housing): type TGGT, 250°C, in flexible conduit. Flexible conduit to be liquid-tight flexible metal jacket material having limited smoke, low flame spread, and low toxic gas emissions in the event of fire.
D. PVC insulation or jacket shall not be used in the tunnel.
E. Class 1 and 2 control circuits, except jet fan connections: type THHN/THWN stranded, in raceway.
F. Class 1 and 2 control circuits for jet fan connections: type TGGT stranded, 250°C, in flexible metal conduit. Flexible conduit shall be liquid-tight flexible metal jacket material having limited smoke, low flame spread, and low toxic gas emissions in the event of fire.

CONNECTORS AND SPLICES

Connectors and splices shall be UL-listed, factory-fabricated wiring connectors of size, ampacity rating, material, type, and class for application and service as shown on the plans.

Tunnel jet fan connection leads shall conform to NFPA 502, paragraph 7-7.1. Tunnel ventilation jet fan motors and all related electrical supply components that may be exposed to the ventilation airflow shall be designed to remain operational for a minimum of one hour in an airstream temperature of 250°C.

INSTALLATION

Raceways and other elements to receive cables shall be examined for compliance with requirements for installation tolerances and other conditions, such as proximity to electro-magnetic interference producing equipment, which may affect the performance of the contained transmission media. Raceways shall be clean and clear of obstructions prior to beginning installation of cable.

Conductors and cables shall be installed using industry standard pulling means, including fish tape, cable, rope, and basket-weave wire or cable grips. Pulling means shall not damage cables or raceway.

The Contractor shall use manufacturer-approved pulling compounds or lubricants to facilitate conductor and cable installations. The lubricating compounds utilized shall not deteriorate the associated conductor or its insulation:

A. Cable shall be protected from construction damage during cable preparation and pulling. Cable shall not be laid directly on the roadway surface or ground for measuring or pulling purposes. Cable shall be measured by using a meter while winding from one reel to another, and shall be pulled in directly off a reel.
B. Pulling tensions and side-wall pressure values shall not exceed manufacturer's recommended maximum values.
C. A calibrated dynamometer shall be used on all pulls over 30 m.
D. All cable pulls shall be performed in the presence of the Engineer.

Written documentation shall be submitted to the Engineer for each pull over 30 m in length, and shall include the following data:

A. Date and time of the pull.
B. Circuit and conductor identification.
C. Calculated maximum pulling and side-wall tension with pulling configuration sketch.
D. Measured pulling tension.
E. Signature of data collector who certifies installation.

The Contractor shall seal around cables penetrating fire-rated elements in accordance with "Basic Electrical Materials and Methods" of these special provisions.

Conductors and cables shall be identified in conformance with "Electrical Identification" of these special provisions.

CONNECTIONS

Conductor and cable connections shall conform to the following requirements:

A. Conductor splices: Splices will not be permitted unless otherwise shown on the plans.
B. Stranded conductors shall be terminated in apparatus mounted mechanical lugs or provided with crimped-on (compression) lugs as follows:

    1. Use compression type, nylon insulated locking fork tongue connectors for stranded conductors #10 and smaller.
    2. Use 90°C, compression type, single-hole, bare ring tongue connectors for stranded conductors #8 through #1.
    3. Use 90°C, compression type, two-hole, bare ring tongue connectors for stranded conductors larger than #1.

C. Use oxide inhibitor in each terminal block, inside the junction boxes used for tunnel lighting and tunnel jet fans.
D. Wiring at outlets: install conductor at each outlet, with at least 305 mm of slack.
E. Connect outlets and components to wiring and to ground as indicated and instructed by manufacturer.
F. Electrical connectors and terminals, including screws and bolts, shall be tightened according to equipment manufacturer's published torque-tightening values for equipment connectors. Where manufacturer's torquing requirements are not available, connectors and terminals shall be tightened according to tightening requirements specified in UL 486A and UL 486B.

FIELD QUALITY CONTROL

An independent testing agency shall perform field quality-control testing. Testing shall be performed on installation of conductors and cables and before electrical circuitry has been energized. Tests shall include the following:

A. Perform each visual and mechanical inspection and electrical test stated in NETA ATS, Section 7.3.1. Test results shall be certified to be in compliance with NETA test parameters.

Malfunctioning cables shall be replaced and retested.

MEASUREMENT

Conductors and cable will be measured on a lump sum basis.

PAYMENT

The lump sum contract price paid for conductors and cables shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in installing all circuit conductors including equipment ground and terminations, (except final tap circuits from the power terminal box to tunnel roadway luminaires), complete in place, including testing, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

Full compensation for final tap circuits from the power terminal box to tunnel roadway luminaires shall be considered as included in the contract lump sum price paid for tunnel lighting and no additional compensation will be allowed therefor.

10-4.__ MEDIUM VOLTAGE CABLES

GENERAL

The work shall consist of furnishing and installing medium voltage cables, including single-conductor 15 kV shielded power cables and related splices terminations, and accessories suitable for use in wet or dry locations, in conduit, and underground ducts, conforming to these special provisions.

SUMMARY

Scope.--Medium voltage cables shall be installed from PG&E manholes to the OMC building, South equipment chamber, Center equipment chamber and North equipment chamber. One PG&E manhole is located on the south side of the tunnel and the other manhole is on the north side of the tunnel. The medium voltage cables shall be installed in concrete encased duct banks.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, “Equipment List and Drawings,”of the standard Specifications and the requirement specified herein.

Product data.--The submittals shall include complete details, information, and drawings for the medium voltage cable system as shown and as specified in these special provisions. The submittals shall also include the following:

A. Product data for medium voltage cables and medium voltage cable accessories, including terminations.
B. Product certificate signed by manufacturer that its products comply with the specified requirements.
C. Qualification data for firms and persons specified in "Quality Assurance" of this special provision section to demonstrate their capabilities and experience. Include list of completed projects with project names, addresses, names of engineers and owners, and other information specified.
D. Product test reports: certified reports of manufacturers' design and production tests indicating compliance of cable and accessories with referenced standards. Cables with the manufacturing date exceeding 12 months prior to the date of delivery to the project site will not be accepted.
E. Schedule of cable pulls showing calculated pulling tension and sidewall pressure values.
F. Field test reports indicating and interpreting test results relative to compliance with performance requirements specified.
G Certified copies of field test records.

QUALITY ASSURANCE

Medium voltage cables and accessories installation shall be in conformance with the followings:

A. ANSI/IEEE C2 National Electrical Safety Code.
B. IEEE 48 Test Procedures and Requirements for High Voltage Alternating Current Cable Terminations.
C. NEMA WC 8 Ethylene Propylene Rubber Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy.
D. NETA ATS - Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems (International Electrical Testing Association).
E. NFPA 70 (National Fire Protection Association) – National Electrical Code.
F. ICEA (Insulated Cable Engineers Association) (ICEA)

Single-source responsibility:

A. All medium-voltage cable shall be the product of a single manufacturer.
B. All medium-voltage cable terminations shall be the product of a single manufacturer.

Medium Voltage Cable manufacturer shall have 10 years experience in manufacturing medium-voltage cable with triple extrusion of EPR insulation and accessories similar to those specified for use on this project, with a record of successful in-service performance and having ISO-9000 approval certification.

Cable shall be new and of recent manufacture (no more than 12 months old) and shall have label showing the name of cable manufacturer, size, plant location, insulation type, insulation thickness, voltage rating, insulation level, sequential footage, year of manufacture and UL designations.

Manufacturer shall provide 40-year warranty for design service life.

Medium-voltage cable, terminations, and accessories shall be listed and labeled as defined in NFPA 70, Article 100

Cable shall comply with UL Standard 1072 for Type MV-105.

Installer qualifications: The Contractor shall engage experienced and certified electricians to install and terminate medium-voltage cable:

A. Cable installation foreman shall have a minimum of 3 years of experience with medium voltage installations of similar design and complexity.
B. Cable terminator shall have a minimum of 3 years of medium voltage cable termination experience and shall be certified by the termination manufacture for the exact product used on this project.
C. Qualification of testing agency shall conform to "Systems Studies and Field Testing" of these special provisions.

DELIVERY, STORAGE, AND HANDLING

The Contractor shall deliver medium-voltage cable on factory reels and store on elevated platforms in a dry location.

CABLES

The medium voltage cables shall be as follows:

A. Type MV-105.
B. Single copper conductor
C. Compact Class B conductor stranding.
D. Ethylene propylene rubber (EPR) insulation in conformance with NEMA WC 8 (ICEA S-68-516).

    1. 15 KV, insulation Voltage.
    2. 133 percent insulation level with thickness per manufacturer's standard.

E. 0.127-mm uncoated copper tape with 12.5 percent minimum overlap helically applied over semi-conducting insulation shield.
F. Sunlight-resistant polyvinylchloride (PVC) jacket.

SOLID TERMINATION KITS

Conductor terminations kit shall be in conformance with IEEE Standard 48, Insulation class shall equivalent to that of the cable. Terminations for shielded cables shall include a shield grounding strap:

A. Class 1 termination for shielded cable shall be modular type, furnished as a kit, with stress-relief tube, multiple molded silicone rubber insulator modules, shield ground strap, and compression-type connector, or:
B. Class 1 termination for shielded cable shall be heat-shrinkable type with heat-shrinkable inner stress control and outer nontracking tubes, and compression-type connector.

SEPARABLE INSULATED CONNECTORS

Separable insulated connectors shall be modular system complying with IEEE 386. Disconnecting, single-pole, cable terminators and matching stationary, plug-in, dead-front terminals designed for cable voltage and for sealing against moisture:

A. Load-break cable terminators shall be elbow-type units with 200A load make/break and continuous current rating. Coordinate with insulation diameter and conductor size and material of cable being terminated. Include capacitively coupled test point on terminator body.
B. Grounding kit shall include jumpered elbows, portable feed-through accessory units, protective caps, test rods suitable for concurrently grounding three phases of feeders, and carrying case.
C. Standoff insulator shall be portable, single dead-front terminal for removable mounting on accessory stand of stationary terminal junction. Insulators suitable for fully insulated isolation of energized cable elbow terminator.
D. Tool set shall be shotgun-type hot stick with energized terminal indicator, fault indicator test tool, and carrying case.

ARC-PROOFING MATERIALS

A. Tape for first course on metal objects shall be 0.25-mm thick, corrosion-protective, moisture-resistant, PVC pipe-wrapping tape.
B. Arc-proofing tape shall be fireproof, flexible, conformable, intumescent to 8mm thick, and compatible with the cable jacket on which used.
C. Glass cloth tape shall be pressure-sensitive adhesive type, 13 mm wide.

FAULT INDICATORS

Indicators shall be manual-reset fault indicator, arranged to clamp to cable sheath and provide a display after the cable has faulted:

A. The instrument shall immune to heat, moisture, and corrosive conditions.
B. Indicators shall have spare contacts for remote monitoring.

Resetting tool shall be designed for use with fault indicators, with moisture-resistant carrying case.

SOURCE QUALITY CONTROL

Manufacturer shall test and inspect cables in conformance with NEMA WC 8 (ICEA S-68-516) before shipping.

INSTALLATION

The Contractor shall examine and swab out raceways to receive medium-voltage cable for compliance with installation tolerances and other conditions affecting performance of the cable. Installation shall not proceed until unsatisfactory conditions have been corrected.

The Contractor shall install medium-voltage cable as shown on plans in accordance with manufacturer's written instructions.

Cable shall be protected from construction damage during cable preparation and pulling. Cable shall not be laid directly on the roadway surface or ground for measuring or pulling purposes.

The Contractor shall pull conductors simultaneously where more than one cable is indicated in same raceway:

A. Manufacturer-approved pulling compound or lubricant shall be used.
B. Rollers and pulleys of the recommended radius for the cable shall be used
C Fish tape, cable, rope and basket-weave/cable grips shab be used.
D. Manufacturer's recommended maximum pulling tensions and side-wall pressure values shall not be exceeded.
E. A calibrated dynamometer shall be used on all pulls over 30 m.
F. All pulls shall be witnessed by the Engineer.

An approved cable pulling form shall be completed by the Contractor for each pull over 30 m. As a minimum, the following data shall be provided:

A. Date and time
B. Circuit and conductor identification
C. Calculated maximum pulling and side-wall tension with pulling configuration sketch.
D. Actual pulling tension
E. Signature of data collector and witness that certify satisfactory installation.

The Contractor shall train cables around walls of manholes by the longest route from entry to exit and support cables at intervals adequate to prevent sag. Arrange cables in manholes to avoid interference with duct entrances.

The Contractor shall ground shields and metal bodies of shielded cable at all terminations.

The Contractor shall provide fault indicators on every load-break separable insulated connector.

The Contractor shall install underground duct warning tape as specified under "Electrical Identification" of these special provisions, 152 mm above ductbank.

The Contractor shall install terminations at ends of conductors using a standard kit.

Cable ties shall be nylon, 6 mm wide, tensile strength of 530 N, self-locking type:

Cable shall be supported in equipment at not more than 0.9-m intervals. Supports shall be provided by the equipment manufacturers and shall be of insulating material

Arc-proofing: The Contractor shall arc-proof medium-voltage cable in all manholes. Apply as follows and as recommended by the manufacturer of the arc-proofing tape:

A. Clean cable sheath.
B. Wrap metallic cable components with 0.25-mm pipe wrapping tape.
C. Smooth surface contours with electrical insulation putty.
D. Apply arc-proofing tape in one half-lapped layer with the coated side toward the cable.
E. Band the arc-proofing tape with 25 mm wide bands of half-lapped adhesive glass-cloth tape 51 mm on center.

GROUNDING

The Contractor shall ground shields of shielded cable at terminations, and separable insulated connectors. The Contractor shall also ground metal bodies of terminators, cable and separable insulated connector fittings, and hardware in accordance with manufacturer's written instructions.

IDENTIFICATION

All system components, wiring, cabling, junction boxes,manholes, power circuits and terminals shall be identified with permanent labeling in conformance with “Electrical Identification” of these special provisions.

CONDUCTOR COLOR CODING:

The Contractor shall comply with the following phase color standard for 12,470 Volts (ac), 3-phase, 3-wire Delta:

A. Phase A black / orange
B. Phase B red / orange
C. Phase C blue / orange

FIELD QUALITY CONTROL

The Contractor shall engage a qualified independent testing agency to perform field quality control testing. Upon installation of medium-voltage cable and before electrical circuitry has been energized, demonstrate product capability and compliance with requirements. Procedures:

A. The Contractor shall perform each visual and mechanical inspection and electrical test stated in NETA Standard ATS, Section 7.3.2. Certify compliance with test parameters.
B. The Contractor shall Megger all cables before high-potential testing. Use the following megger voltages:

Cable Rating	Megger Voltage
15 kV	15 kV

C. The Contractor shall determine the insulation resistance values with cables disconnected at each end. Megger cable and high-potential test only after all splices and terminations are made.
D. The Contractor shall perform field Hi-potential test for all cables in conformance with IEEE 400 and ICEA No. S-68-516, "Electrical Tests on Completed Cables."
E. 15kV, EPR, 133 percent insulation level grounded shielded cable tests:

Cable Size (AWG or kcmil)	Test Voltage (kV, DC)	Duration (Minutes)
1-750	40 (15kV Cable)	15

F. Cable shall not be tested with an AC test set. Disconnect cables from all equipment during testing. Testing cable on reel will not be acceptable. Test cable after installation but before final connection of equipment. Individually test each conductor with all other conductors grounded. Ground all shields.
G. Use standard NETA test forms and record results.
H. The Contractor shall correct deficiencies and retest to demonstrate compliance.

PROTECTION

The Contractor shall provide final protection to prevent entrance of moisture into the cable and ensure that medium-voltage cable is without damage or deterioration at the time of final inspection of the contract.

MEASUREMENT

Medium voltage cable will be measured as a lump sum basis.

PAYMENT

The lump sum contract price paid for medium voltage cable shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for performing all the work involved in installing medium voltage cables, and equipment ground conductors, complete in place, including terminations and testing, as shown on the plans, and as specified in these special provisions, and as directed by the Engineer.

10-4.__ RACEWAYS AND BOXES

GENERAL

Raceways and boxes including fittings, enclosures, and cabinets devices testing shall conform to the provisions in Section 86 "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions.

SUMMARY

Scope.--Raceways and boxes shall consist of raceways, fittings, boxes, enclosures, and cabinets for electrical wiring including the following:

A. Galvanized rigid steel (GRS).
B. Electrical metallic tubing (EMT).
C. Flexible metal conduit (FMC).
D. Liquid-tight flexible metal conduit (LFMC).
E. Surface raceways.

Boxes, enclosures, and cabinets shall include the following:

A. Device boxes.
B. Outlet boxes.
C. Pull and junction boxes.
D. Cabinets and hinged-cover enclosures.
E. Medium voltage junction stands.

SUBMITTALS

A. Product data shall be submitted for the following:

1. Wireways,
2. Hinged-cover enclosures,
3. Medium voltage junction cabinets,

B. Working Drawings shall include layout drawings showing components and wiring for:

1. Medium voltage junction cabinets.
2. All boxes with terminal strips

3. Nonstandard low-voltage boxes, enclosures, and cabinets.

QUALITY ASSURANCE

Raceways and boxes shall be listed and labeled in conformance with NFPA 70, Article 100.

Raceways and boxes shall comply with NECA's "Standard of Installation" and shall conform to ANSI C80.1.

COORDINATION

The Contractor shall coordinate layout and installation of raceways and boxes with other construction elements to ensure adequate headroom, working clearance, and access.

METAL CONDUIT

Metal Conduit .--Metal conduit shall conform to the following requirements:

A. Rigid Steel Conduit shall be galvanized.
B. FMC shall be zinc-coated steel.
C. LFMC shall be liquidtight flexible steel conduit with jacket: Polyvinyl chloride (PVC) jacket in equipment chambers and outside of the tunnel locations
D. LFMC shall be low-smoke liquidtight flexible steel conduit with jacket: Thermoplastic polyurethane jacket in roadway and cross-passage tunnel locations for low products of combustion.
E. Fittings shall be in conformance with NEMA FB 1 and compatible with conduit and tubing materials.
F. Expansion and deflection couplings shall be UL Standard 514B. Coupling fitting shall be watertight, corrosion-resistant, and shall have cast metal threaded hubs, molded neoprene outer jacket, stainless steel jacket clamps, tinned copper flexible braid ground strap. Coupling shall allow up to 19 mm movement in any direction.
G. Conduit hub fittings shall be UL Standard 514B, zinc plated, cast metal, watertight with neoprene gasket and insulated throat.

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Outlet And Device Boxes.--Outlet and devices boxes shall be cast-metal boxes in conformance with NEMA FB 1, Type FD, and cast box with gasketed cover.

PULL AND JUNCTION BOXES

Tunnel boxes.--Tunnel flush mounted boxes used for tunnel ceiling and wall embedment shall conform to the following requirements:

A. NEMA 4X junction and pull boxes shall be sized in accordance with the NEC and shall be stainless steel 316L. All related nuts, bolts, screws and mounting hardware shall be stainless steel 316.
B. External flanged shall be heavy-duty junction boxes with stainless-steel back-panel mounting plate.
C. Conduit entry of junction and pull boxes shall include the following features:

1. Factory bossed, drilled, and tapped conduit holes (hubbed entry): or
2. Field drilled slip-hole with conduit hub fittings.

Chamber boxes.--Surface mount boxes in equipment chambers shall be UL 50, Type 12, steel and include the following:

A. Continuous hinged cover with neoprene gasket.
B. Steel back-panel.
C. Corrosion inhibitor primer, polyester powder box and back panel, paint inside and outside.
D. Stainless steel bolts and cover clamps.

Cross-passage boxes.--Surface mount boxes in cross-passage and exterior locations shall be UL 50, Type 4X, stainless-steel and include the following:

A. Continuous hinged cover with neoprene gasket.
B. Stainless-Steel back-panel.
C. Stainless steel bolts and cover clamps.

Terminal blocks--Terminal blocks as shown on the plans shall include the following:

A. Through-type, power distribution blocks.
B. Tin or nickel-plated copper alloy bus, screws.
C. Listed for the largest sized conductor terminated.
D. Polycarbonate base, barriers and safety covers for individual terminals.

METAL WIREWAYS

A. Material shall be NEMA Type 12, unless noted otherwise, sheet metal sized and shaped as shown on the plans.
B. Wireway covers shall be gasketed, continuously hinged with snap-down latches.
C. Fittings and accessories shall include couplings, offsets, elbows, expansion joints, adapters, hold-down straps, end caps, and other fittings to match and mate with wireways as required for a complete system.
D. Finish shall be corrosion resistant primer with powder-coat polyester finish.

ENCLOSURES AND CABINETS

Enclosures and cabinets shall comply with NEMA 250, and shall be Type 12, galvanized steel box with removable interior panel and removable front, finished inside and out with manufacturer's standard enamel. Hinged door in front shall be covered with flush latch and concealed hinge. Key latch shall match panelboards. Metal barriers shall be included to separate wiring of different systems and voltage, and include accessory feet where required for freestanding equipment.

MEDIUM VOLTAGE JUNCTION STANDS

Medium voltage junction stands shall be NEMA Type 12, single access, double door enclosure and include the following features:

A. Enclosure shall be constructed of 2.7 mm (12 gauge) steel with 3.4 mm (10 gauge) steel, full back panel.

B. Doors shall be gasketed and overlapping type with no center post. In each door, a 3-point latching mechanism with key-locking handle, with heavy gauge continuous hinges shall be provided.
C. Provide 306 mm high floor stand kit for freestanding enclosure.
D. Enclosure finish shall be a corrosion-resistant primer, white enamel inside and ANSI 61 gray enamel outside.

200 A, 15 kV class loadbreak junction bars shall include the following features:

A. One three-point junction per phase.
B. Fully insulated continuous solid copper bus bar.
C. Junction bars shall be in accordance with IEEE Standard 386.
D. Adjustable and direct wall mount U-strap type stainless steel brackets, as shown on the plans.

Assembly shall include the following features:

A. Stands shall be fully shop fabricated by a UL authorized shop.
B. Provide full air space clearances between phases and ground, as required by junction manufacturer.
C. Solid copper ground bus as shown on the plans.
D. Shop installed bonding of all components.

EXAMINATION

Surfaces of receive raceways, boxes, enclosures, and cabinets shall be examined for compliance with installation tolerances and other conditions affecting performance of raceway installation. Installation shall not proceed until all raceways, boxes, enclosures and cabinets are clean and clear and installation tolerances are met.

APPLICATIONS

Materials shall be installed in conformance with the following:

A. Galvanized rigid steel shall be installed in all areas except as specified in "Underground Ducts and Vaults" of these special provisions.
B. Connection to vibrating or removable equipment, including tunnel luminaires, transformers and hydraulic, pneumatic, electric solenoid, or motor-driven equipment:

    1. LFMC in all equipment chambers and non-tunnel areas.
    2. LFMC-LS in exposed roadway and cross-passages.

C. Provide boxes and enclosures as shown on the plans and in these special provisions.

INSTALLATION

Raceways, boxes, enclosures.--Raceways, boxes, enclosures, and cabinets shall be installed as shown on the plans, and according to manufacturer's written instructions.

Minimum Raceway Size shall be 21 mm trade, except where noted.

Plans indicate where buried, embedded or exposed raceway shall be used. In general, exposed conduit shall be used in the equipment chambers, cross-passages, and OMC electrical room. All roadway tunnel conduits shall be buried or embedded.

Raceways shall be installed level and square and at proper elevations. The Contractor shall provide adequate headroom.

The Contractor shall complete raceway installation before starting conductor installation.

Support raceways shall conform to the requirements as specified in "Seismic Controls for Electrical Work" of these special provisions.

Temporary closures shall be used to prevent foreign matter from entering raceways.

Stub-ups shall be protected from damage where conduits rise through floor slabs. Curved portion of bends shall not visible above the finished slab.

Make bends and offsets so cross-section of pipe shall not be reduced. Legs of bends shall be kept in the same plane and straight legs of offsets parallel, unless otherwise indicated.

The Contractor shall use raceway fittings compatible with raceways and suitable for use and location.

The Contractor shall run concealed raceways, with a minimum of bends, in the shortest practical distance considering the type of construction and obstructions, unless otherwise indicated.

Raceways embedded in slabs shall be installed in middle third of slab thickness where practical, and leave at minimum 50 mm concrete cover:

A. Secure raceways to reinforcing rods to prevent sagging or shifting during concrete placement.
B. Space raceways laterally to prevent voids in concrete.
C. Run conduit larger than 27 mm trade size parallel to or at right angles to main reinforcement. Where at right angles to reinforcement, place conduit close to slab support.

Exposed raceways shall be installed parallel to or at right angles to nearby surfaces or structural members, and follow the surface contours as much as practical:

A. Run parallel or banked raceways together, on common supports where practical.
B. Use factory elbows where correct radius is available; otherwise, provide field bends for raceways.

Raceways shall be joined with fittings designed and approved for the purpose and make joints tight:

A. Make raceway terminations tight. Use bonding bushings or wedges at connections subject to vibration. Use bonding jumpers where joints cannot be made tight.
B. Use insulating bushings to protect conductors.
C. For embedded conduit, use expansion/deflection couplings at all structural expansions joints.
D. Provide conduit expansion joints as noted on plans.
E. Provide conduit hub fittings for all conduit entries into NEMA 12 steel boxes and all other terminations for GRS where boss/hubs are not integral to the box.
F. All wireway connections shall be gasketed.

Wireways.--Wireways shall be installed as shown on the plans, and mount on 20 mm high strut with opening facing out from wall, with hinge mounted on top. Dividers shall be provided as shown on the plans.

Terminations.--Raceways shall be terminated with locknuts and bushings, align raceways to enter squarely and locknuts shall install with dished part against the box. Two locknuts shall be used (one inside and one outside the box) where terminations are not secure with one locknut.

The end bears against the wire protection shoulder shall be used where raceways are terminated with threaded hubs, screw raceways or fittings tightly into the hub. Where chase nipples are used, raceways shall be align so the coupling is square to the box and tighten the chase nipple so no threads are exposed.

Pull wires shall be installed in empty raceways. Monofilament plastic line with not less than 90 kg tensile strength shall be used. At least 914 mm of slack shall be left at each end of the pull wire.

Stub-up connections.--All conduit stub-ups shall be galvanized rigid steel. Stub-up conduit shall extend a minimum of 76 mm above finished slab and terminate in a insulated grounding type bushing inside floor mounted switchgear and switchboards or as otherwise shown for free-standing equipment. GRS stub-ups subject to moisture, shall be wrapped with corrosion protection tape from 152 mm below top of slab to 76 mm above top of slab.

Flexible connections.--Flexible connections shall use maximum of 1.8 m of flexible conduit for lighting fixtures; and for equipment subject to vibration, noise transmission, or movement; and for all motors. Liquid-tight flexible conduit shall be used in all locations. Flexible conduit shall be installed as indicated in tunnel applications.

Sidewalk-type junction boxes shall set level and adjust to finished surface.

Hinged-cover enclosures and cabinets plumb shall be installed and supported at each corner.

PROTECTION

Final protection and maintenance conditions shall be provided, in a manner acceptable to manufacturer and installer that ensure coatings, finishes, and cabinets are without damage or deterioration at system in service.

Damage to galvanized finishes with zinc-rich paint recommended by manufacturer shall be repaired by the Contractor.

CLEANING

Exposed finish including outlet fittings and devices shall be inspected on completion of installation. Burrs, dirt, and construction debris shall be removed and damaged finish shall be repaired, including chips, scratches, and abrasions

MEASUREMENT

Raceways and boxes will be measured on a lump sum basis.

PAYMENT

The lump sum contract price paid for raceways and boxes shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in installing raceways, fittings, boxes, enclosures, and cabinets for electrical wiring (except final tap circuits from the power terminal box to tunnel roadway luminaires), complete in

place, as shown on the drawings, as specified in these special provisions, and as directed by the Engineer.

Full compensation for raceways and boxes for final tap circuits from the power terminal box to tunnel roadway luminaires shall be considered as included in the contract lump sum price paid for tunnel lighting and no additional compensation will be allowed therefor.

10-4.__ UNDERGROUND DUCTS AND VAULTS

GENERAL

Underground ducts and vaults shall consist of furnishing, installing, and testing of underground ducts and vaults including manholes, and handholes in conformance with the provisions in Section 86 "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--Underground ducts and vaults shall include the following:

A. Below grade ducts in tunnel duct banks.
B. Below grade ducts in duct banks outside of tunnel to the limits as shown on the plans.
C. Direct buried single ducts outside of tunnel to the limits as shown on the plans.
D. Handholes and handhole accessories.
E. Manholes and manhole accessories

SUBMITTALS

The Contractor shall submit an equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and the requirements specified herein.

Product data.--The submittals shall include complete details, information, and drawings of each type of underground ducts and vaults as shown on the plans. The submittals shall also include the data on features, accessories, finishes, and the following:

A. Manholes, handholes and hardware.
B. Conduit and ducts, including elbows, bell ends, bends, fittings, and solvent cement.
C. Duct-bank materials, including spacers and miscellaneous components.
D. Warning tape.

Product shall have certificates for concrete and steel used in underground precast manholes in conformance with ASTM C 858.

QUALITY ASSURANCE

Electrical components, devices, and accessories (including ducts for communications and telephone service) shall be listed and labeled in conformance with NFPA 70, Article 100.

Electrical components, devices, and accessories including ducts for communications and telephone service shall conform to the following:

A. ANSI C2.
B. ASTM C 858
C. AASHTO H20

DELIVERY, STORAGE, AND HANDLING

Ducts shall be delivered to the project site with ends capped. Nonmetallic ducts shall be stored with supports to prevent bending, warping, and deforming.

Precast concrete units shall be stored at project site as recommended by manufacturer to prevent damage. Units shall be arranged so identification markings are visible.

Precast concrete units shall be lifted and supported only at designated lifting or supporting points.

PROJECT CONDITIONS

The medium voltage duct bank and manhole systems shall consist of two isolated utility sources, one for the north and one for the south. Each source shall occupy only designated ducts and manholes. Separation between the manholes of opposite sources shall be provided to reduce the probability of common failures due to short circuit or fire in any one manhole or duct. Medium voltage manholes within the tunnel roadway shall be provided with solid concrete lids and seals to protect cables from fuel spills in the tunnel.

COORDINATION

The Contractor shall coordinate layout and installation of ducts, manholes, and hand-holes with final arrangement of other utilities and site grading.

Manholes and ducts shall be coordinated with the rock boring and civil work to assure specified depth shown on the plans is achieved at all locations.

MATERIALS

Conduit and Ducts.--Rigid steel conduit (GRS) and fittings shall conform to the provisions "Raceways and Boxes" of these special provisions.

Rigid nonmetallic conduit shall conform to NEMA TC 2, Type EPC-40-PVC, UL 651, and shall include matching fittings by the same manufacturer as the conduit, in conformance with NEMA TC 3 and UL 514B.

Plastic utilities duct shall conform to NEMA TC 8, Type DB-120-PVC, ASTM F 512, and shall include matching fittings by the same manufacturer as the conduit, in conformance with NEMA TC 9.

Fabric mesh innerduct shall be multi-cell, fabric mesh, innerduct for use in PVC or GRS ducts. Each cell shall contain color-coded pull tapes. Innerduct shall be prelubricated and shall be water-resistant. Innerduct shall not spiral when pulled through the duct.

Handholes.--Precast handholes shall be constructed of reinforced concrete in conformance with Standard Plan. Sizes and special features of precast handholes shall be as noted on plans.

Cover legends shall conform to Standard Plan.

Precast Manholes-- Precast units shall include the following features:

A. ASTM 478, with interlocking mating sections, complete with accessories, hardware, and features as shown on the plans..

B. Design and fabricate structure according to ASTM C 858.
C. Design structure according to sizes shown on plans.
D. Structural design loading: ASTM C 857, Class A-16 and AASHTO H20 traffic loading.
E. Joint sealant: continuous extrusion of asphaltic-butyl material with adhesion, cohesion, flexibility, and durability properties necessary to withstand maximum hydrostatic pressures at the installation location with the ground-water level at grade.
F. Provide 203 mm diameter cast-in sump.
G. Source quality control: inspect structures according to ASTM C 1037.
H. Pulling eyes in walls: eyebolt with reinforcing-bar fastening insert 51 mm diameter eye and 25 mm x 102 mm bolt. Working load shall be embedded in 152 mm, 27 MPa concrete: 57.8 kN minimum tension.
I. Pulling and lifting irons in floor: 22 mm diameter, hot-dip-galvanized, bent steel rod; stress relieved after forming; and fastened to reinforced rod. Exposed triangular opening. Ultimate yield strength: 178 kN shear and 267 kN tension.
J. Expansion anchors for installation after concrete is cast: stainless-steel-wedge type with stainless-steel expander clip with 13 mm bolt, 23.6 kN rated pullout strength, and minimum 30.2 kN rated shear strength.
K. Cable support racks: Racks shall be non-metallic, non-conductive, 50 percent glass-reinforced nylon and U.L. listed non-corrosive, non-flammable materials. Which shall be manufactured in a one-piece molding comprising a heavy-duty integral wall mount support with adjustable rack arms.
L. Grounding materials: comply with "Grounding and Bonding" of these special provisions.
M. Duct-sealing compound: non-hardening, safe for contact with human skin, not deleterious to cable insulation, and workable at temperatures of 2°C. Duct-sealing compound shall be capable of withstanding temperature of 149°C without slump and of adhering to clean surfaces of plastic ducts, metallic conduits, conduit coatings, concrete, masonry, lead, cable sheaths, cable jackets, insulation materials, and common metals.

Vaults outside of tunnel shall include the following features:

A. Cover shall have identification label.
B. Lid shall be made of non-skid aluminum.
C. Concrete knockout panels for conduit entrance and (1)-51 mm knock-out for ground rod shall be included.
D. Welded cover legends: "ELECTRIC" or "SIGNAL"

Inside tunnel medium voltage vaults shall include the following features:

A. Cover shall have identification label.
B. Lid shall be made of concrete slab that will fit on a galvanized metal frame.
C. Lid gasket material shall be water and gasoline resistant.
D. Engraved cover legends: "ELECTRIC"

Miscellaneous

Duct spacers-- Rigid polyvinyl chloride (PVC) interlocking spacers shall be installed to provide minimum duct spacing and cover depths as shown on the plans while supporting ducts during concrete pouring and back-filling. Spacers shall be produced by the same manufacturer as the ducts.

Warning tape-- Underground-line warning tape shall conform to "Electrical Identification" of these special provisions.

CONSTRUCTION MATERIALS

Mortar shall conform to ASTM C 270, Type M, except for quantities less than 56,634 cc where packaged mix in conformance with ASTM C 387, Type M, may be used.

Concrete shall be 20 MPa minimum, 28-day compressive strength and 10 mm maximum aggregate size. Concrete and reinforcement shall conform to "_____" of these special provisions.

Controlled Density Fill (CDF) shall conform to "Controlled Low Strength Material" of these special provisions.

Different type of concrete shall be used as follow:

A. Outside of tunnel and in shoulder of roadway: CDF encased duct bank with Type EPC-40-PVC.
B. Outside of tunnel and in roadway: concrete encased duct bank with Type DB-120-PVC.
C. Inside tunnel underground concrete encased duct bank: Type GRS.
D. Underground direct- buried duct, 53 mm and smaller: Type EPC-40-PVC.

TRENCH VAULTS

Vault walls and floor shall be cast-in-place as an integral element of the floor or walkway structure, and shall conform to the details shown on the plans. Sizes and location shall conform to the electrical and systems plans, with final location and sizing details coordinated by the Contractor.

Lids shall be coordinated with the structural for frame cast-in-place:

A. Lid features per plans, H-20 rated.
B. Cover shall have identification label.
C. Welded cover legends: "SIGNAL".

EARTHWORK

Excavation and backfill shall conform to "Earthwork" of these special provisions. Heavy-duty, hydraulic-operated, compaction equipment.

CONDUIT AND DUCT INSTALLATION

Slope.--Ducts shall pitch a minimum slope of 1:300 down toward manholes and handholes and away from buildings and equipment. Ducts shall be sloped between two manholes to drain in one or both directions.

Curves and bends.--Curves and bends shall be installed as follow:

A. Inside of tunnel, equipment chambers, and OMC electrical room: Use manufactured long sweep GRS bends with a minimum radius of 916 mm, both horizontally and vertically; except, use manufactured GRS elbows with a minimum radius of 610 mm for stub-ups at equipment.
B. Outside of tunnel: use manufactured long sweep PVC bends with a minimum radius of 1524 mm, both horizontally and vertically.

Duct joints.--Duct joints shall be installed as follow:

A. Use solvent-cement joints in PVC ducts and fittings and make watertight according to manufacturer's written instructions.
B. Use GRS threaded couplers in GRS ducts and make watertight with appropriate joint compound.
C. Stagger couplings so those of adjacent ducts do not lie in the same plane.

Duct entrances.--Duct entrances to manholes and handholes shall be installed as follow:

A. Maintain 175 mm on center spacing of ductbank conduits entering manholes.
B. Terminate PVC conduits at manholes using flush mounted end bells.
C. Terminate GRS conduits at tunnel vaults using GRS grounding fittings with bushings.
D. Grout all conduit terminations in vault walls from both sides to provide a water-tight seal.

Ducts.--Ducts shall be installed as follows:

A. PVC duct separator installation: Separators shall be spaced close enough to prevent sagging and deforming of ducts. Separators shall be secured to earth and to ducts to prevent floating during concrete placement. Spacers shall be staggered approximately 152 mm between tiers. Entire assembly shall be tied together using fabric straps. Tie wires or reinforcing steel that may form conductive or magnetic loops around ducts or duct groups shall not be used.
B. CDF backfill placement: CDF shall be carefully spaded during pours to prevent voids under and between conduits and at exterior surface of envelope. A heavy mass of CDF shall not fall directly onto ducts. A plank shall be used to direct concrete down sides of bank assembly to trench bottom. CDF shall flow to center of bank and rise up in middle, uniformly filling all open spaces. Power-driven agitating equipment shall not be used unless specifically designed for duct-bank application. Each run of envelope between manholes or other terminations shall be poured in one continuous operation.
C. Tunnel GRS duct: Ducts shall be secured with strut and clamps as indicated prior to concrete encasement.
D. Reinforcement: steel reinforcement shall be provided within the duct banks as shown on the plans.
E. Forms: walls of trench shall be used to form side walls of duct bank where soil is self-supporting and CDF envelope can be poured without soil inclusions; otherwise, forms shall be used.
F. Depth: install as indicated on the plans.
G. Direct buried conduit depth: top of conduit shall be installed at least 460 mm below finished grade in non-traffic areas and at least 610 mm below finished grade in vehicular traffic areas. Maximum depth to the top of the duct bank shall not exceed 762 mm below finished grade.

Warning tape.--Warning tape shall be buried approximately 300 mm above all direct buried conduit and CDF-encased duct banks. Tape shall be aligned parallel to and within 76 mm of the centerline of duct bank.

Stub-ups.--Rigid steel conduit shall be used for stub-ups to equipment. For equipment mounted on outdoor concrete bases, steel conduit shall be extended a minimum of 1524 mm

from edge of base. Insulated grounding bushings shall be installed on terminations. Steel conduits shall be coupled to non-metallic ducts with adapters designed for this purpose and coupling shall be encased with 76 mm of concrete.

Sealing.--Temporary closure shall be provided at terminations of ducts that have cables pulled. Spare ducts shall be sealed at terminations. Sealing compound and plugs shall be used to withstand at least 103 kPa hydrostatic pressure.

Pulling cord.--445 N test nylon cord shall be installed in ducts, including spares.

MANHOLE AND HANDHOLE INSTALLATION

Elevation.--Handholes and manholes shall be installed with rooftop flush at finished pavement for roadway and sidewalk located vaults, and with roof surface 25 mm above grade for outdoor non-paved locations. Handholes shall be installed with depth as indicated on Standard Plan.

Hardware.--Removable hardware, including pulling eyes, cable stanchions, cable arms, and insulators, shall be installed.

Field-installed bolting anchors.--The Contractor shall not drill deeper than 98 mm for anchor bolts installed in the field. A minimum of two anchors shall be used for each cable stanchion.

Grounding.--A ground rod shall be installed through floor in each outdoor manhole structure with top protruding 102 mm above floor. Floor opening shall be sealed against water penetration with waterproof non-shrink grout. Exposed metal components and hardware shall be grounded with bare-copper ground conductors. Conductors shall be routed neatly around corners. Cable clamps secured with expansion anchors shall be used to attach ground conductors.

Installation of precast concrete manhole and handhole shall conform to ASTM C 891 and the following requirements:

A. Units shall be installed level and plumb and with orientation and depth coordinated with connecting ducts to minimize bends and deflections required for proper entrances.
B. Unless otherwise indicated, units shall be supported on a level bed of crushed stone or gravel, graded from 25 mm sieve to No. 4 sieve and compacted to same density as adjacent undisturbed earth.

FIELD QUALITY CONTROL

Testing.--The Contractor shall demonstrate capability and compliance with requirements on completion of installation of underground ducts and utility structures.

Grounding.--The Contractor shall test manhole grounding to ensure electrical continuity of grounding and bonding connections. The Contractor shall measure and report ground resistance in conformance with "Grounding and Bonding" of these special provisions.

Duct integrity--The Contractor shall pull aluminum or wood test mandrel through duct to prove joint integrity and test for out-of-round duct. The Contractor shall provide mandrel equal to 80 percent fill of the duct. If obstructions are indicated, the Contractor shall remove obstructions and re-test.

The Contractor shall correct installations and retest to demonstrate compliance. Defective products shall be removed, replaced and retested.

CLEANING

The Contractor shall pull leather-washer-type duct cleaner, with graduated washer sizes, through full length of ducts. The Contractor shall follow with rubber duct swab for final cleaning and to assist in spreading lubricant throughout ducts.

The Contractor shall clean internal surfaces of manholes, including sump and shall remove foreign material.

INNERDUCT

The Contractor shall install fabric mesh innerduct after complete duct and manhole system is complete and clean.

Innerduct shall not spiral when pulled through the duct. The Contractor shall use a swivel pulling fitting or other means to facilitate pulling.

MEASUREMENT

Underground ducts and vaults will be measured on a lump sum basis.

PAYMENT

The lump sum contract price paid for underground ducts and vaults shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing ducts, vaults, marker, and backfill, complete in place including testing, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-4.__ LOW VOLTAGE ELECTRICAL SYSTEM

GENERAL

Low voltage electrical system shall be furnished, installed, and tested in conformance to the details shown on the plans and these special provisions. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

Low voltage electrical system shall include the following:

A. Wiring devices including receptacles, connectors, switches, and finish plates.
B. Enclosed safety switches consisting of individually mounted enclosed switches used for disconnecting equipment.
C. Panelboards and switchboard, consisting of lighting and appliance branch-circuit panelboards.
D. Dry-type transformers including dry-type distribution and specialty transformers rated 1000 V and less.
E. Miscellaneous lighting including lighting fixtures, lamps, ballasts, exit fixtures, and accessories for installation in the cross passages, equipment chambers, and special fixtures in the roadway tunnels.

SUMMARY

Scope.--Wiring devices, enclosed safety switches, panelboards, and dry-type transformers shall be installed in the tunnel chambers; Miscellaneous lighting shall be installed in the tunnel chambers, tunnel cross-passages and in the tunnel above the telephone cabinet as shown on the

plans. Irrigation control switchboard shall be installed at the Operation and Maintenance Center (OMC).

SUMITTALS

The Contractor shall submit an equipment lists and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and the requirements specified herein.

Product data.--The submittals shall include complete details, information, and drawings of each type of item as shown on the plans. The submittals shall include the following:

A. Wiring devices:

1. Product data: for each product specified.
2. Operation and Maintenance data to be included in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

B. Enclosed safety switches:

1. Product data: for each type of switch, fuse, accessory, and component shown on the plans. Data submitted shall include dimensions and manufacturers' technical data on features, performance, electrical characteristics, ratings, and finishes.
2. Operation and Maintenance data for enclosed switches, including routine maintenance requirements for components and manufacturer's written instructions for testing and adjusting to be included in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

C. Panelboards and switchboard:

1. Dimensions and manufacturer's technical data on features, performance, electrical characteristics, ratings, and finishes.
2. Tabulations of installed devices, equipment features and ratings, bus configuration, current and voltage ratings, and short-circuit current rating of panelboards and overcurrent protective devices.
3. Maintenance manuals for panelboards in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions, including time-current curves, with selectable ranges for each type of overcurrent protective device.

D. Transformers:

1. Data on features, components, ratings, and performance for each type of transformer.
2. Dimensioned plans, sections, and elevation views.
3. Minimum clearances and installed devices and features.
4. Wiring diagrams including detail wiring and terminals for tap changing and connecting field-installed wiring.

5. Operation and Maintenance data for transformers to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

E. Miscellaneous lighting fixtures:

1. Dimensions of lighting fixtures.
2. Data sheets for fluorescent and high-intensity-discharge ballasts.
3. Operation and Maintenance data for miscellaneous lighting fixtures to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

QUALITY ASSURANCE

All electrical components, devices, and accessories shall conform to the following requirements:

A. Listed and labeled as defined in NFPA 70, Article 100.
B. Equipment shall comply with IEEE C2 and NFPA 70.
D. Wiring devices shall comply with NEMA WD 1.
E. Enclosed safety switches shall comply with NEMA KS 1.
F. Transformers shall comply with California State Energy Code Requirements for Efficiencies.

Testing agency qualifications shall conform to "Systems Studies and Field Testing" of these special provisions.

DEFINITIONS

A. GFCI: Ground-fault circuit interrupter.
B. The terms "listed" and "labeled": as defined in NFPA 70, Article 100.

SEISMIC CERTIFICATION

The Contractor shall submit certification that transformers, panelboards, overcurrent protective devices, accessories, and components will withstand seismic forces as specified in "Seismic Controls for Electrical Work" of these special provisions. The seismic certification shall include the following:

A. Basis for certification: indicate whether withstand certification is based on actual test of assembled components or on calculation.
B. Dimensioned outline drawings of equipment unit: identify center of gravity and locate and describe mounting and anchorage provisions.
C. Equipment anchorage devices: detailed description of devices on which the certification is based and their installation requirements.

PROJECT CONDITIONS

Equipment shall be capable of operating continuously under the following conditions:

A. Ambient temperature: –30°C to +40°C.

B. Altitude: not exceeding 300 m.

The Contractor shall coordinate the layout and installation of all components with other construction, including conduit, piping, equipment, and adjacent surfaces. The Contractor shall maintain required workspace clearances and required clearances for equipment and access doors and panels.

DELIVERY, STORAGE, AND HANDLING

The Contractor shall apply temporary heat according to manufacturer's written instructions within the enclosure of each ventilated-type unit throughout periods during which equipment is not energized and is not in a space that is continuously under normal control of temperature and humidity.

WARRANTY

A warranty for transformers, panelboards and miscellaneous lighting fixtures shall be provided and signed by the manufacturer and installer agreeing to correct system deficiencies and replace components that fail in materials or workmanship. The warranty shall be two years from the date of system in service.

MATERIALS

Wiring Devices.--Wiring devices shall include the following:

A. Receptacles: Straight-blade and locking receptacles shall be 20 A, heavy-duty grade. GFCI receptacles shall be termination-type, with integral NEMA WD 6, configuration 5-20R of duplex receptacle arranged to protect connected downstream receptacles on same circuit. Units shall be designed for installation in a 70 mm deep outlet box without an adapter.
B. Switches: Snap switches shall be heavy-duty, quiet type.
C. Motion Sensor: Passive infrared motion sensor shall be 180 degree, 8 m radius horizontal detection, outlet box mounted with 120 volt power, 1500 watt output contact, adjustable vertical detection field and adjustable time delay off.
D. Wall Plates: Single and combination types of wall plates shall be stainless steel plate-securing screws or galvanized steel and match corresponding wiring devices.

Enclosed Safety Switches.--Enclosed safety switches shall include the following features:

A. Enclosed, non-fusible switch: NEMA KS 1, Type HD, with lockable handle.
B. Enclosure: NEMA AB 1 and NEMA KS 1 to meet environmental conditions at installed location:

    1. Equipment chamber locations: NEMA 250, Type 1.
    2. Roadway tunnel, cross passage, and outdoor areas: NEMA 250, Type 4X, stainless steel.

C. Finish: manufacturer's standard grey paint applied to factory-assembled and -tested enclosures before shipping.

Panelboards.--Panelboards shall be manufactured by the same manufacturer that supplies the switchboards and Motor Control Centers (MCC)s.

A. Panelboards shall be fabricated and tested according to IEEE 344 to withstand seismic forces defined in "Electrical Supports and Seismic Restraints" of these special provisions.
B. Panelboards shall be fully rated to interrupt symmetrical short-circuit current available at terminals.
C. Surface-mounted cabinets type NEMA PB 1 shall include the following features:

1. Enclosure: NEMA Type 1
2. Hinged front cover: entire front trim hinged to box and with standard door within hinged trim cover.
3. Doors: concealed hinges; secured with flush latch with tumbler lock; keyed alike.
4. Finish: manufacturer's standard enamel finish over corrosion-resistant treatment or primer coat.
5. Directory card: card with transparent protective cover, mounted in metal frame, inside panelboard door.

D. Phase and ground buses shall include the following:

1. Material: hard-drawn copper, 98 percent conductivity.
2. Equipment ground bus: adequate for feeder and branch-circuit equipment ground conductors; bonded to box.

E. Conductor connectors shall be manufactured for use with copper conductor material:

1. Main and neutral lugs: compression type.
2. Ground lugs and bus configured terminators: compression type.

F. Service equipment shall be UL labeled for use as service equipment for panelboards with main service disconnect switches.
G. Branch overcurrent protective devices shall be bolt-on circuit breakers, replaceable without disturbing adjacent units and shall conform to the following:

1. Molded-case circuit breaker: UL 489, with interrupting capacity to meet available fault currents.
2. Thermal-magnetic circuit breakers: inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits.
3. Molded-case circuit-breaker features and accessories: standard frame sizes, trip ratings, and number of poles.
4. Lugs: mechanical style, sized for number, size, trip ratings, and conductor materials.
5. Application listing: appropriate for application; Type SWD for switching fluorescent lighting loads; Type HACR for heating, air-conditioning, and refrigerating equipment.

H. The Contractor shall install mounting brackets, bus connections, and necessary appurtenances required for installation of devices.

Transformers.--Transformers shall include the following features:

A. Description: factory-assembled and -tested, air-cooled units of types specified, designed for 60-Hz service.
B. Cores: grain-oriented, non-aging silicon steel.
C. Coils: continuous windings without splices, except for taps.
D. Internal coil connections: brazed or pressure type.
E. Enclosure: class complies with NEMA 250 for the environment in which installed.
F. Finishes: manufacturer's standard paint over corrosion-resistant pretreatment and primer.

General-purpose distribution and power transformers shall include the following features:

A. Listing: Comply with NEMA ST 20 and with UL 1561.
B. Cores: One leg per phase.
C. Windings: One coil per phase in primary and secondary.
D. Enclosure: Indoor, ventilated.
E. Insulation class: 185 or 220°C class for transformers 15 kVA or smaller; 220°C class for transformers larger than 15 kVA. Rated temperature rise: 150°C maximum rise above 40°C, for 220°C class insulation; 115°C maximum rise for 185°C class insulation.
F. Taps: for transformers 3 kVA and larger, full-capacity taps in high-voltage windings are 15 through 500 kVA: Six 2.5 percent taps, two above and four below rated high voltage.

Miscellaneous Lighting Fixtures.--Miscellaneous lighting fixtures shall comply with the following:

Fluorescent fixtures shall conform to UL 1598. Fluorescent lamp ballast shall conform to the following requirements:

A. Designed for type and quantity of lamps at full light output.
B. Total harmonic distortion rating: Less than 10 percent.
C. Rapid start, thermally protected, automatic resetting.
D. UL listed Class P, high power factor (95 minimum).
E. Instant start ballast.
E. Sound rating: A.

Electronic ballasts for linear lamps shall conform to the following requirements:

A. Certified ballast manufacturer certification: indicated by label.
B. Encapsulation: without voids in potting compound.
C. Parallel lamp circuits: multiple lamp ballasts connected to maintain full light output on surviving lamps if one or more lamps fail.
D. Temperatures 4°C and above starting temperature.
E. Full replacement warranty of 5 years from data of manufacture.

Ballasts for compact fluorescent lamps shall be programmed start.

Reflecting surfaces of fluorescent fixtures shall have minimum reflectance as follows:

A. White surfaces: 85 percent.
B. Specular surfaces: 83 percent.
C. Diffusing specular surfaces: 75 percent.
D. Laminated silver metallized film: 90 percent.

Lenses, diffusers, covers, and globes shall be 100 percent annealed crystal glass or virgin acrylic plastic with high resistance to yellowing and other changes due to aging, exposure to heat, and ultraviolet radiation. The minimum thickness of lens shall be 3 mm.

Exit signs.--Exit signs shall conform to UL 924. The lamps of internally lighted signs for AC operation shall be light-emitting diodes, 70,000 hours minimum rated lamp life.

The fluorescent color temperature index of lamps shall be 4100 K for cool white lamps. Fluorescent lamp life shall be rated average of 20,000 hours at 3 hours per start when used on rapid-start circuits.

Fixture support components including steel strut channel system and fittings for mounting lights shall be galvanized. Beam clamps, wall mount brackets, and channel shall be manufactured by the same manufacturer.

Finishes of fixtures shall conform to the manufacturer's standard. Paint finish shall be applied over corrosion-resistant treatment or primer, free of defects. Metallic finish shall be corrosion resistant.

Interior Lighting Fixtures.--The interior lighting fixtures shall conform the following:

A. Fixture Type E1, Exit:

1. Severe duty type, NEMA Type 4X, UL50, UL924
2. Cast aluminum or polycarbonate housing
3. Voltage: 120-V (ac).
4. Mounting: end mount.
5. Number of faces: Double-face.
6. Nominal dimensions: 330 mm X 75 mm X 200 mm.
7. Lamps: low wattage, Green LED, 25 year lamp life.
8. External finish: aluminum/gray.

B. Fixture Type E2, Exit:

1. Severe duty type, NEMA Type 4X, UL50, UL924
2. Cast aluminum or polycarbonate housing
3. Voltage: 120-V (ac).
4. Mounting: end mount.
5. Number of faces: Single-face.
6. Nominal dimensions: 330 mm X 75 mm X 200 mm.
7. Lamps: low wattage, Green LED, 25 year lamp life.
8. External finish: aluminum/gray.

C. Fixture Type E3, Exit:

1. Severe duty type, NEMA Type 4X, UL50, UL924
2. Cast aluminum or polycarbonate housing
3. Voltage: 120-V (ac).
4. Mounting: ceiling mount.
5. Number of faces: Double-face.
6. Nominal dimensions: 330 mm X 75 mm X 200 mm.

7. Lamps: low wattage, Green LED, 25 year lamp life.
8. External finish: aluminum/gray.

D. Fixture Type E4, Exit:

1. Severe duty type, NEMA Type 4X, UL50, UL924
2. Cast aluminum or polycarbonate housing
3. Voltage: 120-V (ac).
4. Mounting: back mount.
5. Number of faces: Single-face.
6. Nominal dimensions: 330 mm X 75 mm X 200 mm.
7. Lamps: low wattage, Green LED, 25 year lamp life.
8. External finish: aluminum/gray.

E. Fixture Type F1, enclosed industrial fluorescent:

1. Gasketed, enclosed, damp label
2. Voltage: 120 V (ac).
3. Mounting: ceiling or strut mounted.
4. Nominal dimensions: 1220 mm X 305 mm.
5. Lamps: two 32W, T8.
6. Ballast types and features: electronic.
7. Housing: heavy-duty steel with shatter-resistant acrylic diffuser.

F. Fixture Type F2, heavy-duty turret industrial fluorescent:

1. Voltage: 120-V (ac).
2. Mounting: strut or pendant mounted.
3. Nominal dimensions: 1220 mm X 305 mm.
4. Lamps: two 32W, T8.
5. Ballast types and features: electronic.
6. Up-light: 10 to 15 percent
7. Housing: heavy steel with die embossed reflector.
8. External finish: high gloss baked white enamel over rust inhibitor.

G. Fixture Type F3, "Blue Light":

1. Wet label
2. Voltage: 120-V (ac).
3. Mounting: wall mounted.
4. Lamps: 9W, compact fluorescent.
5. Ballast types and features: electronic.
6. Housing: copper-free aluminum.
7. Globe: glass, blue color.
8. Reflector: fiberglass-reinforced.

H. Fixture Type F4:

1. Wet label

2. Voltage: 120-V (ac).
3. Mounting: wall mounted.
4. Lamps: 9W, compact fluorescent, 2700 K color temperature.
5. Ballast types and features: electronic.
6. Housing: copper-free aluminum.
7. Globe: glass, clear color.
8. Reflector: fiberglass-reinforced.

Switchboard.--The switchboard for the irrigation system at the Operation and Maintenance Center (OMC) shall be NEMA PB 2, deadfront and metal-enclosed. The main bus shall be rated as shown on the plans and shall have a UL integrated equipment rating of 35,000 A. Switchboard shall be UL listed as service entrance equipment.

Equipment shall be fully rated. Series rated equipment will not be accepted. Devices shall be front accessible and shall be completely isolated between sections by vertical steel barriers. Sections of switchboard in front and rear shall align.

Equipment shall be provided with interconnections, instrumentation, and control wiring as shown on the plans. Switchboard enclosures shall consist of indoor NEMA 1 main and distribution sections. Service entrance shall be top feed from transformer secondary to switchboard.

Bases, frames, and channels of switchboards which come in contact with concrete shall be corrosion resistant and shall be fabricated of hot-dip galvanized steel.

Buses and Connections shall be three phases, and four wire. Buses and Connections shall include the following features:

A. Phase and Neutral Bus Material: hard drawn copper of 98 percent conductivity.
B. Ground Bus: equipped with pressure connector terminations for feeder and branch circuit ground conductors. For busway feeders extend insulated equipment grounding cable to busway ground connection and support cable at intervals in vertical run.

Overcurrent Protective Devices.--Molded-Case Circuit Breaker shall comply with NEMA AB 1, and interrupting capacity to meet available fault currents.

A. Thermal-Magnetic Circuit Breakers: Inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Magnetic trip settings shall be adjustable for circuit-breaker frame sizes 250 A and larger.

Control Power.--120 V control circuits supplied shall be provided through secondary disconnect devices from control power transformer to electrically operated devices or ground fault relays requiring external power.

Control Power Fuses.--Primary and secondary fuses shall be provided for current limiting and overload protection of transformer and also, for protection of control circuits.

Control Wiring.--Factory shall install control wiring, complete with bundling, lacing, and protection. Flexible conductors shall be provided for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

INSTALLATION

General.--Installation shall conform to the following requirements:

A. Examine elements and surfaces to receive enclosed switches for compliance with installation tolerances and other conditions affecting performance.
B. Unless otherwise indicated, devices shall be surface-mounted, with long dimensions vertical, and grounding terminal of receptacles on top. Group adjacent switches under single, multigang wall plates.
C. Proceed with installation only after unsatisfactory conditions have been corrected.
D. Comply with mounting and anchoring requirements specified in "Seismic Controls for Electrical Work" of these special provisions.
E. Mount all disconnects switches and panelboards on 6 mm minimum standoffs to prevent condensation on back side.
F. Install devices and assemblies plumb and secure.
G. Identify enclosure, field-installed conductors, and components as specified in "Electrical Identification" of these special provisions.
H. Install equipment grounding connections for switches and circuit breakers with ground continuity to main electrical ground bus.
I. Protect panels, enclosures, devices and assemblies during painting.

Panelboards.—Installation of panelboards shall conform to the following:

A. Panelboards and accessories shall be installed in conformance with NEMA PB 1.1. The top of trim shall be mounted 1880 mm above finished floor. Box shall be mounted plumb and rigid without distortion of the box.
B. Install overcurrent protective devices and controllers. Filler plates shall be installed in unused spaces.
C. Arrange conductors in gutters into groups and bundle and wrap with wire ties.
D. Make grounding connections for separately derived systems to grounding electrodes and bonding connections to metallic piping as shown on the plans and in conformance with NFPA 70.

Dry-type transformers.--Equipment shall be arranged to provide adequate spacing for access and for circulation of cooling air.

Connections.--Connections shall conform to the following:

A. Electrical connectors and terminals shall be tightened according to manufacturer's published torque-tightening values. If manufacturers torque values are not available, the Contractor shall use those specified in UL 486A and UL 486B.
B. Wiring device grounding terminal shall be connected to outlet box with bonding jumper.
C. Wiring device grounding terminal shall be connected to branch-circuit equipment grounding conductor.
D. Equipment shall be grounded in conformance with "Grounding and Bonding" of these special provisions. Connections shall be provided in conformance with "Conductors and Cables" of these special provisions.

Identification.--Identification shall conform to the following:

A. The Contractor shall identify field-installed conductors, interconnecting wiring, panelboards, safety switches, and components; provide warning signs as specified in "Electrical Identification" of these special provisions.
B. A panelboard directory shall be created to indicate installed circuit loads. Handwritten directories will not be permitted.

FIELD QUALITY CONTROL

Receptacles.--Receptacle testing shall conform to the following:

A. Wiring devices shall be tested for proper polarity and ground continuity. Each device shall be operated at least six times.
B. GFCI devices shall be tested with both local and remote fault simulations according to manufacturer's written instructions.
C. Damaged or defective components shall be replaced and retested.

Enclosed safety switches.--Enclosed safety switch testing shall conform to the following:

A. Enclosed safety switches shall be prepared for acceptance tests as follows:

    1. Test insulation resistance for each enclosed switch and components.
    2. Test continuity of each line- and load-side circuit.

B. An independent testing agency shall perform the following specified testing, after installing enclosed switches and after electrical circuitry has been energized:

    1. Procedures: perform each visual and mechanical inspection and electrical test indicated in NETA ATS, Section 7.5 for switches. Certify compliance with test parameters.
    2. Repair or replace malfunctioning units and retest.

C. The Contractor shall submit to the Engineer a written record of inspections, tests, and detailed test results in the form of a test log, upon the completion of tests.

Panelboards.--Panelboard testing shall conform to the following:

A. An Independent testing agency shall perform the field tests, inspections and prepare test reports.
B. The following field tests, and inspections shall be performed:

    1. The Contractor shall perform each electrical test and visual and mechanical inspection stated in NETA ATS, Section 7.5 for switches and Section 7.6 for molded-case circuit breakers. Certify compliance with test parameters.
    2. Malfunctioning units shall be repaired or replaced, and retested.
    3. The Contractor shall test insulation resistance for each panelboard bus, component, connecting supply, feeder, and control circuit.
    4. Continuity of each circuit shall be tested.

D. An infrared scanning of each panelboard shall be performed to measure temperature or to detect significant deviations from normal values. Test shall be completed after final

inspection, but not more than 60 days after the system is in service. Panel fronts shall be removed to access joints and connections for portable scanner. The Contractor shall provide calibration record for infrared scanner.

E. The Contractor shall submit to the Engineer a written record of inspections, tests, and detailed test results in the form of a test log, upon the completion of tests.

Dry-type transformers.--Dry-type transformers shall be tested as follows:

An independent testing agency shall perform the following field tests, inspections, and prepare test reports:

A. The following minimum inspections and tests shall be included in accordance with manufacturer's written instructions and with IEEE C57.12.91 for test methods and data correction factors.

1. Inspection: Inspect accessible components for cleanliness, mechanical and electrical integrity, and damage or deterioration. Include internal inspection through access panels and covers. Inspect bolted electrical connections for tightness according to manufacturer's published torque values or, if not available, those specified in UL 486A and UL 486B.
2. Insulation resistance: perform megohmmeter tests of primary and secondary winding to winding and winding to ground.
3. Minimum test voltage: 1000 V, (dc).
4. Minimum insulation resistance: 500 megohms.
5. Duration of each test: 10 minutes.
6. Temperature correction: correct results for test temperature deviation from 20°C standard.
7. Transformer Tap Settings: Adjust transformer taps to provide optimum voltage conditions at utilization equipment throughout normal operating cycle of facility, record primary and secondary voltages and tap settings, and submit to the Engineer with test results.

B. Test results shall be compared with specified performance or manufacturer's data. Deficiencies identified by tests shall be corrected or repaired, and retested.

C. The Contractor shall submit to the Engineer a written record of inspections, tests, and detailed test results in the form of a test log, upon the completion of tests.

Interior Lighting Fixtures.--The Contractor shall inspect each installed fixture for damage. Damaged fixtures and components shall be replaced by the Contractor. The Contractor shall provide advance notice a minimum of 2 working days to the Engineer for the dates and times of field tests. The Contractor shall provide instruments to make and record test results.

The Contractor shall conduct following tests:

A. Verify normal operation of each fixture after installation.
B. Verify normal transfer to battery source and retransfer to normal.
C. Report results in writing.

Fixtures and components that failed tests shall be repaired or replaced, and then retested.

The Contractor shall submit to the Engineer a written test report including test procedure, test results, repairs made, test date and signature of test person within 5 working days after tests are completed.

Corrosive fixtures shall be replaced during warranty period.

CLEANING

The Contractor shall internally clean panels, enclosures, devices, and device outlet boxes. The Contractor shall clean fixtures internally and externally prior to acceptance of system using methods and materials recommended by manufacturer.

The Contractor shall replace stained or improperly painted wall plates or devices. Touch-up paint scratched enclosures and doors.

MEASUREMENT

Low voltage electrical system will be measured on a lump sum basis.

PAYMENT

The contract lump sum contract price paid for low voltage electrical system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing low voltage electrical system, complete in place, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-4.__ UNINTERRUPTIBLE POWER SUPPLY

GENERAL

Uninterruptible power supply shall conform to the provisions in these special provisions.

SUMMARY

Scope.--Uninterruptible power supply (UPS) shall consists of furnishing and installing on-line reverse transfer battery inverters that automatically sense loss of normal AC supply and transfer loads to a battery supply on supply power failure, and that automatically retransfer back to normal supply when normal power is restored.

The system shall be a double conversion type with no interruption in output power, and shall be designed for electronic and HID lighting loads.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions. The following shall be submitted to the Engineer:

A. Product data: include dimensions and data on features and components for each product specified. Include wiring diagrams and elevation view of front panel showing control and indicating devices. Include data on ratings, and a detailed description of operating modes and load limitations.
B. Battery sizing calculations and line-side molded case circuit breaker size.
C. Record of field tests covering tests and commissioning efforts required by NFPA 70 and these special provisions.

D. Operation and Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods".
E. Warranties.

QUALITY ASSURANCE

UPS components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. The system and components shall conform to NFPA 70, UL 294, and 47 CFR 15, 17, and 76.

WARRANTY

A warranty for the UPS and system components shall be provided and signed by the manufacturer and installer agreeing to correct system deficiencies and replace components that fail in materials or workmanship. The warranty shall be for 15 years from the date of system in service. The Contractor warranty shall replace batteries that do not meet requirements or that fail within the warranty period.

SYSTEM COMPONENTS

The UPS shall be a factory-fabricated standard product from a single manufacturer.

Load description.--The UPS shall supply power without noise, vibration, pulsation of load, or abnormal output or visual appearance for the following loads types, in any combination and at any percentage of unit capacity:

A. Electronic equipment.
B. Fluorescent lights with magnetic ballasts.
C. Fluorescent lights with electronic ballasts.
D. HID lights with magnetic ballasts.

Operation.--The UPS normally supplies power from a single, external, normal supply source through the rectifier and inverter system to output circuits. When normal power fails, the unit shall automatically transfer from the normal source to an internal battery source. When normal power is restored, the load automatically re-transfers to the normal supply and the battery is recharged:

A. The system shall be the double conversion type, such that it shall maintain the HPS tunnel lighting system without losing the lamp arch during any transfer or retransfer operation.
B. The harmonics current reflected to the utility AC supply by the rectifier shall be no more than 10 percent of the RMS supply current.
C. The Contractor shall provide UPS as shown on the plans in the following ratings:

    1. Three-phase, 480 volt input and three phase, 480/277 volt output.
    2. Single-phase, 277-volt input and single-phase, 120-volt output.
    3. Single-phase, 208-volt input and single-phase, 120-volt output.

Inverter.--The inverter shall be a solid-state PWM type, with the following features:

A. Output voltage: automatically regulated to within plus or minus 5 percent.

B. Output frequency: automatically regulated to within plus or minus 1 Hz, from no load to full load at unit power factor over the operating range of the battery voltage.
C. Total conversion efficiency:

1. Three phase unit: 90 percent, minimum.
2. Single phase unit: 84 percent, minimum.

D. Output waveform of unit: sine-wave with maximum 5-percent total harmonic distortion throughout the battery operating-voltage range, from no load to full load.

Battery charger.--The charger shall be a solid-state, automatic, 3-charging-rate type with the following features:

A. Minimum charger efficiency: 85 percent.
B. Equalizing charge: automatically applied to battery every 90 days.
C. Low voltage disconnect to prevent over discharge of battery.

Battery.--The battery shall be a premium-sealed, lead-calcium type designed for maintenance-free operation, including no addition of water for the service life of the battery. The battery shall conform to the following requirements:

A. Operation and Maintenance Center (OMC) battery system shall be emergency power listed and sized to maintain the system voltage for 90 minutes at rated load.
B. All other Battery systems shall be sized to maintain the system voltage for 30 minutes at rated load.
C. Nominal service life: 20 years.

Instrumentation and controls.--UPS controls shall include the following minimum array:

A. Ready normal-power on light.
B. Charge light.
C. Inverter supply load light.
D. Battery voltmeter.
E. AC output voltmeter.
F. Load ammeter.
G. Test switch to simulate AC failure.
H. Meter accuracy within 2 percent or scale range.
I. Self-diagnostics/battery discharge test with user selectable battery test intervals.
J. All indicator lights shall be long-life LED type

Enclosure.--The enclosure shall be NEMA 250, Type 1 steel cabinets with hinged doors and flush tumbler lock and catch.

Output-branch circuit breakers.--Single or dual circuit breakers shall be provided as noted on the plans. Total breaker ratings shall not exceed 125 percent of unit output.

Input-main circuit breaker.--The input-main circuit breaker shall be a single molded case breaker sized per manufacturer's standard design and rated for 24,000 AIC minimum. The

Contractor shall coordinate the circuit breaker size with the electrical contractor for placement in the supply switchboard.

Dry contact out-puts shall be wired to the terminal block for future remote monitoring. Alarm signals shall indicate derangement of the UPS due to charger or inverter failure, low battery voltage, open output circuit breaker, high temperature, and load on batteries.

The UPS shall be provided a manual non-load-interrupting maintenance by-pass switch.

FINISH

The cabinet shall have a manufacturer's standard baked-enamel finish over corrosion-resistant prime treatment.

INSTALLATION

Clearance.--The UPS shall be installed to conform with required clearances in accordance with manufacturer's written instructions, but not less than one meter in front of unit.

IDENTIFICATION

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in conformance with "Electrical Identification" of these special provisions.

FIELD QUALITY CONTROL

Manufacturer's field services shall include the supervision of unit installation, connections, adjustments, and field testing by a factory-authorized service representative.

Tests: The Contractor shall notify the Engineer at least 5 days prior to testing. The Contractor shall perform tests in accordance with manufacturer's written instructions. The Contractor shall test the UPS functions, operations, and protective features. The Contractor shall adjust the UPS to ensure the operation complies with these specifications. Perform tests required by NFPA 70, Articles 700 and 701. Tests shall be performed upon completion of UPSt installation and after building circuits have been energized. The Contractor shall provide instruments to permit accurate observation of the tests. Testing shall include the following:

A. Simulate malfunctions: verify protective device operation.
B. Demonstrate low-battery-voltage shutdowns, and transfers due to normal source failure and restoration.
C. Verify emergency-supply duration.
D. Test for successful supply: operate each type of load served by the unit for this Project without symptoms of abnormal supply such as noise, vibration, or pulsation of the load or its output.
E. Verify all instrument, monitoring, and control functions

The Contractor shall correct deficiencies identified by tests and observations and retest.

Test report: provide inspection and test report signed by factory-authorized service representative.

CLEANING

On completion of installation, inspect unit components. Remove paint splatters and other spots, dirt, and debris. Touch up scratches and abrasions in finish to match original finish. Clean unit internally using methods and materials recommended by manufacturer.

DEMONSTRATION AND TRAINING

Training.--A factory-authorized service representative shall perform the demonstration and train the Department's maintenance personnel to adjust, operate, and maintain UPS equipment, as follows:

A. Train Department's maintenance personnel on procedures and schedules for troubleshooting, servicing, and maintaining equipment.
B. Demonstrate methods of determining optimum adjustment of components and settings for system controls.
C. Review data in maintenance manuals.
D. Schedule training with the Department with at least seven days advance notice.
E. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

COMMISSIONING

Battery equalization.--The Contractor shall manually equalize charging of battery cells in accordance manufacturer's written instructions. Individual cell voltages shall be recorded and submitted to the Engineer.

MEASUREMENT

Uninterruptible power supply will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for uninterruptible power supply shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all work involved in furnishing and installing uninterruptible power supply, complete in place, including testing, and demonstration and training, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-4.__ SECONDARY UNIT SUBSTATIONS

GENERAL

Secondary unit substations shall consist of furnishing, installing, and testing, including all wire, cable and mounting in conformance with the provisions in Section 86, "Signals, Lighting and Electrical Systems" of the Standard Specifications and these Special Provisions. Secondary unit substations shall also include the installation of conduit and raceway in conformance with "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--Secondary unit substations shall conform to these special provisions and shall consist of:

A. Medium-voltage dry-type transformer
B. 480-volt secondary distribution switchboards with draw-out main air circuit breaker and compartmentalized feeder breakers.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and the requirements specified herein:

A. **Working drawings:** The Contractor shall submit working drawings including a coordinated unit substation set of plans, elevations, and details showing all section alignments and field connections between sections.
B. **Coordination drawings:** The Contractor shall submit unit substation dimensioned plans, elevations, sections, including required clearances and service space around equipment for each substation section. The drawings shall show switchgear layout and relationships between components and adjacent structural and mechanical elements. The drawings shall also show support locations, type of support, and weight on each support. The drawings shall identify field measurements.
C. **Manufacturer seismic qualification certification:** The Contractor shall submit certification that unit substation sections, accessories, and components will withstand seismic forces as defined in "Seismic Controls for Electrical Work" of these special provisions. Submittal shall include the following:

1. Basis for certification: The Contractor shall indicate whether withstand certification is based on actual test of assembled components or on calculation. The term "withstand" means the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.
2. Dimensioned outline drawings of equipment unit: The Contractor shall identify center of gravity and locate and describe mounting and anchorage provisions.
3. The Contractor shall submit a detailed description of equipment anchorage devices on which the certification is based and their installation requirements.

D. **Design calculations:** The Contractor shall submit design calculations signed and sealed by a qualified professional engineer. Submittal shall include calculations for requirements for seismic anchorage restraints.
E. **Equipment pads:** The Contractor shall provide coordinated equipment pad layout and attachment detail working drawings.
E. Contractor shall submit working drawings and data sheets on all unit substation sections and components including dimensions and manufacturer's technical data on features, performance, electrical characteristics, ratings, and finishes.

Medium-Voltage Transformer submittal shall include the following:

A. Product data: Submittal shall include rated nameplate data, capacities, weights, dimensions, minimum clearances, installed devices and features, location of each field connection, and performance for each type and size of transformer indicated.
B. Working drawings:

1. Outline and section plans showing components and arrangement
2. Primary and secondary bus termination details
3. Anchorage details.
4. Diagram power and signal wiring.

C. Factory test reports.

Secondary Switchboard submittal shall include the following:

A. Product data: Submitall shall include rated nameplate data, capacities, weights, dimensions, minimum clearances, installed devices and features, location of each field connection, and performance for each type and size of switchboard indicated.

B. Working drawings:

1. Outline and section plans showing components and arrangement
2. Primary bus termination details
3. Bus configuration, current, and voltage ratings.
4. Short-circuit current rating of switchboards and overcurrent protective devices.
5. Unit substation alignment and connection details.
6. Coordinated transformer bus connections on line side.
7. Descriptive documentation of optional barriers specified for electrical insulation and isolation.
8. Mimic-bus diagram.
9. Features, characteristics, ratings, and factory settings of individual overcurrent protective devices and auxiliary components.
10. Wiring Diagrams including power, signal, and control wiring.

C. Factory test reports.

Field Quality-Control for Unit Substation Sections and Components submittal shall include the following:

A. Field Test Data:

1. Test procedures used.
2. Test results that comply with requirements.
3. Results of failed tests and corrective action taken to achieve test results that comply with requirements.

B. Field Service Reports.

1. Test procedures used.
2. Equipment and components inspected.
3. Inspection items.
4. Inspection results and remedies taken.

C. Operation and maintenance manuals for unit substation sections and components.

D. Warranty for unit substation and components.

QUALITY ASSURANCE

Electrical components, devices, and accessories shall be listed and labeled in conformance with NFPA 70, Article 100.

Electrical components, devices, and accessories shall comply with NECA's "Standard of Installation” and shall conform to ANSI C80.1.

Secondary unit substations shall conform to the following:

A. NFPA 70
B. IEEE C37.121.
C. UL-1008
D. ANSI/IEEE C37.20.3.
E. ANSI/IEEE C37.20.4
F. ANSI/IEEE C37.22.
G. IEEE C37.121.
H. NEMA SG5.
I. NEMA SG6.
J. ANSI C57.12.10,
K. ANSI C57.12.50,
L. ANSI C57.12.51,
M. IEEE C57.12.70,
N. IEEE C57.12.80.

PROJECT CONDITIONS

Service conditions shall conform to IEEE C37.121, usual service conditions except for the following:

A. Exposure to seismic shock or to abnormal vibration, shock, or tilting.
B. Unusual space limitations.

Installation pathway: The Contractor shall coordinate with structural sequence to provide pathway for moving substation sections into place.

Product selection for restricted space: plans indicate all dimensions for unit substation sections, including clearances between switchgear and adjacent surfaces and other items. The Contractor shall select products to conform to indicated maximum dimensions.

DELIVERY, STORAGE AND HANDLING

Factory preparation:

A. Prepare equipment for shipment. Provide suitable crating, blocking, and supports so equipment will withstand expected domestic shipping and handling shocks and vibration. Weatherproof equipment for shipment. Close connection openings to prevent entrance of foreign material during shipment and storage.

Equipment shall be handled and stored in conformance with manufacturer's instructions. One copy of these instructions shall be included with the equipment at time of shipment.

Secondary unit substations shall be delivered in sections or lengths that can be moved past obstructions in delivery path. Sections shall be stored indoors in clean dry space with uniform temperature to prevent condensation. Sections shall be protected from exposure to dirt, fumes, water, corrosive substances, and physical damage. Switchboards shall be handled in conformance with NEMA PB 2.1 and NECA 400.

OPERATION AND MAINTENANCE MANUALS

The Contractor shall provide ten copies of the equipment operation and maintenance manuals. Operation and maintenance manuals shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MANUFACTURERS

The manufacturer shall be ISO 9000, 9001 or 9002 certified for the secondary unit substation equipment specified herein.

The Contractor shall obtain all secondary unit substations and associated components through one manufacturing source. The source manufacturer shall be responsible for the complete unit substation design; and shall, at a minimum, be the manufacturer of the secondary switchgear sections:

A. All working drawings shall conform to industry standard (IEEE) drafting and nomenclature standards.
B. All working drawings shall be reviewed and signed by a qualified staff engineer.

The manufacturer of the medium voltage transfer switchgear assembly shall be a major medium-voltage interrupter switch manufacturer and shall have a qualified in-house engineering staff for the switch assembly and controls system design.

MANUFACTURED UNITS

Proposed products with dimensions larger than shown on plans shall not be acceptable. Size of the secondary unit substations shall meet code requirements for the work space and maintenance access clearances.

Four secondary unit substations: all substations shall be of the single unit type except for the south equipment chamber, where space restrictions do not provide adequate clearance space for a single unit.

TRANSFORMER

The Contractor shall provide dry-type, 2-winding transformers in conformance with NEMA ST 20, IEEE C57.12.01, ANSI C57.12.50 or ANSI C57.12.51. Transformers shall be UL 1562 listed and labeled.

A. The OMC substation shall be indoor, ventilated, vacuum-pressure impregnated and with insulation system rated at 220°C with a 150°C average winding temperature rise above a maximum ambient temperature of 40°C.
B. All equipment chamber substations shall be indoor, ventilated, vacuum-pressure impregnated and with insulation system rated at 220°C with an 115°C average winding temperature rise above a maximum ambient temperature of 40°C, and fans.

Insulation materials shall conform to IEEE C57.12.01, and shall be rated at 220°C.

High-voltage basic impulse level: 95 kV, low-voltage basic impulse level: 10 kV.

Full-capacity voltage taps: four nominal 2.5 percent taps, 2 above and 2 below rated primary voltage.

Cooling system:

A. OMC, 150°C: Class AA, self-cooled.
B. Equipment chambers, 115°C: Class AA/FA, self-cooled, and with forced-air-cooled rating, complying with IEEE C57.12.01.
C. Automatic forced-air cooling system controls, including thermal sensors, fans, control wiring, temperature controller with test switch, source power panel with current-limiting fuses, indicating lights, alarm, and alarm silencing relay.

Sound level shall not exceed sound levels listed in NEMA TR 1, without fans operating.

Impedance: nominal 5.75 percent.

Transformer primary bus connections: See "Primary Switchgear" of this special provision section.

Secondary switchboard bus connections:

A. OMC substation secondary connection shall be top entry and include an air terminal compartment with removable door. The Contractor shall provide tin-plated copper bar for incoming line termination, predrilled to accept terminals for indicated conductors.
B. All equipment chamber secondary connections shall be bussed with transition bus section or bus transition internal to transformer enclosure, with copper bus connection pattern to match switchboard. The Contractor shall provide flex bus connections to switchboard buses.

Factory tests: The Contractor shall perform design and routine tests in conformance to standards specified for components. Transformer tests shall be conducted in conformance to ANSI C57.12.50 ANSI C57.12.51 IEEE C57.12.91, as applicable.

The Contractor shall perform the following factory-certified tests on each transformer:

A. Resistance measurements of all windings on rated-voltage connection and on tap extreme connections.
B. Ratios on rated-voltage connection and on tap extreme connections.
C. Polarity and phase relation on rated-voltage connection.
D. No-load loss at rated voltage on rated-voltage connection.
E. Excitation current at rated voltage on rated-voltage connection.
F. Impedance and load loss at rated current on rated-voltage connection and on tap extreme connections.
G. Applied potential.
H. Induced potential.
I. Temperature test: if transformer is supplied with auxiliary cooling equipment to provide more than one rating, test shall be performed at lowest kilovolt-ampere Class AA rating and highest kilovolt-ampere Class AA/FA rating. Temperature test shall not required if record of temperature test on an essentially duplicate unit is available.

SECONDARY SWITCHBOARD

The following shall be manufactured units:

A. Front- and rear-accessible switchboard: front or rear aligned as noted, with features as follows:

    1. Service rated and listed.

2. Main devices: drawout mounted.
3. Branch devices: fixed and individually compartmented mounted.

B. Nominal system voltage: 480Y/277 V.
C. Main-bus continuous: as shown on plans.
D. Fabricate and test switchboards in conformance to IEEE 344 to withstand seismic forces defined in "Seismic Controls for Electrical Work" of these special provisions.
E. Enclosure: Steel, NEMA 250, Type 1.
F. Enclosure finish for indoor units: factory-applied finish in manufacturer's standard gray finish over a rust-inhibiting primer on treated metal surface.
G. Barriers: between adjacent switchboard sections.
H. Insulation and isolation for main bus of main section and main and vertical buses of feeder sections.
I. Bus transition sections: matched and aligned with basic switchboard.
J. Removable, hinged rear doors and compartment covers: secured by captive thumb screws, for access to rear interior of switchboard.
K. Hinged front panels: allow access to circuit breaker, metering, accessory, and blank compartments.
L. Buses and connections: three phase, four wire, unless otherwise indicated:

1. Phase- and neutral-bus material: hard-drawn copper of 98 percent conductivity with feeder circuit-breaker line connections. Copper shall be used for feeder circuit-breaker line connections.
2. Load terminals: insulated, rigidly braced, silver-plated, copper runback bus extensions equipped with pressure connectors for outgoing circuit conductors. The Contractor shall provide load terminals for future circuit-breaker positions at full ampere rating of circuit-breaker position.
3. Ground bus: 6.4-by-51-mm minimum-size, hard-drawn copper of 98 percent conductivity, equipped with pressure connectors for feeder and branch-circuit ground conductors.
4. Contact surfaces of buses: silver plated.
5. Main phase buses, neutral buses, and equipment ground buses: uniform capacity for entire length of switchboard's main and distribution sections. The Contractor shall provide for future extensions from both ends.
6. Isolation barrier access provisions: permit checking of bus-bolt tightness.
7. Neutral buses: 50 percent of the ampacity of phase buses, unless otherwise indicated, equipped with pressure connectors for outgoing circuit neutral cables.

M. Future devices: The Contractor shall equip compartments with mounting brackets, supports, bus connections, and appurtenances at full rating of circuit-breaker compartment.
N. Bus-bar insulation: factory-applied, flame-retardant, tape wrapping of individual bus bars or flame-retardant, spray-applied insulation. Minimum insulation temperature rating: 105°C.

Transient Voltage Suppression Devices

A. IEEE C62.41, integrally mounted, plug-in-style, solid-state, parallel-connected, sine-wave tracking suppression and filtering modules:

1. Direct connected to bus.
2. Integral fuse protection and disconnect switch.

B. Minimum single-impulse current rating shall be as follows:

1. Surge current per phase: 250,000 A
2. Line to neutral: 125,000 A.
3. Line to ground: 125,000 A.
4. Neutral to ground: 125,000 A.

C. Protection modes shall be as follows:

1. Line to neutral.
2. Line to ground.
3. Neutral to ground.

D. EMI/RFI noise attenuation using 50-ohm insertion loss test: 55 dB at 100 kHz.
E. Maximum UL 1449 clamping levels shall not exceed 800 V, line to neutral and line to ground on 277/480 V systems.
F. Withstand capabilities: 3000 Category C surges with less than 5 percent change in clamping voltage.
G. Accessories:

1. Form-C contacts, one normally open and one normally closed, for remote monitoring of system operation. Contacts shall reverse position on failure of any surge diversion module.
2. Audible alarm shall be activated on failure of any surge diversion module.
3. Six-digit transient-counter shall be set to total transient surges that deviate from the sine-wave envelope by more than 125 V.

Main Circuit Breaker

A. Description: comply with IEEE C37.13.
B. Ratings: as indicated for continuous, interrupting, and short-time current ratings for each circuit breaker; voltage and frequency ratings same as switchgear.
C. Operating mechanism: mechanically and electrically trip-free, stored-energy operating mechanism with the following features:

1. Normal closing speed: independent of both control and operator.
2. Slow closing speed: optional with operator for inspection and adjustment.
3. Stored-energy mechanism: electrically charged, with optional manual charging.
4. Operation counter.

D. Trip devices: solid-state, overcurrent trip-device system shall consist of one or two current transformers or sensors per phase, a release mechanism, and the following features:

1. Functions: long-time-delay, short-time-delay, and instantaneous-trip functions, independent of each other in both action and adjustment.
2. Field-adjustable, time-current characteristics.

3. Current adjustability: dial settings and rating plugs on trip units or sensors on circuit breakers, or a combination of these methods.
4. Three bands, minimum, for long-time- and short-time-delay functions; marked "minimum," "intermediate," and "maximum."
5. Pickup points: five minimum, for long-time- and short-time-trip functions. Equip short-time-trip function for switchable I2t operation.
6. Pickup points: five minimum with "off", for instantaneous-trip functions.
7. Ground-fault protection with at least three short-time-delay settings and three trip-time-delay bands; adjustable current pickup. The Contractor shall arrange to provide protection for three-wire circuit or system, or four-wire circuit or system, where shown on the plans.
8. Trip indication: labeled, battery-powered lights or mechanical targets on trip device to indicate type of fault.

E. Auxiliary contacts shall be for interlocking or remote indication of circuit-breaker position, with spare auxiliary switches and other auxiliary switches required for normal circuit-breaker operation. Quantity shall be provided as indicated. Each shall consist of two Type "a" and two Type "b" stages (contacts) wired through secondary disconnect devices to a terminal block in stationary housing.

F. Drawout features shall include a circuit-breaker mounting assembly equipped with a racking mechanism to position circuit breaker and hold it rigidly in connected, test, and disconnected positions and shall include the following features:

1. Interlocks: prevent movement of circuit breaker to or from connected position when it is closed, and prevent closure of circuit breaker unless it is in connected, test, or disconnected position.
2. Circuit-breaker positioning: an open circuit breaker may be racked to or from connected, test, and disconnected positions only with the associated compartment door closed unless live parts are covered by a full dead-front shield. An open circuit breaker may be manually withdrawn to a position for removal from the structure with the door open. Status for connection devices for different positions includes the following:
3. Test position: primary disconnect devices disengaged, and secondary disconnect devices and ground contact engaged.
4. Disconnected position: primary and secondary devices and ground contact disengaged.

G. Arc chutes: readily removable from associated circuit breaker when it is in disconnected position, and arranged to permit inspection of contacts without removing circuit breaker from switchgear.

H. Padlocking provisions: for installing at least three padlocks on each circuit breaker to secure its enclosure and prevent movement of drawout mechanism.

I. Electric close button: one for each electrically operated circuit breaker.

J. LED indicating lights: to indicate circuit breaker is open or closed, for main and bus tie circuit breakers interlocked either with each other or with external devices.

Distribution Molded-Case Circuit Breakers

Shall conform to NEMA AB 3, with interrupting capacity to meet available fault currents:

A. Compartmentally mounted.
B. Thermal-magnetic circuit breakers: inverse time-current element for low-level overloads, and instantaneous magnetic trip element for short circuits. Adjustable magnetic trip setting for circuit-breaker frame sizes 250 A and larger.
C. Electronic trip-unit circuit breakers shall have RMS sensing, field-replaceable rating plug, and the following field-adjustable settings:

   1. Instantaneous trip.
   2. Long- and short-time pickup levels.
   3. Long- and short-time time adjustments.
   4. Ground-fault pickup level, time delay, and I2t response.

D. Lugs: Compression style, suitable for number, size, trip ratings, and conductor material.

Instrumentation

A. Instrument transformers shall conform to NEMA EI 21.1, IEEE C57.13, and shall include following:

   1. Potential transformers: secondary voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.
   2. Current transformers: ratios shall be as indicated with accuracy class and burden suitable for connected relays, meters, and instruments.
   3. Control-power transformers: dry type, mounted in separate compartments for units larger than 3 kV.
   4. Provide 2-percent accuracy, 3-phase, 4–20 mA current transducer for secondary main bus, with output wired to field terminal block.

B. Multifunction digital-metering monitor: microprocessor-based unit suitable for three- or four-wire systems and shall include the following features:

   1. Switch-selectable digital display of the following values with maximum accuracy tolerances as indicated:
   2. Phase currents, each phase: plus or minus 1 percent.
   3. Phase-to-phase voltages, three phase: plus or minus 1 percent.
   4. Phase-to-neutral voltages, three phase: plus or minus 1 percent.
   5. Megawatts: plus or minus 2 percent.
   6. Megavars: plus or minus 2 percent.
   7. Power factor: plus or minus 2 percent.
   8. Frequency: plus or minus 0.5 percent.
   9. Megawatt demand: plus or minus 2 percent; demand interval programmable from 5 to 60 minutes.
   10. Accumulated energy, megawatt hours: plus or minus 2 percent. Accumulated values unaffected by power outages up to 72 hours.
   11. Mounting: display and control unit flush or semiflush mounted in instrument compartment door.

Control Power

A. Control circuits: 120 V, supplied through secondary disconnecting devices from control-power transformer.

B. Control-power fuses: primary and secondary fuses for current-limiting and overload protection of transformer and fuses for protection of control circuits.
C. Control wiring: factory installed, with bundling, lacing, and protection included. Provide flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.

Accessory Components and Features

A. Accessory set: The Contractor shall furnish tools and miscellaneous items required for circuit-breaker and switchgear test, inspection, maintenance, and operation.

1. Racking handle to manually move circuit breaker between connected and disconnected positions.
2. Portable test set for testing all functions of circuit-breaker, solid-state trip devices without removal from switchgear.

B. Circuit-breaker removal apparatus: portable, floor-supported, roller-base, elevating carriage shall be arranged for moving circuit breakers in and out of compartments.
C. The Contractor shall furnish accessory set including tools and miscellaneous items required for overcurrent protective device test, inspection, maintenance, and operation.

Factory Testing

Standard factory tests shall be performed on the equipment under this section. All tests shall conform to the latest version of ANSI and NEMA standards. The manufacturer shall provide 3 certified copies of factory test reports.

FACTORY FINISH

Prior to assembly, the Contractor shall thoroughly clean and phosphatize all enclosing steel. The Contractor shall electrostatically apply a powder coating, then fused on by baking in an oven. The coating shall have a thickness of not less than 0.038-mm (1.5 mils). The finish shall have the following properties:

A. Impact resistance (ASTM D-2794): 60 direct/60 indirect
B. Pencil hardness (ASTM D-3363): H
C. Flexibility (ASTM D-522): Pass 4 mm mandrel
D. Salt spray (ASTM B117-85 [20]): 600 hours
E. Color: ANSI 61 gray

IDENTIFICATION

A. Substation nameplates: The Contractor shall label substation and switchboard compartments to conform to "Electrical Identification" of these special provisions.
B. Mimic bus: Continuously integrated mimic bus factory shall be applied to front of switchboard. The Contractor shall arrange in single-line diagram format, using symbols and letter designations consistent with final mimic-bus diagram. The Contractor shall coordinate mimic-bus segments with devices in switchboard sections to which they are applied. The Contractor shall produce a concise visual presentation of principal switchboard components and connections:

1. Mimic bus: continuous mimic bus shall be applied to front of switchgear, arranged in single-line diagram format, using symbols and lettered designations consistent with approved final mimic-bus diagram.
2. Mimic-bus segments shall be coordinated with devices in switchgear sections to which applied, to produce a concise visual presentation of principal switchgear components and connections.
3. Medium: painted graphics, as approved.
4. Color: contrasting with factory-finish background; selected by Engineer.

FIELD EXAMINATION

The Contractor shall examine areas and conditions for compliance with requirements for secondary unit substations.

The Contractor shall examine roughing-in of conduits and grounding systems to verify the following:

A. Wiring entries comply with layout requirements.
B. Entries are within conduit-entry tolerances specified by manufacturer and no feeders will have to cross section barriers to reach load or line lugs.

The Contractor shall examine walls, floors, roofs, and concrete bases for suitable mounting conditions where transformers will be installed.

The Contractor shall verify that ground connections are in place and that requirements in "Grounding and Bonding" of these special provisions have been met. Maximum ground resistance shall be 5 ohms at location of transformer.

The Contractor shall proceed with installation only after unsatisfactory conditions have been corrected.

INSTALLATION

The unit substation assembly and switching components shall be certified to conform to applicable seismic requirements of the California Building Code (CBC) through zone 4 application. Guidelines for the installation consistent with these requirements shall be provided by the switchgear manufacturer and shall be based upon testing of representative equipment. The test response spectrum shall be based upon a 5 percent minimum damping factor, CBC: a peak of 2.15g's, and a ZPA of 0.86 g's applied at the base of the equipment. The tests shall fully envelope this response spectrum for all equipment natural frequencies up to at least 35 Hz.

The Contractor shall construct concrete bases to conform to structural plans, with dimensions adjusted for the actual equipment provided, but not less than 100 mm larger in both directions than supported unit and 100 mm high.

The Contractor shall anchor each section to concrete bases to conform to manufacturer's written instructions, seismic codes at project, and requirements in "Seismic Controls for Electrical Work" of these special provisions.

The Contractor shall install all unit substation equipment in conformance with the manufacturer's recommendations and the plans. All necessary hardware to secure the assembly in place shall be provided by the Contractor. The Contractor shall make all connections between the unit substation sections to conform to the manufacturer's instructions.

The Contractor shall install epoxy-coated anchor bolts, for supported equipment, that extend through concrete base and anchor into structural concrete floor.

The Contractor shall maintain minimum clearances and workspace at equipment in conformance with manufacturer's written instructions and NFPA 70.

The Contractor shall identify field-installed conductors, interconnecting wiring, and components and shall provide warning signs in conformance with "Electrical Identification" of these special provisions.

The Contractor shall assemble close-coupled equipment to conform to the manufacturer's instructions and utilizing materials provided by manufacturers of the primary and secondary switchgear.

The Contractor shall ground equipment to conform to "Grounding and Bonding" of these special provisions.

The Contractor shall connect wiring to conform to "Conductors and Cables" of these special provisions.

FIELD QUALITY CONTROL

Contractor shall prepare for acceptance tests as follows:

A. Test insulation resistance for each substation bus, component, connecting supply, feeder, and control circuit.
B. Test continuity of each circuit.

Manufacturer's field service: the Contractor shall engage a factory-authorized service representative to inspect field-assembled components and equipment installation, including connections, and to assist in field testing. The Contractor shall report results in writing:

A. The manufacturer's representative(s) shall be knowledgeable each section of the secondary unit substations.
B. The manufacturer's representative shall provide technical direction and assistance to the Contractor in general assembly of the equipment, connections and adjustments, and testing of the assembly and components contained therein.
C. The manufacturer's representative shall provide three copies of a written report on the installation and operational testing of the equipment per the manufacturer's written instructions. The manufacturer's representative shall list inspections and tests conducted and all results, including any problems found and how they were rectified. The manufacturer's representative shall certify equipment is ready for acceptance testing.

Testing agency: The Contractor shall engage a qualified testing and inspecting agency to perform the following field tests and inspections and prepare test reports:

A. Testing agency and testing technician shall be qualified in conformance to "Systems Studies and Field Testing" of these special provisions.
B. After installing substation but before primary is energized, the testing agency shall verify that grounding system at substation is tested at specified value or less.
C. After installing substation and after electrical circuitry has been energized, the testing agency shall test for compliance with requirements.
D. The testing agency shall perform visual and mechanical inspection and electrical test stated in NETA ATS. Certify conformace to test parameters.
E. The testing agency shall test switches/ATS in conformance with NETA 7.5.1.2 and 7.22.3.
F. The testing agency shall test transformer in conformance with NETA 7.2.1.

G. The testing agency shall test secondary switchboard in conformance with NETA ATS, Sections 7.1, 7.6, 7.9, 7.10, 7.11, and 7.14 as appropriate
H. The testing agency shall set field-adjustable switches and circuit-breaker trip ranges.
I. The testing agency shall test and adjust controls and safeties.
J. The testing agency shall perform the following infrared scan tests and inspections and prepare reports:

1. Initial infrared scanning: after final inspection of the contract, but not more than 60 days after acceptance of contract, the testing agency shall perform an infrared scan of each switchboard. The testing agency shall remove front and rear panels so joints and connections are accessible to portable scanner.
2. Follow-up infrared scanning: The testing agency shall perform an additional follow-up infrared scan of each switchboard 11 months after date of substantial completion.
3. The testing agency shall use an infrared scanning device designed to measure temperature or to detect significant deviations from normal values. The testing agency shall provide calibration record for device.
4. The testing agency shall prepare a certified report that identifies switchboards included and that describes scanning results. The testing agency shall include notation of deficiencies detected, remedial action taken, and observations after remedial action.

The Contractor shall remove and replace malfunctioning units and components and retest as specified above.

Test reports: The Contractor shall prepare written reports to record the following:

A. Test procedures used.
B. Test results that comply with requirements.
C. Test results that do not comply with requirements and corrective actions taken to achieve compliance with requirements.
D. The Contractor shall provide three copies of the test report.

MANUFACTURER'S CERTIFICATION

A qualified factory-trained manufacturer's representative(s) shall certify in writing that the equipment has been installed, adjusted and tested in accordance with the manufacturer's recommendations. The Contractor shall provide three (3) copies of the manufacturer's representative's certification.

COMMISSIONING

Voltage monitoring and adjusting: The Contractor shall perform the following voltage monitoring as a part of the overall tunnel systems commissioning, after all system components have been tested and accepted:

A. During a full load test, with all control system allowable fans and tunnel lights on, the Contractor shall record for 10 minutes, the three-phase voltage at secondary terminals of each transformer. The Contractor shall use voltmeters with calibration traceable to National Institute of Science and Technology standards and with a chart speed of not less than 25 mm per hour. Voltage unbalance greater than one percent between phases, or deviation of any phase voltage from nominal value by more than plus or minus 5 percent during test period, is unacceptable.

B. Corrective actions: if test results are unacceptable, the Contractor shall perform the following corrective actions, as appropriate:

   1. Adjust transformer taps.

C. Retests: after corrective actions have been performed, the Contractor shall repeat monitoring until satisfactory results are obtained.
D. Report: The Contractor shall prepare a written report covering monitoring and corrective actions performed.

CLEANING

On completion of installation, The Contractor shall inspect interior and exterior of secondary unit substations. The Contractor shall remove paint splatters and other spots. The Contractor shall vacuum dirt and debris and shall not use compressed air to assist in cleaning. The Contractor shall repair exposed surfaces to match original finish.

DEMONSTRATION AND TRAINING

The Contractor shall engage a factory-authorized service representative to train Department's maintenance personnel to adjust, operate, and maintain secondary unit substations, switching controls, overcurrent protective devices, instrumentation, and accessories. The Contractor shall provide up to 2 training classes of 4 hours each, including instruction materials.

MEASUREMENT AND PAYMENT

The lump sum contract price paid for secondary unit substations shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for performing all the work involved in installing substations, complete in place, as shown on the plans, as specified in these special provisions, and as directed by the Engineer.

10-4.__ MEDIUM VOLTAGE SERVICE SWITCHGEAR

GENERAL

SUMMARY

Scope.--This work shall consist of furnishing and installing medium voltage service switchgear in conformance to the detail shown on the plans and to the requirements in these special provisions. Medium voltage service switchgear shall include metal-clad, circuit-breaker switchgear and PG&E meter cabinet with the following components:

A. PG&E approved 12.47 kV meter section: Section 400 of the Electric Utility Service Equipment Requirements Committee (EUSERC) book.
B. Copper bus, silver-plated at connection points.
C. Surge arresters.
D. Mimic bus.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and the requirements specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the medium voltage service switchgear as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Rated capacities, operating characteristics, furnished specialties, and accessories for individual circuit breakers.
B. Time-current characteristic curves for overcurrent protective devices, including circuit-breaker relay trip devices.

Working drawings.--Working drawings for each type of switchgear shall include the following:

A. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment.
B. Method of field assembly and location and size of each field connection.
C. Tabulation of installed devices with features and ratings.
D. Outline and general arrangement drawing showing dimensions, shipping sections, and weights of each assembled section.
E. Drawing of cable termination compartments showing locations for conduits and indicating space available for cable terminations.
F. Floor plan drawing showing locations for anchor bolts and leveling channels.
G. Current ratings of buses.
H. Short-time and short-circuit ratings of switchgear assembly.
I. Nameplate legends.
J. Mimic-bus diagram.
K. Utility company's metering provisions with indication of approval by utility company.

Design calculations.--Design calculations shall be signed by an engineer who is registered as an Electrical Engineer in the State of California.

Wiring diagrams.--Wiring diagrams for each type of switchgear shall include the following:

A. Power, signal, and control wiring.
B. Three-line diagrams of current and future secondary circuits showing device terminal numbers and internal diagrams.
C. Schematic control diagrams.
D. Diagrams showing connections of component devices and equipment.
E. Schematic diagrams showing connections to remote devices including Supervisory Control and Data Aquisition (SCADA) remote terminal unit.

Coordination drawings.--The Contractor shall submit floor plans showing dimensioned layout, required working clearances, and required area above and around switchgear where pipes and ducts will not be permitted. Coordination drawings shall also show the switchgear layout

and relationships between components and adjacent structural and mechanical elements, support locations, type of support, and weight on each support.

Manufacturer seismic qualification certification.--The Contractor shall submit certification that switchgear, accessories, and components will withstand seismic forces as specified in "Seismic Controls for Electrical Work" of these special provisions. The certification shall include the following:

A. Basis for certification shall indicate whether withstand certification is based on actual test of assembled components or on calculation. The term "withstand" means "the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event."
B. Dimensioned outline drawings of equipment unit shall identify center of gravity and locate and describe mounting and anchorage provisions.
C. Describe in detail of equipment anchorage devices on which the certification is based and their installation requirements.

Reports.--Reports shall include source quality control test reports and field quality control test reports.

Operation and maintenance data.--The Contractor shall include switchgear and switchgear components to emergency, operation, and maintenance manuals. The Contractor shall include the following operation and maintenance data:

A. Manufacturer's written instructions for testing and adjusting overcurrent protective devices.
B. Time-current curves, including selectable ranges for each type of overcurrent protective device.

QUALITY ASSURANCE

Testing agency qualifications and testing agency's field supervisor shall conform to "Systems Studies and Field Testing" of these special provisions.

Source limitations.--The Contractor shall obtain switchgear through the same manufacturer as the secondary unit substations.

Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100.

Medium voltage metering cabinet shall comply with IEEE C2 and Section 400 of the Electric Utility Service Equipment Requirements Committee (EUSERC) book.

DELIVERY, STORAGE, AND HANDLING

Switchgear shall be delivered in sections of lengths that can be transported through doors and openings. Switchgear shall be stored indoors in clean dry space with uniform temperature to prevent condensation. Switchgear shall be protected from exposure to dirt, fumes, water, corrosive substances, and physical damage.

Loose packing and flammable materials shall be removed from inside switchgear. Electric heating (250 W per section) shall be installed to prevent condensation.

PROJECT CONDITIONS

Environmental limitations.--Equipment shall be capable of operating continuous ly at indicated ampere ratings for the following conditions:

A. Ambient temperature not exceeding 50°C.
B. Altitude is less than 100 meters above sea level.

Installation pathway.--The Contractor shall coordinate with structural sequence to provide pathway for moving switchgear into place.

Product selection for restricted space.--Switchgear shall conform to the dimensions and spaces as shown on the plans.

COORDINATION

Prior to start of fabrication the manufacturer shall submit 3 sets of switchgear drawings to PG&E for review and approval.

The Contractor shall coordinate layout and installation of switchgear and components with other construction including conduit, piping, equipment, ventilation ducts, and adjacent surfaces. The Contractor shall maintain required clearances for workspace and equipment access doors and panels. The Contractor shall coordinate size and location of concrete bases.

TOOLS

The Contractor shall furnish the following operation tools:

A. Fuse-handling tool.
B. Extension rails, lifting device, transport or dockable dolly or mobile lift, and all other items necessary to remove circuit breaker from housing and transport to remote location.
C. Racking handle to move circuit breaker manually between connected and disconnected positions, and a secondary test coupler to permit testing of circuit breaker without removal from switchgear.

MANUFACTURED UNITS

Switchgear shall be factory assembled and tested, and in conformance with IEEE C37.20.1.

Switchgear shall be capable for application in 3-phase, 60-Hz, solidly grounded-neutral system.

System voltage shall be 12.47 kV nominal; 15 kV maximum.

METAL-CLAD, CIRCUIT-BREAKER SWITCHGEAR

Switchgear shall comply with IEEE C37.20.3. Nominal interrupting-capacity class shall be 250 MVA.

Switchgear ratings shall comply with IEEE C37.04. Main-bus rating shall be as shown on plans.

Circuit breakers shall be three-pole, single-throw, electrically operated, drawout-mounting units using three individual, vacuum-sealed interrupter modules and including the following features:

A. Switchgear shall be designed to operate at rated voltage to interrupt fault current within its rating within five cycles of trip initiation. For systems with X/R ratio of 17 or less,

transient voltage during interruption shall not exceed twice the rated line-to-ground voltage of the system.

B. Contact-wear indicator shall be accessible to field maintenance personnel.
C. Minimum of six Type A and six Type B contacts shall be provided.
D. Circuit breakers shall be interchangeable with vacuum circuit breakers of same current and interrupting ratings.
E. Current rating of main circuit breaker shall be as shown on plans.
F. Operating mechanism shall be electrically charged, mechanically and electrically trip-free, stored-energy operated:

    1. Closing speed of moving contacts to be independent of both control and operator.
    2. Design mechanism to permit manual charging and slow closing of contacts for inspection or adjustment.
    3. Provide shunt trip capability independent of overcurrent trip.

The Contractor shall provide test accessories relay and meter test plugs.

The Contractor shall provide grounding and testing device for phasing out, testing, and grounding switchgear bus or feeder if device is installed in place of circuit breaker. Portable grounding and testing device shall be included and shall be interchangeable with drawout-mounting, medium-voltage circuit breakers to provide interlocked electrical access to either bus or feeder; electrically operated.

FABRICATION

Switchgear fabrication shall conform to the following requirements:

A. Indoor enclosure shall be fabricated of steel.
B. Finish shall be manufacturer's standard gray finish over rust-inhibiting primer on phosphatizing-treated metal surfaces.
C. Utility meter and incoming-line unit shall conform to the following:

    1. The unit shall be arranged for bottom entry.
    2. PG&E meter base is located between 914 mm to 1780 mm from equipment base.
    3. PG&E will provide PT and CT within the metering section.

D. Outgoing main-breaker unit shall be arranged for top entry.
E. Auxiliary compartments shall be arranged to suit house meters, relays, controls, and auxiliary equipment; isolated from medium-voltage components.

SWITCHGEAR COMPONENTS

Switchgear components shall conform to the following requirements:

A. Main bus shall be copper, silver plated at connection points; full length of switchgear.
B. Ground bus shall be copper, silver plated or copper, tin plated; minimum size (6.4 mm by 51 mm); full length of switchgear.
C. Bus insulation shall be covered with flame-retardant insulation.
D. Instrument transformers shall comply with IEEE C57.13:

    1. Potential transformers shall have secondary voltage rating of 120 V and NEMA accuracy class of 0.3 with burdens of W, X, and Y.

2. Current transformers: burden and accuracy class shall be capable for connected relays, meters, and instruments.

E. Analog instruments shall be rectangular, 114 mm square, 1% accuracy, semiflush mounting, with antiparallax 250-degree scale and external zero adjustment, and complying with ANSI C39.1:

1. Ammeters shall cover an expanded scale range of bus rating plus 10 percent.
2. Ammeter selector switch shall permits current reading in each phase and keeps current-transformer secondary circuits closed in off position.
3. Locate meter and selector switch on circuit-breaker compartment door for indicated feeder circuits only.

F. Relays shall comply with IEEE C37.90, digital type; with test blocks and plugs. At the main circuit breaker: provide (3) 50/51 phase protective devices.

G. Surge arresters shall be distribution class, metal-oxide-varistor type.in conformance with NEMA LA 1:

1. Surge arrester shall be installed in cable termination compartments in each phase of circuit.
2. The Contractor shall coordinate surge arrester rating with PG&E.

H. Control power transformer shall supply 120-V control circuits through secondary disconnect devices including the following features:

1. Dry-type transformers shall be in separate compartments for units larger than 3 kVA, including primary and secondary fuses.
2. Control power fuses including primary and secondary fuses shall be for current-limiting and overload protection.

I. Control wiring shall be factory installed, completed with bundling, lacing, and protection; and complying with the following:

1. Flexible conductors for No. 8 AWG and smaller, for conductors across hinges, and for conductors for interconnections between shipping units.
2. Conductors sized according to NFPA 70 for duty required.

IDENTIFICATION

Switchgear identification shall conform to the following requirements:

A. All system components including wiring, cabling, and terminals shall be identified with permanent labeling in accordance with "Electrical Identification" of these special specifications.

B. Mimic bus shall be continuous bus applied to front of switchgear, and arranged in single-line diagram format, using symbols and lettered designations consistent with approved final mimic-bus diagram:

1. Mimic-bus segments shall be coordinated with devices in switchgear sections to produce a concise visual presentation of principal switchgear components and connections.
2. Medium shall be painted graphics.
3. Color of the mimic bus shall be contrasting with factory-finish background and shall be selected as recommended by the manufacturer.

SOURCE QUALITY CONTROL

Prior to shipment of equipment, the Contractor shall perform the following tests and prepare test reports:

A. Production tests on circuit breakers according to ANSI C37.09.
B. Production tests on completed switchgear assembly according to IEEE C37.20.2.

The Contractor shall prepare equipment for shipment:

A. Provide crating, blocking, and supports so equipment will withstand expected shipping and handling shocks and vibration.
B. Weatherproofing of equipment for shipment. Connection openings shall be closed to prevent entrance of foreign material during shipment and storage.

FACTORY FINISHES

Prior to assembly, all enclosing steel shall be thoroughly cleaned and phosphatized. A powder coating shall be applied electrostatically, then fused on by baking in an oven. The coating shall have a thickness of not less than 0.038 mm. The finish shall have the following properties:

A. Impact resistance (ASTM D-2794):	60 direct/60 indirect
B. Pencil hardness (ASTM D-3363):	H
C. Flexibility (ASTM D-522):	Pass 4 mm mandrel
D. Salt spray (ASTM B117-85 [20]):	600 hours
E. Color:	ANSI 61 gray

EXAMINATION

The Contractor shall examine elements and surfaces to receive switchgear for compliance with requirements for installation tolerances, clearances, and other conditions affecting performance.

The Contractor shall proceed with installation only after unsatisfactory conditions have been corrected.

INSTALLATION

Concrete bases shall be 100 mm high, reinforced, with chamfered edges in conformance with the details shown on the plans. Base shall be extended no less than 75 mm in all directions beyond the maximum dimensions of switchgear.

Sills shall be selected to suit switchgear; level and grout flush into concrete base.

Switchgear assembly shall be anchored to 100 mm, channel-iron sill embedded in concrete base and attached by bolting.

The Contractor shall design each fastener and support to carry load calculated from seismic restraint requirements as specified in "Seismic Controls for Electrical Work" of these special provisions.

Temporary lifting eyes, channels, and brackets and temporary blocking of moving parts shall be removed from switchgear units and components.

CONNECTIONS

Cable terminations at switchgear shall conform to "Medium Voltage Cables" of these special provisions.

Bus joints, electrical connectors, and terminals shall be tightened according to manufacturer's published torque-tightening values.

Equipment shall be grounded in conformance with "Grounding and Bonding" of these special provisions.

FIELD QUALITY CONTROL

Testing.--Test results shall be documented in writing and submitted to the Engineer prior to final acceptance of the medium voltage service switchgear. The following field quality control testing shall be performed:

A. Test insulation resistance for each switchgear bus, component, connecting supply, feeder, and control circuit.
B. Test continuity of each circuit.

A factory-authorized service representative shall perform the following:

A. Inspect switchgear, wiring, components, connections, and equipment installation.
B. Assist in field testing of equipment.
C. Report results in writing.

An independent testing and inspecting agency shall perform field tests and inspections and prepare test reports.

Field tests and inspections shall be performed, and the test reports shall be prepared. Each electrical test and visual and mechanical inspection shall be performed in accordance with NETA ATS including the following:

A. Switchgear.
B. Circuit breakers.
C. Protective relays.
D. Ground-fault systems.
E. Surge arresters.

Malfunctioning units, if identified, shall be removed and replaced and the test shall be rerun.

Infrared scanning.--Within 60 days after final inspection of the all switchgears, the Contractor shall perform infrared scan for each switchgear. Front and rear panels shall be removed so joints and connections are accessible to portable scanner:

A. Follow-up infrared scanning: perform an additional follow-up infrared scan of each switchgear 11 months after date of substantial completion.

B. Instrument: use an infrared-scanning device designed to measure temperature or to detect significant deviations from normal values. Provide calibration record for device.
C. Record of infrared scanning: prepare a certified report that identifies switchgear checked and that describes infrared-scanning results. Include notation of deficiencies detected, remedial action taken, and observations after remedial action.

ADJUSTING

The Contractor shall set field-adjustable, protective-relay trip characteristics according to results in "Short-Circuit and Protective Device Coordination Studies" of these special provisions.

CLEANING

On completion of installation, the Contractor shall inspect interior and exterior of switchgear. The Contractor shall vacuum dirt and debris. Compressed air shall not be used to assist in cleaning. Damaged finishes shall be repaired.

DEMONSTRATION AND TRAINING

The factory-authorized service representative shall perform the demonstration and train Department's maintenance personnel to adjust, operate, and maintain switchgear including the following:

A. Procedure and schedules for trouble shooting, servicing, and maintaining switchgear.
B. Review data in maintenance manual.
C. Training shall be scheduled with the Engineer with at least seven days advance notice.
D. The Contractor shall provide qualified factory authorized service representative to train the State's maintenance personnel.
E. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

Medium voltage service switchgear will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for medium voltage service switchgear shall include full compensation for furnishing all labors, materials, tools, equipment, and incidentals and for doing all the work involved in furnishing and installing the medium voltage service switchgear, complete in place, including testing, and demonstration and training, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ MOTOR CONTROL CENTERS

GENERAL

Motor control centers for use on AC circuits rated 600 V and less shall be furnished, installed, and tested in conformance to the details shown on the plans and these special provisions. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--Motor control centers shall include the following:

A. Tunnel jet fan starter assemblies.
B. Integrated open frame mounted, FVNR Fan Combination Starters for Cross-passages.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.—The contractor shall submit data for each type of controller and each type of motor-control center. Data provided shall include dimensions and manufacturer's technical data on components, features, performance, electrical characteristics, ratings, and finishes.

Working drawings.--The following working drawings shall be provided:

A. Dimensioned plans, elevations, sections, and details, including required clearances and service space around equipment.
B. Tabulations of installed devices, equipment features, and ratings and the following:

    1. Each installed unit's type and details.
    2. Nameplate legends.
    3. Short-circuit current ratings of buses and installed units.
    4. Vertical and horizontal bus capacities.
    5. Features, characteristics, ratings, and factory settings of each motor-control center unit.

C. Wiring diagrams including power, signal, and control wiring for class and type of motor-control center. Manufacturer-installed wiring and field-installed wiring shall be differentiated. Schematic wiring diagram for each type of controller shall be provided.
D. Coordination drawings including floor plans showing dimensioned layout, required working clearances, and required area above and around motor-control centers where pipe and ducts are prohibited. Motor-control center layout and relationships between electrical components and adjacent structural and mechanical elements shall be shown on the coordination drawings. Support locations, type of support, and weight on each support shall be shown and field measurements shall be indicated.

Maintenance data.--Submit data for motor control centers, all installed devices, and components to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods

Warranty.--A warranty for the motor control center and components shall be provided and signed by the manufacturer and installer agreeing to correct system deficiencies and replace components that fail in materials or workmanship. The warranty shall be for two years from the date of system in service.

QUALITY ASSURANCE

Testing agency and field supervisor qualifications shall be in conformance with "Systems Studies and Testing" of these special provisions.

Electrical Components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. All components shall be UL Listed.

Product selection for restricted space: plans indicate maximum dimensions for motor-control centers, including clearances between motor-control centers, and for adjacent surfaces and other items. The equipment supplied shall comply with the maximum dimensions as shown on the plans.

COMPONENTS

The motor control center (MCC) and all starter units shall be manufactured by the same manufacturer as of the switchboards and panelboards.

The motor control center(s) shall be 600 volt class suitable for operation on a three-phase, 60 Hz system. The system operating voltage and number of wires shall be as shown on the plans.

MCC shall be totally enclosed deadfront, free-standing assemblies. They shall be 2.28 m high and 0.4 m deep for front-mounted units. Structures shall contain a horizontal wireway at the top, isolated from the horizontal bus via metal barriers and shall be readily accessible through a hinged cover. Adequate space for conduit and wiring to enter the top or bottom shall be provided without structural interference.

A vertical wireway with a minimum of 452 square centimeters of cross-sectional area shall be adjacent to each vertical unit and shall be covered by a hinged door. Wireways shall contain cable supports.

All starter units shall be of the drawout type. Drawout provisions shall include a positive guide rail system and stab shrouds to absolutely ensure alignment of stabs with the vertical bus. Drawout units shall have a tin-plated stab assembly for connection to the vertical bus. No wiring to these stabs shall extend into the unit compartment. Interior of all units shall be painted white for increased visibility. Units shall be equipped with side-mounted, positive latch pull-apart type control terminal blocks rated 300 volts. Knockouts shall be provided for the addition of future terminal blocks. All control wire shall be Type SIS, 14 gauge minimum.

All drawout units shall be secured by a quarter turn indicating type fastening device located at the top left of the unit. Each unit compartment shall be provided with an individual front door.

An operating mechanism shall be mounted on the primary disconnect of each starter unit. It shall be mechanically interlocked with the unit door to prevent access unless the disconnect is in the OFF position. A defeater shall be provided to bypass this interlock. With the door open, an interlock shall be provided to prevent inadvertent closing of the disconnect. A second interlock shall be provided to prevent removal or reinsertion of the unit while in the ON position. Padlocking facilities shall be provided to positively lock the disconnect in the OFF position with the door open or closed. Means shall be provided to padlock the unit in a partially withdrawn position with the stabs free of the vertical bus.

Bus.--Each MCC shall contain a main horizontal copper silver-plated bus, with ampacity as shown on the plans. The horizontal bus shall be rated at 65°C temperature rise over a 40°C ambient in compliance with UL standards. Vertical bus feeding unit compartments shall be tin plated copper and shall be securely bolted to the horizontal main bus. All joints shall be front-accessible for ease of maintenance. The vertical bus shall have a minimum rating of 300 amperes for front-mounted units. All vertical bus shall be fully rated. Reduced rating of the vertical bus by means of center feeding is not acceptable.

The vertical bus shall be completely isolated and insulated by means of a labyrinth design barrier. It shall effectively isolate the vertical buses to prevent any fault-generated gases from passing from one phase to another. The vertical bus shall include a shutter mechanism to provide complete isolation of the vertical bus when a unit is removed.

Buses shall be braced for 65,000 amperes rms symmetrical.

A copper ground bus shall be furnished securely attached to each vertical section structure and shall extend the entire length of the motor control center.

Each structure shall contain tin plated vertical ground bus rated for 300 amperes. The vertical ground bus shall be directly connected to the horizontal ground bus via a tin-plated copper connector. Units shall connect to the vertical bus via a tin-plated copper stab.

Each structure shall contain a tin-plated DC bus to distribute control voltage from the control power supply unit to the motor control units.

Wiring/Terminations.--Wiring shall be NEMA Class II, Type B.

Motor Starters.--Provide combination starter units as indicated on plans:

A. Tunnel jet fans shall be solid-state reduced-voltage, reversible starters (SSRV).
B. Leach water pumps and cross-passage fans shall be FVNR.

Combination motor starters shall conform to the following requirements:

A. Each combination unit shall be rated 65,000 AIC symmetrical at 480 V. The motor circuit protector (MCP) shall provide adjustable magnetic protection, which has an adjustment range that can be set to 1700 percent motor nameplate full load current to comply with NEC requirements. All MCP combination starter units shall have a "tripped" position on the unit disconnect and a push-to-test button. The MCP shall include transient override feature for motor inrush current. MCP shall be used to provide Type 2 coordination to 65,000 amperes.
B. Electromechanical type motor starters shall be provided with coil control and overload integrated into a single or dual microcontroller.
C. The motor starter shall operate over a temperature range of –23°C to +40°C and shall meet or exceed the following standards and certifications: UL, NEMA ICS1, ICS2, ICS5, IEC 60947-4-1, CE, and KEMA where applicable. Devices shall meet Electromagnetic Compatibility (EMC) Requirements per EMC IEC 61000-4.
D. One torroidal current sensor shall be provided per phase. Sensor shall be accurate to 2 percent providing input to analog circuitry and software which yields a time-current curve paralleling actual motor heating. Motor FLA shall be set via a potentiometer for 1.0 or greater Service Factor settings.
E. User-selectable overload Trip Class of 10, 20 and 30 shall be provided on each overload relay.
F. Phase loss and phase current unbalance protection shall be provided. If the phase unbalance of any phase is greater than or less than approximately 50 percent of the average, the device trips. This feature shall be user enabled/disabled.
G. Ground fault protection shall be provided for all starter units by the addition of a ground fault relay. Upon detection of a ground fault the relay shall:

    1. Provide indication only for the tunnel jet fan SSRV starters.
    2. Trip the starter for the leach water FVNR starters.

H. A microcontroller shall be provided with the following features:

1. Energizes coil.
2. Monitors user control inputs (i.e. permissive stop, forward, reverse, local reset, remote reset, test/test to trip. Control inputs shall be rated 24V (dc) (3-5 mA).
3. Operates an LED indicator which displays for thermal capacities over 70 percent, test button depression, trip indication, class setting, phase enablement/disablement, and microcontroller reset condition.
4. Monitors 3-phase current.
5. Provides thermal memory which shall be saved to non-volatile memory for safety purposes in the event of a power loss or removal and restore event.
6. Controls an alarm output which is a solid-state open collector or emitter type output at 24V (dc) 250 mA.
7. Solves a first order differential equation for an actual motor heating model to calculate trip points.
8. Provides an "alarm only" or "alarm without trip" mode for critical must run applications.
9. Provides built-in logic to provide either 2- or 3-wire control, eliminating the need to provide and wire auxiliary contacts to seal-in and interlock the contactor coil

I. Control Voltages shall meet the following requirements:

1. The starter voltage shall be nominal 24V (dc) from 20 to 28V (dc).
2. 24V (dc) control shall be provided by a control power stab that connects to the DC Bus. The control power stab shall contain fuseless overcurrent protection.
3. Control power for field circuits shall be supplied by 24V (dc) from the starter unit.

J. Motor starters shall have replaceable fixed and movable contacts.

K. The following accessories shall be provided:

1. Motor starters shall accommodate auxiliary contacts. Contacts shall be rated 10 amperes continuous. Provide number required for control logic plus one spare "a" and one spare "b" contact.
2. Mechanical interlock shall be provided on reversing contactors of a pivot-type mechanism to prevent closing of one contactor when the other is closed. Coil controller energizes both forward and reverse contactors providing one control point for wiring.
3. Provide control devices to perform the indicated input/output control functions shown on the plans. Controls shall include oil-tight pushbuttons, selector switches, and LEDs. All switch and LED functions shall be provided with clearly written identification.

Each starter shall be equipped with a 24V (dc) control power stab with fuseless overcurrent protection, two (2) 24V (dc) LED type indicating lights (Run and Stop), with the controls and LED pilot lights as shown on control plans.

Solid-state reduced-voltage, reversible starters shall be provided where shown on the plans. The solid-state reduced-voltage starter shall be UL and CSA listed in the motor control center, and consist of an SCR-based power section, logic board and paralleling bypass contactor. The

paralleling bypass contactor shall be energized when the motor reaches full speed. The starter shall support the following features:

A. Adjustable time ramp start.
B. Adjustable current limit start.
C. Adjustable time ramp stop.

Control Power Supply Units.--Each MCC shall have a control power supply unit that will provide 24V (dc) control power to other control units in that structure. This will be accomplished by using a single control power supply that converts line voltage to 24V (dc) directly, without the use of a control power transformer.

Each power supply unit shall be sized to power the units provided plus 20 percent spare. The power supply shall be sized to provide 14 cycle ride-through at 0V on the primary, when fully loaded.

Power supplies shall contain an electronic fuseless overcurrent protection that will safely shut down the power supply in the event of a short circuit on the power supply output.

Circuit Breakers.--Individual feeder breakers shall have a minimum interrupting capacity of 65 kAIC at rated voltage or as scheduled on the plans.

Miscellaneous Devices.--Solid-state motor winding heater, (tunnel jet fans only) shall conform to the following requirements:

A. Located in starter cubicle, supply power from line side connections with controlled current by-pass of contactor during heater mode.
B. Rated for 480 V (ac), 2 percent voltage regulation on output
C. Maximum amperage: 10 Amps
D. Fuse protection for SCR and heater circuit.
E. Surge protection for SCR components.
F. Isolation contactor when motor is running in forward or reverse directions.

Incoming Feeder Terminations and Device.--Incoming cable shall terminate within the MCC on a main lug termination point. Main lug terminations shall have adequate dedicated space for the type and size of cable used and the lugs shall be compression-type with antiturn feature. Top-hat shall be provided to provide added termination space.

Customer Metering.--Where indicated on the plans, the Contractor shall provide a separate customer metering compartment with front hinged door. Current transformers (CTs) shall be provided for each meter. Current transformers shall be wired to shorting-type terminal blocks. Potential transformers (PTs) including fused potential taps shall be provided as the potential source for metering as shown on the plans.

The microprocessor-based metering system, shall include the following features:

A. Phase currents
B. Voltage, L-L, L-N
C. Power: real, reactive, apparent
D. Energy: watt hours, var hours, and VA hours
E. ANSI C12. 16 Revenue metering accuracy (1 percent)

Enclosures.--The enclosure provided shall be in accordance with NEMA standards for type 12 dust-tight and drip-proof. All enclosing sheet steel, wireways and unit doors shall be gasketed.

Nameplates.--MCC and each cubicle shall be labeled as specified in "Electrical Identification" of these special provisions.

Finish.--The control center shall be given a phosphatizing pretreatment. The paint coating shall be a polyester urethane, thermosetting powder paint. Manufacturer's standard color shall be used. The control center finish shall pass 600 hours of corrosion-resistance testing per ASTM B 117.

Integrated Combination Starters for Cross-Passages.--The starters shall meet the following requirements:

A. Open-frame, for the integrated mounted, FVNR combination starters for tunnel jet fans.
B. Same combination motor starter type and control voltage as for MCC.
C. No ground fault protection or indication.

INSTALLATION

The Contractor shall examine areas and surfaces to receive motor-control centers for compliance with requirements, installation tolerances, and other conditions affecting performance. Surfaces and areas shall be corrected to be incompliance with requirements prior to installation.

The Contractor shall install motor-control centers on concrete bases. Each motor-control center assembly shall be anchored to steel-channel sills arranged and sized according to manufacturer's written instructions and attached by bolting. Level and grout sills flush with motor-control center mounting surface.

The Contractor shall identify motor-control center, motor-control center components, and control wiring in conformance with section "Electrical Identification" of these special provisions.

Wiring shall be installed between motor-control devices in conformance with section "Conductors and Cables" of these special provisions. Wiring shall be bundled, trained, and supported in enclosures.

Connect hand-off-automatic switch and other automatic-control devices to meet the following requirements:

A. Connect selector switches to bypass only manual- and automatic-control devices that have no safety functions when switch is in hand position.
B. Connect selector switches with motor-control circuit in both hand and automatic positions for safety-type control devices such as high-temperature cutouts, and motor overload protectors.

Tighten electrical connectors and terminals according to manufacturer's published torque-tightening values. If manufacturer's torque values are not available, use those specified in UL 486A and UL 486B.

Delivery, Storage, and Handling.--Handle motor-control centers according to NEMA ICS 2.3, "Instructions for the Handling, Installation, Operation, and Maintenance of Motor Control Centers." Use factory-installed lifting provisions.

Store motor-control centers indoors in clean, dry space with uniform temperature to prevent condensation. Protect motor-control centers from exposure to dirt, fumes, water, corrosive substances, and physical damage.

Coordination.—Contractor shall coordinate layout and installation of motor-control centers with other construction including conduit, piping, equipment, and adjacent surfaces. Maintain required workspace clearances and required clearances for equipment access doors and panels.

Coordinate size and location of concrete bases. Cast anchor-bolt inserts into bases. Concrete, reinforcement, and formwork requirements shall conform to "Concrete Structures," of these special provisions.

Coordinate features of motor-control centers, installed units, and accessory devices with pilot devices and control circuits to which they connect.

Coordinate features, accessories, and functions of each motor-control center, each controller, and each installed unit with ratings and characteristics of supply circuit, motor, required control sequence, and duty cycle of motor and load.

FIELD QUALITY CONTROL

Manufacturer's field service: A factory-authorized service representative shall inspect field-assembled components and equipment installation, including pre-testing and adjusting solid-state motor manager overload controllers in accordance with the system studies report.

Testing Preparation.--The Contractor shall prepare for acceptance tests as follows:

A. Test insulation resistance for each motor-control center element, bus, component, connecting supply, feeder, and control circuit.
B. Test continuity of each circuit.

Testing.--Engage a qualified testing agency to perform the following field quality-control testing:

A. Perform each electrical test and visual and mechanical inspection indicated in NETA ATS, Sections 7.5, 7.6, and 7.16.
B. Certify compliance with test parameters.
C. Correct malfunctioning units on-site, where possible, and retest to demonstrate compliance; otherwise, replace with new units and retest.

Test Reports.--The Contractor shall submit to the Engineer a written record of inspections, tests, and detailed test results in the form of a test log, on the satisfactory completion of tests. All equipment, stations, and other components at which tests have been satisfactorily completed shall be tagged to indicate completion of testing. Complie list of load-current and settings of adjustable overload relays after motors have been installed.

Adjusting.--Adjust settings for field-adjustable switches and circuit-breaker trip ranges as needed to correct test deficiencies.

Cleaning.--Clean controllers internally, on completion of installation, according to manufacturer's written instructions. Vacuum dirt and debris; do not use compressed air to assist in cleaning.

START-UP SERVICE

A factory-authorized service representative shall perform startup service.

The contractor shall verify that motor-control centers and components are installed and connected as shown on the plans.

Installation and startup checks shall be completed according to manufacturer's written instructions.

DEMONSTRATION AND TRAINING

A factory-authorized service representative of the manufacturer shall provide equipment demonstration and training for the Department's maintenance personnel to adjust, operate, and maintain motor-control centers in accordance with “Basic Electrical Materials and Methods” of these specifications.

MEASUREMENT

Motor Control Centers will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for motor control centers shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in motor control centers, complete in place, including tests, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4__ TUNNEL LIGHTING

GENERAL

The tunnel lighting system shall consist of furnishing, installing, and testing of tunnel luminaires, including all wire, cable and mounting in conformance with the provisions in Section 86, "Signals, Lighting and Electrical Systems" of the Standard Specifications and these Special Provisions. The tunnel lighting system shall also include the installation of conduit and raceway in conformance with "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--The tunnel luminaires shall be installed in the tunnel as shown on the plans to provide good visibility for the drivers during day and night.

SUBMITTALS

The Contractor shall submit an equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and the requirements specified herein.

Product data.--The submittals shall include complete details, information, and drawings of each type of lighting unit arranged in order of lighting unit designation as shown on the plans. The submittals shall also include the data on features, accessories, finishes, and the following:

A. Materials and dimensions of luminaires.
B. Certified results of laboratory tests for fixtures and lamps for photometric performance.
C. High-intensity-discharge luminaire ballasts.
D. For each type of tunnel luminaire, the following working drawings shall be submitted:

    1. Specification of light fixture and related components such as housing, latches, fuses, terminal block, lamp housing, ballast, gasket, identification label and anchor plate, if necessary.
    2. Product drawings with top, side, and bottom views, and the necessary details, including required clearance.
    3. Photometric file in Illuminating Engineering Society (IES) formatting and lighting calculations.

E. Product certificates signed by manufacturers of lighting units certifying that products comply with requirements. A certificate of compliance for each lighting unit shall be furnished to the Engineer in conformance with the provisions in Section 6-1.07, "Certificates of Compliance," of the Standard Specifications.
F. Field test reports that indicate and interpret test results for compliance with performance requirements.
G. Installation procedures, sequences, schedule, and tolerances.
H. Maintenance manuals for lighting units.
I. Warranty for lighting units or components.

QUALITY ASSURANCE

Luminaires and accessories shall be listed and labeled in conformance with NFPA 70, Article 100, for their intended use, location, and installation conditions.

Luminaires and accessories shall conform to the following:

A. ANSI C2.
B. ANSI/IES RP-22-96.
C. AASHTO 1994, “Information Guide for Roadway Lighting”.
D. FHWA 1994, “Tunnel Lighting Design and Procedures”,
E. ANSI/IES RP-8-00.

The Contractor's attention is directed to "Tunnel Control Systems" of these special provisions for lighting control system.

DEFINITIONS

A. Lighting unit: A luminaire or an assembly of luminaires complete with support accessories.
B. Luminaire (light fixture): A complete lighting device consisting of lamp(s) and ballast(s), when applicable, together with parts designed to distribute light, to position and protect lamps, and to connect lamps to power supply.

MATERIALS

Lighting Unit Type Tunnel Luminaires.--All manufactures shall meet the intended product quality, serviceability, space restraints, and illumination standards as specified in these special provisions. Lamp and ballast technology shall conform to the requirements specified in these special provisions.

Warranty.--Manufacturer shall warrant that the factory-installed electrical system (consisting of a coil ballast, starting aid, capacitor, terminal board and wiring) shall be free from defects in material and workmanship for 5 years from the date that the fixtures are shipped from manufacturer's factory.

Description.--The Contractor shall furnish counterbeam and IES Type IV lighting fixtures complete with lamps, ballasts, fuses, terminal blocks, capacitors, reflector, gaskets, latches, lenses, hinges, lamp holders, wiring, starters, and all accessories necessary to perform tunnel lighting as a coordinated assembly.

A. All luminaire components shall meet the requirements of the latest version of UL l572 40°C High Intensity Discharge Lighting Fixture (wet label) specifications.
B. The luminaires shall be for use in exterior environments between –18 and +38°C, and zero to 100 percent humidity.
C. The luminaires shall be suitable for the environment encountered in marine and vehicular covered roadways. The following conditions shall be taken into account:

    1. Air containing a large percentage of lint and dust particles.
    2. Exposure to chemically corrosive solutions from auto emissions, pavement deicing salts, and pavement traction minerals.
    3. Concrete leaching onto mounting plates and luminaires.
    4. Covered roadway cleaning involving high pressure detergent wash downs.
    5. Vibration from large tractor trailer trucks traveling within 620 mm of the luminaires.
    6. Fog.

D. Daytime counterbeam and nighttime IES Type IV luminaires shall be identical except that the reflectors and ballasts can vary. The luminaires shall have the following features to facilitate maintenance:

    1. Quick and easy luminaire removal with gloves on for the purpose of repair in shop.
    2. Luminaire cleaning using high pressure water and detergent.
    3. Luminaire relamping.
    4. Quick and easy replacement of modular interior components, including ballasts tray and lens with luminaire housing in fixed, overhead mounting position.

E. All internal fixture components and wiring shall be capable of operating at the internal temperatures found inside the fixture without affecting component life by accelerating deterioration.
F. Lamp holders shall be mogul, heavy-duty type, composed of glazed porcelain rated for 4,000 volts pulse voltage. The mogul socket shall be UL listed for 600 volt, 1,500 watt operation.
G. Each luminaire shall be provided with a grounding terminal suitable for a single conductor as shown on the plans with stranded copper wire connection.

Lamps.--High-pressure sodium lamps shall conform to the ANSI C78 series for each type of lamp. The type and wattage of lamps shall conform to the details as shown on the plans. Lamps shall be non-cycling, reduced lead and mercury, high pressure sodium lamps. Lamps shall be constructed with a lead-free welded base in conformance with Federal TCLP requirements.

Mounting.--The mounting arrangements for the tunnel luminaires shall conform to the detailed shown on the plans. The mounting assembly shall be supplied by the manufacturer of luminaires in conformance with the mounting method and wiring as shown on the plans.

Housing.--Housing shall conform to the following requirements:

A. The housing shall be formed of cast aluminum alloy using the permanent mold process. The casting shall have a minimum 3 mm wall thickness and shall be designed to provide the luminaire body with adequate rigidity by incorporating suitable ribs in the structure. No welding will be permitted in constructing the luminaire housing.
B. Stainless steel screws or bolts used for attachment of the mounting or hinging components to the luminaire housing shall be provided with a nonmetallic coating to prevent corrosive interaction between the stainless steel fastener and the luminaire aluminum alloy. The coating shall withstand the standard 5 percent salt spray corrosion test by more than 1000 hours.
C. All luminaire assemblies shall be designed for removal. The removal is carried out by the following:

    1. Open the fixture and open the disconnect and fuse terminal block and remove the fuses.
    2. Disconnect power to the fixture by shutting off the circuit breaker which serves the fixture. (Or alternatively, remove the load wires from the terminal blocks within the distribution junction box which feeds the fixture. CAUTION! Terminal blocks are energized at 480 V (ac).)
    3. Remove the incoming wires from the fixture terminal blocks, and remove the rigid conduit or flexible metal conduit.
    4. Unlatch the latches and swing the luminaire downward.
    5. Slide the luminaire off the hinges.

D. In order to prevent entry of moisture into the luminaire housing, the Contractor shall provide a NEMA ICS 6, Type 4 enclosure. All electrical components mounted in the luminaire enclosure shall be compatible with the conditions encountered within a totally enclosed NEMA 4 housing and shall meet UL requirements.
E. The luminaires shall consist of standardized sizes and shapes (not including mounting plate). The housing of all luminaires shall not be greater than 600 mm long by 750 mm wide x 200 mm deep. Luminaires shall be secured by latches to a luminaire mounting plate.
F. The junction between the lens frame and the luminaire housing shall be sealed with a gasket of high strength hollow core silicone rubber . The gasket seal shall be weatherproof, moisture proof, and dust proof. The gasket shall be securely attached to the luminaire housing or lens frame and shall not depend solely on adhesive to hold it in place. Latches shall evenly compress the gasket against the housing.

G. Doors, frames, and other internal access shall be smooth operating, free from light leakage under operating conditions, and arranged to permit relamping without use of tools. Doors, frames, lenses, diffusers, and other pieces shall be arranged to prevent accidental falling during relamping and when secured in operating position. Doors shall be removable for cleaning or replacing lens. When door opens, ballast shall be disconnected.

H. All external luminaire housing auxiliary components shall be manufactured of ANSI 316 stainless steel. These include latches, screws, bolts, nuts, and washers used in constructing the luminaire housing. Hinging components shall be fabricated from ANSI 300 Series stainless steel alloy.

I. A luminaire mounting plate with nominal dimensions of 600 mm wide x 750 mm long shall be supplied for each luminaire. The mounting plate, constructed of 3.3 mm (10 gauge) ANSI 316 stainless steel, shall be furnished with six slotted holes (12.7 mm wide by 25.4 mm long) for bolting plate to the channel and strut light fixture support angles. All exposed metal parts of the luminaire (inside and outside) shall be protected against corrosive environments.

J. The aluminum surfaces inside and outside of the luminaire shall undergo an alkaline cleaning and a pretreatment process of electro-deposited epoxidized acrylic paint. Minimum film thickness of this primer coat shall be 0.02 mm after curing. The paint used for the luminaire protection against the corrosive elements shall be heavy duty, zinc enriched, epoxy powder paint with a minimum total dry film thickness of 0.05 mm. The paint shall be applied on both the inside and the outside of the luminaire housing. Color shall be light gray, ANSI 70. All stainless steel hardware, hinges, and latches shall be installed after the luminaire fixture has been painted.

K. Each luminaire housing shall be permanently marked with the manufacturer's name, the luminaire type, the wattage, and with an arrow indicating direction of traffic flow. This marking shall be visible from below with the lens assembly removed. Also, on the shoulder side of the exterior of the housing, this information shall be shown on with 75 mm high by 40 mm wide black characters on a 90 mm high yellow background made of premium outdoor 0.127 mm grade vinyl with permanent adhesive.

Lens.--

A. The lens shall be manufactured of flat 6.35 mm minimum thickness tempered glass plate. The lens shall be heat resistant, non-discoloring, mechanical and thermal impact resistant, capable of withstanding sound vibrations, liquid pressure, and mechanical impacts. The lens shall conform to the current Glass Tempering Association Specification No. E61.05 for appliance glass. The lens shall withstand a wash down with cold water (4°C) five minutes after the luminaire has been turned off.

B. The lens shall be gasket-sealed into a die-cast aluminum frame which, in turn, shall be gasket-sealed to the housing. The lens frame shall be secured to the housing by use of hinged and spring-loaded, quick-closing latches that create a compressive pressure between the lens frame and housing permitting rapid and efficient opening and replacement of the lens assembly. The frame shall be designed to permit opening and closing the access to the luminaire without distortion or change of water-tightness requirements. Since the lens assembly will be used as the means of entering into the luminaire interior, its frame shall be so designed that it will contain sufficient rigidity to permit opening and closing the access to the luminaire without distortion or change of

water-tightness requirements. The lens frame shall make an allowance for mechanical forces originating from glass expansion and contraction due to temperature changes.

Reflector.--

A. The reflector system shall achieve the photometric performance in conformance with the lighting performance criteria specified in these special provisions. A hydro-formed reflector assembly shall consist of high purity aluminum of minimum 0.75 mm thick sheet. Aluminum used for the reflector shall be 3002 alloy.
B. The reflector shall be treated to provide the necessary light reflectance compatible with the optical design requirements. At the Contractor's option and when approved by the Engineer, the reflector can utilize a thin impermeable coating of high purity borosilicate glass to achieve the necessary reflectance.
C. A fabricated reflector assembly shall consist of a segmented optical system of homogeneous sheet aluminum, electro-chemically brightened, anodized and sealed. The segmented reflector shall be set in a faceted arc image duplicator pattern to achieve the proper distribution. The reflector assembly shall be secured to the luminaire housing to ensure its geometric position with respect to intended light distribution and control requirements. All edges shall be smooth and rounded. The reflector assembly shall not deform when subjected to normal wiping and cleaning.
D. The screw mechanism holding the lamp shall be provided with an anti-rotating device and reinforced to retain the lamp in the socket under normal operating conditions. In addition to the socket engaging the lamp base, the glass envelope of the lamp shall be provided with support for the purpose of reducing the vibration stresses on the lamp base.

Ballast.--

A. Ballasts shall be furnished and installed for all lighting fixtures in conformance with ANSI C82.4. Ballasts shall be designed to meet the latest UL 1029 specification and to operate the lamps as specified in these special provisions. The ballast shall be a three-coil isolated winding magnetic regulator.
B. Each ballast shall be installed on its own mounting plate within the housing. A spring loaded latch or quarter turn, quick release, captive screw fastener shall be used to secure the mounting plate to the housing. The mounting plate and all internal brackets shall be fabricated from 300 Series stainless steel.
C. Ballasts shall be NEMA Class 220 (formerly Class H) type (180°C) and shall be designed for operation on a 480/277 volt grounded system, and shall be connected to 480 volts, phase to phase. The terminal block and all connections shall be rated 600 volts, with a total insulation level of 10.0 kV. Ballast operating temperature shall not exceed 150°C for full ballast life.
D. The ballast shall supply an open circuit voltage as recommended by the lamp manufacturer and shall be guaranteed to start at least 90 percent of seasoned lamps at minus 30°C.
E. The lamp current crest factor shall not exceed 1.8 for a plus or minus 10 percent line voltage variation from nominal throughout lamp life.
F. Ballast shall be capable of withstanding momentary dips in voltage up to 30 percent without extinguishing the lamp.
G. Ballast primary current during starting shall not exceed normal operation current.

H. The ballast, including starting aid, shall protect itself against normal lamp failure modes. The ballast shall be capable of operating the lamp in open or short circuit conditions for a period of six months without significant loss of ballast life.
I. The power factor of the lamp ballast system shall not drop below 90 percent for a +10 percent line voltage variation at any lamp voltage, from nominal through life.
J. The starter supplied with the ballast shall be of plug-in type to allow its removal without special tools. Each ballast, starter, and capacitor shall be provided with nameplates indicating manufacturer's product name, model number, rating, and similar essential data.
K. Ballast cores shall be made from laminations of high-grade silicon steel, die-cut to assure tight mechanical tolerances and precision assembled assuring consistent performance from unit to unit. Ballast coils shall be made of high temperature insulated magnetic wire wound into a suitable frame. Precision wound coils shall be used to provide adequate heat dissipation and avoid hot spots. Complete core and coil assembly shall be impregnated with compounds in conformance with NEMA Class 220 (formerly Class H) insulation requirements.
L. The capacitors shall be constructed according to the latest ANSI specification for the luminaire operating temperature (minimum rating 90°C) and shall be of close tolerance to assure consistency of lamps. They shall be non-PCB type and provided with pressure sensitive interrupters.
M. Ballasts shall have an average life in pulsing mode of 10,000 hours at an igniter and starter case temperature of 90°C.
N. Noise shall be uniformly quiet operation, with a noise rating of Class B or better.

Interior Wiring.--

A. Each luminaire shall be provided with two 8.0 ampere Type KTK fuses fitted to a fusible disconnect type terminal block, rated 600 volts. The fusible disconnect type terminal block shall allow a maintenance person to open the disconnect, which will automatically remove the fuses and shut-off power to the fixture. This fuse element shall apply to all luminaires.
B. Wiring between the ballast and the lamp socket shall be made using SF-2 insulated wire, having the rating of 600 volt, 200°C. Wiring between the ballast and its auxiliary components shall be made using XFF cross-linked polyolefin insulated wire rated 150°C. All wiring shall be color coded and arranged in a neat manner.
C. All wiring to or from the ballast shall be made with plug-in connectors to permit removal of the ballast tray in the field without the use of tools.
D. The wiring diagram shall be attached to the luminaire interior wall and shall be legible under field maintenance conditions and throughout the life expectancy of the fixture.

Exterior Attachment to Luminaire.--All luminaires shall be provided with a 12.7 mm threaded hub for liquid-tight flexible conduit connection. The conductors shall be terminated in the fixture at fused disconnect terminal blocks.

Photometric Requirements.--

A. Daytime counterbeam type luminaire: The photometric distribution shall be designed for counterbeam tunnel luminance applications. The fixture shall provide a cutoff, asymmetric distribution of light, with the majority of lamp lumens being directed towards oncoming traffic.

B. Nighttime IES Type IV luminaire: The luminaire shall be designed to house a 150 watt, clear high-pressure sodium lamp, and its optical system shall produce an IES Type IV, medium distribution cut-off pattern. This luminaire is designated for nighttime illumination of the tunnel and shall be designed for asymmetrical tunnel luminance applications. The fixture shall provide a cutoff, asymmetric distribution of light, with the majority of light directed toward the opposite wall of the tunnel. Minimum downward efficiency shall be 70 percent of rated lamp lumens.

C. Lighting performance criteria: The luminaires shown on the plans are positioned to provide a minimum level of photometric performance. The luminaire manufacturer shall submit computer calculations demonstrating that manufacturer's luminaires are in conformance with the following requirements:

SOUTH Bound

TUNNEL ROADWAY AREA	AVERAGE LUMINANCE (cd/m^2)	AVERAGE TO MINIMUM LUMINANCE	MAXIMUM TO MINIMUM LUMINANCE	MAX TO MIN WALL ILLUMINANCE (up to 3 m high)
Threshold Zone, High Level	240	2.0:1	3.5:1	3.5:1
Threshold Zone, Medium Level	160	2.0:1	3.5:1	3.5:1
Threshold Zone, Low Level	80	2.0:1	3.5:1	3.5:1
Interior Zone	6	2.0:1	3.5:1	3.5:1
Night Level	5	2.0:1	3.5:1	3.5:1

NORTH Bound

TUNNEL ROADWAY AREA	AVERAGE LUMINANCE (cd/m^2)	AVERAGE TO MINIMUM LUMINANCE	MAXIMUM TO MINIMUM LUMINANCE	MAX TO MIN WALL ILLUMINANCE (up to 3 m high)
Threshold Zone, High Level	240	2.0:1	3.5:1	3.5:1
Threshold Zone, Medium Level	160	2.0:1	3.5:1	3.5:1
Threshold Zone, Low Level	88	2.0:1	3.5:1	3.5:1
Interior Zone	6	2.0:1	3.5:1	3.5:1
Night Level	5	2.0:1	3.5:1	3.5:1

D. The Contractor shall submit hard copies and compact disks (CDs) in an Illuminating Engineering Society (IES) formatting, of candlepower distribution data for each type of luminaire. A hard copy of photometric candlepower data shall be submitted on 2.5 degree intervals within 10 degrees of the maximum candlepower.

E. In addition, the Contractor shall submit the following:

1. Vertical candlepower curves for the maximum candlepower plane at the 0/180-degree plane and 90/270-degree plane.
2. With the tunnel light fixture at a 4.5 m mounting height from the pavement to the bottom of luminaire:

   a. Isocandela plot with a minimum of 7 contours.
   b. Lux readings on a 300 mm grid.

F. Computer calculations shall be done in accordance with IES standards, except the point samples for spacing along and across the roadway shall be at 600 mm centers. Spacings across roadway shall begin at the left edge of roadway. The roadway is defined as one 3.6 m travel lane, and does not include the shoulder and sidewalk. A maintenance factor of 0.65 shall be used and a maintained wall reflectance shall be 35 percent. Reflectance shall be designed for pavement type R1 in conformance with ANSI/IES RP-8.

Manufacturer's Certification and Testing.--

A. The Contractor shall submit manufacturer certification that the furnished luminaires meet the requirements of these special provisions including a detailed description of each variance for the Engineer's approval.
B. The Contractor shall submit to the Engineer with a list of all the electrical components contained in the luminaires.
C. The Contractor shall propose an independent test laboratory for approval by the Engineer. Before installation, two 400 W counterbeam luminaires and one 150W IES Type IV luminaire will be selected at random by the Engineer from the project luminaires at the job site or at the Contractor's storage facility for independent laboratory testing. If any unit fails, the Engineer will require up to five additional tests to estimate the extent of nonconformance.
D. The test results shall substantiate that the selected luminaires fulfill the specified photometric requirements prior to beginning installation of tunnel luminaires. If test fails to meet any specified requirement, further testing will be required to validate a manufacturer's claim of compliance with these special provisions.
E. The Contractor shall furnish to the Engineer test results from the independent testing laboratory demonstrating conformance with the following requirements for each type of light fixture.

    1. Data: Complete photometric data for each fixture type including, coefficient of utilization table, horizontal and vertical candle-power tabulation in 5 degree increments, graph of candle-power in maximum plane and maximum cone. The photometric data shall conform to the photometric specification to within 10 percent. The photometric data will then be used to demonstrate conformance with the performance criteria.
    2. Lamp: For a simulated installation, in a 35°C outdoor ambient temperature, demonstrate lamp voltage and temperature conformance with ANSI standards C78.388, C78.1350 and C78.1355 for the maximum stabilized fixture temperature. Test shall be run with lamps aged 100 hours. Fixture mounted lamp voltage and temperature shall be compared against performance of a similar but non-enclosed lamp. Tests shall be repeated for lamps of each of the approved lamp manufacturers.

INSTALLATION

Installation shall conform to the following requirements:

A. Luminaire attachment shall be installed to the details as shown on the plans.
B. Low smoke, flexible conduit connection shall be provided from embedded conduit stub-up and conductors, per schedules shown on the plans, shall be installed to embedded terminal boxes.

C. Electrical connectors and terminals shall be tightened in accordance with manufacturer's recommendations.
D. Luminaires shall be installed in accordance with to manufacturer's written instructions. Malfunctioning lamps shall be replaced.

FIELD QUALITY CONTROL

The Contractor shall inspect each installed lighting unit for damage. Damaged lighting units and components shall be replaced by the Contractor at the Contractor's expense.

The Contractor shall provide a minimum of 2 working days advance notice to the Engineer for the dates and times of the field tests. The Contractor shall provide instruments to record test results.

The Contractor shall verify normal operation of the lighting units after installing luminaires and energizing circuits with normal power source, and shall conduct the following field tests:

A. Light intensities shall be measured at night to test illumination performance. Luminance meter shall be used with calibration referenced to NIST standards for the photometric measurements. The photometric measurement shall comply with ANSI/IES LM-71-96.
B. Intensity and uniformity of illumination shall be checked.
C. Any noticeable noisy ballasts shall be checked and replaced.

Luminaires and components that failed any test shall be repaired or replaced, and then retested.

Within 2 working days after tests are completed, the Contractor shall submit to the Engineer a written test report, including test procedure, inspections, observations, verifications, test results, repairs made, test date and signature of test person.

Prior to final acceptance of the installation, all luminaires shall be cleaned with methods and materials recommended by manufacturer.

MEASUREMENT

Tunnel lighting system will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for tunnel lighting shall include full compensation for furnishing all labor, materials, tools, equipment, and incidentals, and for doing all the work involved in tunnel lighting, complete in place, including all luminaires and components, and testing, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

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10-4.__ TUNNEL TRAFFIC CONTROL SYSTEM

GENERAL

Tunnel traffic control system shall consist of furnishing, installing, testing, demonstration, and training of traffic signal lights, loop detectors, weather station, and variable message signs(VMS) including all wire, cable and mounting in conformance with the provisions in Section 86 "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions. Tunnel traffic control system shall also include the installation of Changeable Message Signs (CMS) and 170E Controllers. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--Traffic signal lights shall be installed at each portal and with each variable message sign (VMS) installed in the tunnel. CMS shall be installed at each incoming portal. VMS shall be installed at intervals through the tunnel. Loop detectors shall be installed in the roadway as shown on the plans to monitor traffic for stopped vehicles and incidents in the tunnel. Loops and signal lights shall be monitored and controlled by a 170E controller. Control commands shall reach the 170E through the Direct Digital Control (DDC) system. The VMS shall be controlled through a communication connection to the Operation and Maintenance Center (OMC) and Traffic Management Center (TMC) in Oakland. The CMS shall be controlled remotely through a telephone line connection.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the tunnel traffic control system as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Manufacturer's technical data for each type of product in the tunnel traffic control system.
B. Shop wiring diagrams showing detail wiring and differentiating between manufacturer-installed and field-installed wiring. Diagrams for equipment and for the system shall be included with all terminals and interconnections identified. Device locations and routings of raceway connections shall be indicated.
C. System operation description including detailed description, and method and sequence of operations.
D. Field test reports indicating and interpreting test results for compliance with performance requirements.
E. Maintenance data for systems to include in the maintenance manuals and shall conform to "Basic Electrical Materials and Methods".

QUALITY ASSURANCE

The tunnel traffic control system shall be installed by an installer who is certified by the equipment manufacturer for both installation and maintenance of units.

SYSTEM COMPONENTS

Traffic Signal.--A three color lane signal shall be mounted as shown on the plans to control traffic flow. Each signal shall be controlled through a 170E Controller installed in the equipment chambers. The 170E Controllers will be State-furnished in conformance with the provisions in "Materials" of these special provisions. Traffic signal shall be in conformance with Section 86-04, "Traffic Signal Faces and Fittings," of the Standard Specifications and as specified in these special provisions.

The signal housing shall accommodate standard 38 mm pipe brackets at each end of the signal.

Changeable Message Sign--Model 500 CMS will be State-Furnished in conformance with the provisions in "Materials" of these special provisions. A telephone line shall be installed to the sign for remote control.

Variable Message Sign.--VMS shall be installed at intervals through the tunnel as shown on the plans. The sign shall be a single line electronic message sign and shall have the capability to display a minimum of 20 messages. The Variable Message Sign (VMS) shall consist of an all light-emitting diode (LED), full matrix sign capable of both static and dynamic graphics. The sign shall be mounted in the tunnel in accordance with manufacturer's recommendations.

The VMS sign housing shall be weatherproof and corrosion resistant. The sign shall provide structural support for the display panels. The housing shall have a lens on the front of the sign case. The lens shall be readily removable to allow maintenance or replacement of display panels. The lens shall be gasketed and mounted to prevent entrance of water. The lens shall be coated to reduce glare. The sign assembly shall have a maximum weight of 450 kilograms. All necessary hardware shall be provided including mounting hardware. All mounting hardware shall be stainless steel. Housing for the tunnel signs shall have a maximum size of 910 mm x 6530 mm x 38 mm.

The display shall consist of an LED pixel full matrix display capable of full size static and dynamic graphics and messages. LED's shall be mounted in rows and columns on individual display panels. Display panels shall be interchangeable and shall be 100 percent solid state with no moving parts. Each display panel shall contain the LED circuitry necessary to operate it's associated LED's and no separate driver boards shall be required. No programming modifications shall be required to exchange or replace individual display panels or modules. A minimum of sixteen display panels shall be provided. Character size shall be a minimum of 310 mm high. The sign shall support a minimum of 24 characters.

LED pixels shall be comprised of a single ITE amber LED providing both daytime and nighttime legibility. LED's shall be rated for a 100,000-hour service life.

Power supply for the display shall be capable of operating the sign for both daylight and nighttime conditions, and shall be fully operational in the temperature range of –34ºC to +60ºC. The sign system shall include the required converter to provide reliable DC power to meet the service demands of the sign.

Wiring for display panels shall utilize wiring harnesses to group wire. Wiring shall be configured to preclude a faulty display panel from being able to corrupt any of the other display panels.

The CPU shall consist of a single printed circuit board which shall contain all of the sign message memory and sign operating software. The CPU shall support a minimum of 350 owner-defined messages, 40 pre-programmed messages, 26 graphic displays of traffic control symbols from the Manual of Uniform Traffic Control Devised (MUTCD) and the sign operating software. Memory shall be retained during any interruption in power. The CPU shall continue to operate

the sign in the event the controller is disconnected. The CPU shall be operable in 0 to 95 percent humidity and temperatures from –34ºC to +60ºC. The CPU shall be mounted in the sign cabinet. The CPU shall provide automatic letter sizing and centering without separate programming. The computer shall provide for message and sequence programming while another sequence is being shown on the sign. The CPU shall have an EIA RS-232C communication interface port to allow for remote control and monitoring of the sign. Communication protocol shall adhere to current National Transportation Communications for Intelligent Transportation System Protocol (NTCIP). Proprietary protocols shall not be used.

A keyboard terminal shall be provided for operator control of the sign. The keyboard shall be a standard QWERTY keyboard and a backlit liquid crystal display. The terminal shall be weathertight and shall be rated for operation at 0 to 95 percent humidity and temperatures of -34ºC to +60ºC. Removal of the keyboard shall not interrupt the operation of the CMS.

Sign Software.--The operating software shall be directly accessible through the keyboard. The software shall use a system of pull down menus for operator interface with the operating software. The menu system shall be user friendly and shall require operator confirmation prior to changing sign parameters or messages. The operating software shall have the following features:

A. A password entry system shall limit access to the sign control menus.
B. A sign diagnostics menu to provide information regarding the sign operation including CPU input/outputs, low voltage indicator and ambient light level.
C. Automatic control of LED brightness.
D. Editing feature to edit operator generated messages.
E. Indication of which message is being displayed on the sign.
F. The ability to run test patterns to test every LED in the sign face.
G. Sequence: The sign shall be able to display up to 6 three-line messages in any sequence.
H. Graphics shall be available from the keyboard and shall include chevrons and symbol messages defined in the MUTCD.

Loop Detectors.--Loops shall be monitored through a 170E controller installed in the equipment chambers. Loop detectors shall be in conformance with the Section 86-05, "Detectors," of the Standard Specifications and as specified in these special provisions.

Weather Station.--The roadway weather information system shall consist of wind speed and direction detector, temperature and humidity sensors and visibility sensors. All components shall be installed as shown on the plans and in accordance with the manufacturers' recommendations. All sensors shall be monitored locally by a CPU. The processor shall connect to the Control room at the OMC by means of an NTCIP compatible communication link.

INSTALLATION

Equipment shall be installed as shown on the plans and in accordance with the manufacturers' recommendations. Wire and cable shall conform to "Signal Conductors and Cable" of these special provisions.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in accordance with "Electrical Identification" of these special provisions.

Grounding.--Cable shields and equipment shall be grounded according to system manufacturer's written instructions to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.

Cleaning.--Paint splatters and other spots, dirt, and debris shall be removed. Scratches and marred finishes shall be touched up to match original finish. Units shall be cleaned thoroughly using methods and materials recommended by the manufacturers.

FIELD QUALITY CONTROL

Testing.--After installation, the equipment shall be aligned and adjusted and the Contractor shall perform complete pretesting. The Contractor shall determine, through pretesting, the compliance of the system with the requirements specified in these special provisions. The Contractor shall correct deficiencies observed in pretesting, and replace malfunctioning or damaged items with new ones, and retest until satisfactory performance and conditions are achieved. Forms shall be prepared for systematic recording of acceptance test results.

A factory-authorized service representative shall inspect field-assembled components and connections and to supervise pretesting, testing, and adjustment of the system.

After pretesting is complete, the Contractor shall provide a letter certifying the installation is complete and fully operable, including the names and titles of witnesses to the pretesting.

The Contractor shall provide a minimum of 10 days notice in writing when the system is ready for final acceptance testing, and shall provide a system test plan with the final test notice. The tests shall conform to the following requirements:

A. Verify all wiring is properly terminated, grounded and labeled.
B. Test each device for proper operation from the control cabinet.
C. Test the system for all specified functions according to the approved operation and maintenance manual.
D. Verify the viewing distance to the CMS, VMS, and the traffic signal.
E. Verify legibility of the CMS and VMS.

The Contractor shall correct deficiencies indicated by the tests and completely retest work affected by such deficiencies. The Contractor shall verify by the system test that the total system is in conformance with the requirements specified in these special provisions.

DEMONSTRATION AND TRAINING

The factory-authorized service representative shall perform a demonstration and train Department's maintenance personnel to adjust, operate, and maintain the tunnel traffic control system equipment as specified below:

A. Procedures for operating, troubleshooting, servicing, adjusting, and maintaining equipment.
B. Review data in Maintenance Manual.
C. Training shall be scheduled with the Engineer with at least seven days advance notice.
D. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

Tunnel traffic control system will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for tunnel traffic control system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the tunnel traffic control system, complete in place, including testing, and demonstration and training as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ ENVIRONMENTAL MONITORING SYSTEM

GENERAL

The environmental monitoring system for detection of carbon monoxide (CO) and nitrous oxide (NO) including monitors, mounting, wire and cable, testing and training shall conform to these special provisions. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--CO and NO detectors shall be installed in each tunnel as shown on the plans, to detect hazardous levels of the gases. Monitors shall read the level of CO and the level of NO in the tunnel at regular intervals and provide that data to the Direct Digital Control (DDC) system. Each monitoring location shall consist of one CO monitor and one NO monitor

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the environmental monitoring system as shown on the plans and as specified in these special provisions. The submittals shall include the following:

A. Manufacturer's technical data for each type of product in the environmental monitoring system.
B. Shop wiring diagrams showing detail wiring and differentiating between manufacturer-installed and field-installed wiring. Diagrams for equipment and for the system shall be included with all terminals and interconnections identified. Device locations and routings of raceway connections shall be indicated.
C. System operation description including detailed description of method of operation.
D. Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

QUALITY ASSURANCE

All equipment to be furnished and installed shall be compatible with the Direct Digital Control system specified in "Tunnel Control Systems" of these special provisions. The installation shall comply with NFPA 70, "National Electrical Code."

SYSTEM COMPONENTS

Gas Monitors.--Gas Monitors shall be housed in an aluminum, epoxy-coated enclosure. Sensors shall be mounted external to the monitor for easy replacement. Monitors shall be suitable for an installation in an outdoor environment and shall be designed for the detection of either CO or NO gas. The monitors shall operate in the diffusion mode. A sampling tube will not be required. The monitors shall be calibrated in the factory prior to shipping. The monitors shall have the following features:

A. Automatic calibration at field programmable intervals with no manual intervention required.
B. Internal relay contacts for FAULT, WARNING and ALARM.
C. Real time clock for time and date stamping of events.
D. Logging of minimum, maximum and average gas concentrations over field programmable time intervals.
E. Selectable lock-out of output signals during calibration.
F. Digital multi-drop communications.
G. Local display of the gas concentration, analog output of gas concentration, alarm indications and optional relay outputs.
H. Built-in temperature compensation.
I. Measuring Range: 0-500ppm; Accuracy 1ppm or less.

INSTALLATION

Wiring Installation.--Wire and cable shall conform to "Signal Conductors and Cable" of these special provisions.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in accordance with "Electrical Identification" of these special provisions.

Grounding.--Cable shields and equipment shall be grounded according to system manufacturer's written instructions to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.

Cleaning.--Paint splatters and other spots, dirt, and debris shall be removed. Scratches and marred finishes shall be touched up to match original finish. Units shall be cleaned thoroughly using methods and materials recommended by the manufacturers.

FIELD QUALITY CONTROL

Manufacturer's Field Service.--A factory-authorized service representative shall inspect field-assembled components and connections and supervise pretesting, testing, and adjustment of the system.

Pretesting.--After installation, the monitors shall be adjusted and the Contractor shall perform complete pretesting. The Contractor shall determine compliance of the system with the requirements as specified in these special provisions. The Contractor shall correct deficiencies observed in pretesting, and replace malfunctioning or damaged items with new ones, and retest until satisfactory performance and conditions are achieved.

After pretesting is complete, the Contractor shall provide a letter certifying the installation is complete and fully operable, including the names and titles of witnesses to pretesting.

Final Testing.--When the system is ready for final acceptance testing, the Contractor shall provide the Engineer, in writing, at least ten days advance notice. The Contractor shall provide a proposed test procedure with the final test notice. The minimum required tests shall be as follows:

A. Test each device for proper operation.
B. Test the system for all specified functions according to the operation and maintenance manual.
C. Verify that the DDC system is receiving the correct signals and alarms.
D. Verify all wiring for solid connections and grounding.

Retesting.--The Contractor shall correct deficiencies indicated by the tests and completely retest work affected by such deficiencies. The Contractor shall verify by the system test that the total system is in conformance with the requirement specified in these special provisions.

Report of Tests and Inspections.--The Contractor shall submit to the Engineer a written record of inspections, tests, and detailed test results in the form of a test log, on the satisfactory completion of tests. All equipment, stations, and other components at which tests have been satisfactorily completed shall be tagged to indicate completion of testing.

DEMONSTRATION AND TRAINING

A factory-authorized service representative shall perform the demonstration and train Department's maintenance personnel as specified in the following:

A. Train Department's maintenance personnel on procedures for troubleshooting, servicing, calibrating, and maintaining equipment.
B. Training Aid: use the final version of the operation and maintenance manual as a training aid.
C. Schedule training with the Department with at least seven days advance notice.
D. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

The environmental monitoring system will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for environmental monitoring system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the environmental monitoring system, complete in place, including wiring, testing, and demonstration and training, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ FIRE ALARM AND DETECTION SYSTEM

GENERAL

The fire alarm and detection system including furnishing and installing of manual pull stations, smoke detectors, heat detectors, duct detectors, linear heat detectors, signal equipment, controls, and wire and cable shall conform to the provisions in Section 86 "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions. The fire alarm and detection system shall also include devices testing and training. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--The fire alarm and detection system shall include a noncoded, addressable-analog system with manual and automatic alarm initiation, automatic heat and smoke detectors, and signal transmission dedicated to fire alarm service only. The fire alarm system shall monitor the status of the tunnel standpipe system and fire pumps. A Fire Alarm and Control Panel (FACP) shall be installed in the South Equipment Chamber to monitor all tunnel alarms including the linear detector system alarms, fire pumps and valves. A FACP shall be installed at the Operation and Maintenance Center (OMC) as shown on the plans to monitor all alarms at the OMC Building. The Tunnel FACP shall have a network connection to the OMC FACP.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the fire alarm and detection system as shown on the plans and as specified in these special provisions. The submittals shall include the following:

A. Manufacturer's technical data for each type of product in the fire detection system.
B. Shop wiring diagrams showing detail wiring and differentiating between manufacturer-installed and field-installed wiring. Diagrams for equipment and for the system shall be included with all terminals and interconnections identified. Device locations and routings of raceway connections shall be indicated.
C. Battery sizing calculations.
D. System operation description including method of operation and supervision of each type of circuit and sequence of operations for manually and automatically initiated system inputs and outputs
E. Operating instructions for mounting at each FACP.
F. Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.
G. In addition to distribution requirements for submittals specified in the Standard specifications and these special provisions, the Contractor shall provide the Engineer an identical submittal for submittal to the authorities having jurisdiction. The Contractor shall include copies of annotated contract plans as needed to depict component locations to facilitate review.
H. Certificate of Completion in compliance with NFPA 72.

QUALITY ASSURANCE

The fire detection system shall be installed by a certified representative of the FACP manufacturer for both installation and maintenance of units required.

The fire alarm and detection system shall be installed in compliance with NFPA 72, and all system components shall be UL listed.

DEFINITIONS

FTC: Fire Telephone Cabinet housing fire extinguisher, emergency telephone and manual pull station.

Definitions in NFPA 72 shall apply to fire alarm terms used in these special provisions.

SYSTEM COMPONENTS

FACP.--The fire detection system shall be controlled by the FACP, and shall automatically detect and report open circuits, shorts, and grounds of wiring for initiating device, and notification-appliance circuits.

Automatic alarm response functions resulting from an alarm signal from one device shall not be altered by subsequent alarm, supervisory, or trouble signals. An alarm signal shall have the highest priority. Supervisory and trouble signals shall have second and third level priority. Higher-priority signals shall take precedence over signals of lower priority, even when the lower priority condition occurs first. The system shall annunciate and display all alarm, supervisory, and trouble signals regardless of priority or order received. A signal from one device shall not prevent the receipt of other signals.

All signals shall be manually resettable from the FACP after initiating devices are restored to normal. The system shall automatically route alarm, supervisory, and trouble signals to the control panel in the OMC and the Oakland Traffic Management Cetner (TMC). The connection shall be made through the Direct Digital Control (DDC) system.

Loss of primary power at the FACP shall initiate a trouble signal at the FACP. The FACP shall indicate when the fire alarm system is operating on the secondary power supply.

Unless otherwise specified, operation of a manual station, automatic alarm operation of a smoke or heat detector, or automatic alarm operation of a linear heat detector shall initiate the following:

A. Notification-appliance operation.
B. Identification at the FACP of the origin of the alarm.
C. Transmission of an alarm signal to the control console in the OMC and to the Oakland TMC.
D. Shutdown of fans and other air-handling equipment serving area where the alarm was initiated.
E. Closing of smoke dampers in air ducts of system where alarm was initiated.
F. Recording of the event in the system memory.

Alarm silencing, system reset and indication shall be controlled by switches in the FACP and as follows:

A. Silencing-switch operation halts alarm operation of notification appliances and activates an "alarm silence" light. Display of identity of the alarm or device is retained.
B. Subsequent alarm signals from other devices reactivate notification appliances until silencing switch is operated again.

C. When alarm-initiating devices return to normal and system reset switch is operated, notification appliances operate again until alarm silence switch is reset.

Fire-pump power failure, including a dead-phase or phase-reversal condition, shall initiate the following:

A. A supervisory, audible, and visible "fire-pump power failure" signal indication at the FACP.
B. Recording of the event by the system memory.
C. Transmission of trouble signal to the Oakland TMC.

Removal of an alarm-initiating device or a notification appliance shall initiate the following:

A. A "trouble" signal indication at the FACP for the device involved.
B. Recording of the event by the system memory.
C. Transmission of trouble signal to the Oakland TMC.

The FACP shall print out alarm, supervisory, and trouble events, identifying the device and function, and including the type of signal (alarm, supervisory, or trouble), and date and time of occurrence. Alarm signals shall be differentiated from all other printed indications. System reset events shall also be printed out, including the same information for device, location, date, and time. Commands shall initiate the printout of a list of existing alarm, supervisory, and trouble conditions in the system and a historical log of events.

The FACP shall include an alphanumeric display, showing plain English language descriptions of alarm, supervisory, and trouble events, and addresses and locations of alarm-initiating or supervisory devices originating the report. The alphanumeric display shall also display monitoring actions, system and component status, system commands, programming information, and data from the system's historical memory.

The FACP shall be a mounted in a lockable steel enclosure. Interior components shall be arranged so operations required for testing or for normal maintenance of the system are performed from the front of the enclosure. If more than one unit is required to form a complete control panel, it shall be fabricated with a matching modular unit enclosure to accommodate components and to allow ample gutter space for field wiring and interconnecting panels. Each enclosure shall be identified with an engraved, red, laminated, phenolic-resin nameplate with lettering not less than 25 mm high. Individual components and modules within cabinets shall be identified with permanent labels. The FACP enclosure shall be surface-mounted.

Local visible and audible signals shall announce alarm, supervisory, and trouble conditions. Each type of audible alarm shall have a different sound.

Individual Light Emitting Diode (LED) devices shall identify transmitting signals. Lights shall distinguish between alarm and trouble signals, and indicate the type of device originating the signal. Manual switches and push-to-test buttons shall not require a key to operate. Controls shall include the following:

A. Alarm acknowledge switch.
B. Alarm silence switch.
C. System reset switch.
D. LED test switch.

The system shall prevent the resetting of alarm, supervisory, or trouble signals while the alarm or trouble condition still exists.

Alphanumeric display and system controls shall be arranged for interface between human operator at the FACP and addressable system components, including annunciation and supervision, and shall display alarm, supervisory, and component status messages, time and date, and the programming and control menu, with the following features:

A. Display: Liquid-crystal type, four line, 40 characters per line, minimum.
B. Keypad: Arranged to permit entry and execution of programming, display, and control commands.

A printed or typewritten instruction card shall be mounted behind a plastic or glass cover in a stainless-steel or aluminum frame at a location visible from the FACP. The card shall include interpretation and describe appropriate response for displays and signals. The card shall briefly describe the functional operation of the system under normal, alarm, and trouble conditions.

Manual Pull Stations.--Manual pull stations shall be fabricated of metal or plastic, and finished in red with molded, Braille and tactile letters operating instructions in white enamel.

Manual pull stations shall have a one step mechanism that is capable of being activated with a fist.

Manual pull stations mounted in the tunnel FTC shall have a weatherproof protective shield, including a factory-fabricated clear plastic enclosure, hinged at the top to permit lifting for access to initiate an alarm.

Detectors.--Detectors shall include the following features:

A. The operating voltage shall be 24 Volts DC, nominal.
B. Self-restoring: detectors shall not require resetting or readjustment after actuation to restore them to normal operation.
C. Plug-in arrangement: detector and associated electronic components shall be mounted in a module that connects in a tamper-resistant manner to a fixed base with a twist-locking plug connection. Terminals in the fixed base shall accept building wiring.
D. Integral visual-indicating light: LED type, indicating detector has operated.
E. Sensitivity: shall be able to be tested and adjusted in-place after installation.
F. Integral addressable module: shall be arranged to communicate detector status (normal, alarm, or trouble) to the FACP.
G. Remote controllability: unless otherwise indicated, detectors shall be analog-addressable type, individually monitored at the FACP for calibration, sensitivity, and alarm condition, and individually adjustable for sensitivity from the FACP.

Ionization Detector.--Ionization detector heads shall be sealed against back pressure, dust, dirt and insects, and shall include the following features:

A. Responsive to both visible and invisible products of combustion.
B. Self-compensating for changes in environmental conditions.
C. Integral insect-resistant screen.

Duct Smoke Detector.--A remote indicating lamp shall be installed for each duct smoke detector. Duct smoke detectors shall include the following features:

A. Sampling Tube: Design and dimensions as recommended by the manufacturer for the specific duct size, air velocity, and installation conditions where applied. The sampling tube shall extend the width of the duct.
B. Relay Fan Shutdown: Rated to interrupt fan motor-control circuit.
C. Integral filter system.
D. Capable of operating at air velocities from 90 to 1200 m/min.

Thermal Detector.--Thermal detectors shall detect both rate of rise and fixed temperature exceeding the following limits:

A. Rate of rise setting shall be approximately 8ºC per minute.
B. Fixed temperature setting shall be 60ºC.

Each detector shall be equipped with two sets of Normal Open contacts. Contacts shall actuate on temperature rise only.

Continuous Linear Heat-Detector System.--The continuous linear heat detector system shall consist of a detector cable and control unit, with the following features:

A. The detector cable shall comply with UL 521. The cable shall be suitable for ambient temperatures up to 65ºC. The alarm temperature shall be 88ºC. The cable shall include two steel actuator wires twisted together with spring pressure, wrapped with protective tape, and finished with PVC outer sheath. Each actuator wire shall be insulated with heat-sensitive material that reacts with heat to allow the cable twist pressure to short circuit wires at the location of elevated temperature.
B. The control panel shall be a multizone unit, and shall provide the same system power supply, supervision, and alarm features as specified for the FACP. The control panel shall be mounted in the South Equipment Chamber as shown on the plans.
C. Signals to the FACP: Any type of local system trouble shall be reported to the tunnel FACP as a composite "trouble" signal. Alarms on each detection zone shall be individually reported to the FACP as separately identified zones.
D. Integral addressable modules shall be arranged to communicate detector status (normal, alarm, or trouble) to the FACP for each detector zone.
E. Mounting: The linear heat detector shall be mounted to the tunnel ceiling as shown on the plans using a cable messenger. Stand-off brackets with a rubber grommet shall be installed every 15 m. Turnbuckles shall be installed on the cable messenger at minimum intervals of 75 m.

Notification Appliances.--Notification devices shall be equipped for mounting as shown on the plans and have screw terminals for system connections. Notification devices shall have the following features:

A. Combination devices shall be factory-integrated audible and visible devices in a single-mounting assembly.
B. Horns shall provide three audible alerts that can signal different alarm conditions. Horn power level shall be field selectable and set initially at 100 dBa.
C. Audible and visual signals in combination units shall be capable of operating independently or in unison.

D. Visible alarm devices shall be xenon strobe lights listed under UL 1971 with clear or nominal white polycarbonate lens, mounted on an aluminum faceplate. The word "FIRE" shall be engraved in minimum 25 mm high letters on the lens. The rated Light Output shall be 75 candela. Strobe leads shall be factory-connected to screw terminals.

Remote Device Location-Indicating Lights And Identification Plates.--An LED indicating light shall be provided near each smoke detector that is not readily visible. The light shall be connected to flash when the associated device is in an alarm or trouble mode. The lamp shall be flush mounted in a single gang wall plate. A red, laminated, phenolic-resin identification plate at the indicating light shall identify, in engraved white letters, the device initiating the signal and room where the detector is located.

Remote Annunciator Panel.--The annunciator panel shall be mounted in the control console in the OMC as shown on the plans. The panel shall consist of an array of LED to show point status of fire alarm points. The annunciator panel shall have a system trouble LED indicator, local sounder for alarm conditions and an alarm silence and acknowledge button.

Emergency Power Supply.--The emergency power supply components shall include a gel-cell type battery, charger, and an automatic transfer switch. The battery shall not require ventilation. The battery capacity shall comply with NFPA 72.

The battery charger shall be solid-state, fully automatic, variable charging rate type, and shall provide capacity for 150 percent of the connected system load while maintaining batteries at full charge. If batteries are fully discharged, the charger shall recharge them completely within four hours. Charger output shall be supervised as part of the system power supply supervision.

An integral automatic transfer switch shall be provided that transfers the load to the battery without loss of signals or status indications when normal power fails.

Addressable Interface Device.--A microelectronic monitor module listed for use in providing a system address for listed fire and sprinkler alarm-initiating devices with normally open contacts. The module shall have an indicating LED to indicate alarm:

A. Monitor module: The module shall monitor dry contact initiating devices. It shall provide a unique address to the FACP.
B. Control module: The module shall supervise and control devices and wiring. The module shall have SPDT contacts rated for 2 A @28 V DC; 300 mA @120 V AC.

INSTALLATION

The FACP shall be connected with a disconnect switch with lockable handle or cover. The disconnect switch shall be painted red and labeled "FIRE ALARM."

All devices shall be mounted on a standard electrical backbox. Pull stations mounted in a FTC in the tunnel shall be mounted on a faceplate as shown on the plans.

The linear detector shall be installed on a messenger system suspended from the tunnel ceiling as shown on the plans. The turnbuckle shall be tightened to a maximum of 80 kilograms tension on the messenger.

The linear detector shall be terminated with an end of line resistor housed in a NEMA 4A enclosure with compression strain relief.

Ceiling-mounted smoke and thermal detectors shall be installed not less than 150 mm from a side wall to the near edge. Detector units shall not be installed until all other construction in the area is complete.

Installation of duct smoke detectors shall comply with manufacturer's written instructions and the following:

A. Verify that each unit is listed for the complete range of air velocity, temperature, and humidity possible when air-handling system is operating.
B. Install remote indicating lamp so indication is visible.

Visible and combination audible/visible alarm-indicating devices shall be installed not less than 150 mm below the ceiling. Horns and strobes shall be installed on flush-mounted back boxes with the device-operating mechanism concealed behind a grille.

Wiring Installation.--Wire and cable shall conform to "Signal Conductors and Cable" of these special provisions.

Fire alarm system junction boxes and covers shall be painted in red.

Wiring for the fire alarm system shall be kept physically and electrically separate from all other power and signal system wiring.

Detector wiring shall be Class B in accordance with NFPA 72. Notification circuits shall be Style Y. Control circuits shall be Class B with an end of line resistor on the last device on the circuit.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in accordance with "Electrical Identification" of these special provisions.

Grounding.--Cable shields and equipment shall be grounded according to system manufacturer's written instructions to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.

Cleaning.--Paint splatters and other spots, dirt, and debris shall be removed. Scratches and marred finishes shall be touched up to match original finish. Units shall be cleaned thoroughly using methods and materials recommended by the manufacturers.

FIELD QUALITY CONTROL

Manufacturer's Field Service.--A factory-authorized service representative shall inspect field-assembled components and connections and supervise pretesting, testing, and adjustment of the system.

Pretesting.--After installation, the system shall be aligned and adjusted and the Contractor shall perform complete pretesting. The Contractor shall determine the compliance of the system with the requirements specified in these special provisions. The Contractor shall correct deficiencies observed in pretesting, and replace malfunctioning or damaged items with new ones, and retest until satisfactory performance and conditions are achieved.

After pretesting is complete, the Contractor shall provide a letter certifying the installation is complete and fully operable, including the names and titles of witnesses to pretesting.

Final Testing.--When the system is ready for final acceptance testing, the Contractor shall provide the Engineer, in writing, at least ten days advance notice. The Contractor shall provide a proposed test procedure with the final test notice. The system shall be tested in compliance with procedures in NFPA 72. The minimum required tests shall be as follows:

A. Verify that the control unit is in the normal condition as detailed in the manufacturer's operation and maintenance manual.
B. Test initiating and indicating circuits for proper signal transmission under open circuit conditions. One connection each should be opened at not less than 10 percent of initiating and indicating devices.
C. Test each initiating and indicating device for alarm operation and proper response at the control unit. Test smoke detectors with actual products of combustion.
D. Test the system for all specified functions according to the operation and maintenance manual. Systematically initiate specified functional performance items at each station, including making all possible alarm and monitoring initiations and using all communications options. For each item, observe related performance at all devices required to be affected by the item under all system sequences. Observe indicating lights, displays, and signal tones.
E. Test Both Primary and Secondary Power: Verify that the secondary power system is capable of operating the system for the period and in the manner specified.

Retesting.--The Contractor shall correct deficiencies indicated by the tests and completely retest work affected by such deficiencies.

Report of Tests and Inspections.--The Contractor shall submit to the Engineer a written record of inspections, tests, and detailed test results in the form of a test log, upon the completion of tests.

All equipment, stations, and other components at which tests have been satisfactorily completed shall be tagged to indicate completion of testing.

DEMONSTRATION AND TRAINING

A factory-authorized service representative shall perform the demonstration and train Department's maintenance personnel as specified below:

A. Train Department's maintenance personnel on procedures and schedules for troubleshooting, servicing, adjusting, and maintaining equipment and schedules.
B. Training Aid: use the final version of the operation and maintenance manual as a training aid.
C. Schedule training with the Department with at least seven days advance notice.
D. Conduct training in accordance with "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

Fire alarm and detection system will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for fire alarm and detection system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the fire alarm and detection system, complete in place, including wiring, testing, and demonstration and training, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ SIGNAL SYSTEM CONDUCTOR AND CABLE

GENERAL

Signal system conductor and cable shall conform to the provisions in Section 86.2-08, "Conductors" and Section 86.2.09 "Wiring" of the Standard Specifications and these special provisions. Signal system conductor and cable shall include the following:

A. Coaxial cable.
B. Twisted-pair cable.
C. Multi-conductor cable.
D. Single conductor cable.
E. Optical fiber cable.
F. Optical fiber connectors and couplers.

SUMMARY

Scope.--Wire and cable shall be installed as shown on the plans for the following Systems:

A. CCTV System.
B. Telephone System.
C. Environmental Monitoring System.
D. Radio Rebroadcast System.
E. Intrusion Detection System.
F. Fire Alarm and Detection System.
G. Tunnel Traffic Control System.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions. The submittals shall also include the following:

A. Manufacturer's technical data for signal system conductors and cable and optical fiber connectors.
B. Field test reports indicating and interpreting test results for compliance with performance requirements.
C. Operation and Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

QUALITY ASSURANCE

All cable of each type shall be obtained through one source from a single manufacturer. Products shall be listed and labeled as defined in NFPA 70, Article 100.

The Contractor shall comply with NFPA 70, and NFPA 502.

The Contractor shall coordinate with and obtain review of cable characteristics and certification for use with the connected system equipment by the connected equipment manufacturers.

COPPER CABLE

Multiconductor Cable.--Multiconductor cable shall be No. 19 AWG solid annealed copper conductors; color-coded in accordance with telephone industry standards, with low-loss insulation, aluminum and Mylar shield, gel filled, complying with PE 39. Telephone cable shall be installed for the connections between the OMC Building MDF and the backboards in each equipment chamber.

Twisted Pair Cable.--Twisted pair cable shall be tinned copper conductors, color-coded, rated for 90ºC, unshielded. Telephone system cable installed in the OMC Building shall be 4-pair, Category 6. Telephone cable installed in the tunnel shall be No. 22 AWG. Fire alarm system cable shall be fire rated cable, No 16 AWG minimum.

Single Conductor.--Single Conductor cable shall be solid copper conductors, No. 18 AWG minimum, rated for 90deg C, with color-coded insulation.

Coaxial Cable.--Coaxial cable shall be 100 percent factory-sweep tested in conformance with NFPA 70. Coaxial cable shall be flexible, 22 mm maximum; cellular-polyethylene dielectric, solid copper outer conductor, copper inner core and fire retardant jacket. Attenuation at 800 MHz: 1.20 dB per 30 m maximum. Minimum bending radius shall be 125 mm. Coaxial cable connectors shall be Type N, 50 ohms. PVC insulation or jacket shall not be used in the tunnel. CCTV system coax shall be 75-ohm nominal impedance cable. Coaxial cable for the radio rebroadcast system shall be 50-ohm nominal impedance cable.

Ethernet Cable.--Cable for Ethernet connections for the video and data systems shall be Category 6 cable.

Insulation.--Conductors for the OMC Building indoor circuits shall be Type THHN/THWN or XHHW-2, 90ºC, in raceway. Conductors for the OMC building fire alarm system shall be FEP fire alarm rated cable.

Conductors in the tunnel and exterior to the OMC Building shall be Type XHHW-2, 90ºC, in raceway. PVC insulation or jacketed cable shall not be used in the tunnel. Cable shall be rated for installation in an outdoor, wet environment when installed outside the OMC Building.

OPTICAL FIBER CABLES AND CONNECTORS

Optical Fiber Cable.--Unless otherwise shown on the plans, interconnect cable shall be single mode optical fiber cable. Single mode fiber optic cable shall support transmission at 1310/1550 nm with a maximum attenuation of 0.5 dB/km. Cable shall be rated for installation in an outdoor, wet environment when installed outside the OMC Building.

Optical Fiber Connectors.--Optical fiber connectors shall be stainless steel connectors with quick-connect features, with insertion loss of not greater than 1.0 dB, and shall be SC type.

INSTALLATION

Raceways and other elements to receive cables shall be examined for compliance with requirements for installation tolerances and other conditions affecting performance of transmission media. Raceways shall be clean and clear prior to beginning installation of cable.

Transmission media shall be installed without damaging conductors, shield, or jacket. Cable, in handling or installation, shall not be bent to smaller radii than the minimum recommended by the manufacturer.

Cables shall be pulled without exceeding the cable manufacturer's recommended pulling tensions. Cables shall be pulled simultaneously if more than one is being installed in the same raceway. Pulling compound or lubricant shall be used where necessary; the compound used shall not deteriorate conductors or insulation. Pulling means, including fish tape, cable, rope, and basket-weave wire or cable grips, shall not damage media or raceway.

Exposed cables shall be installed parallel and perpendicular to surfaces or exposed structural members, and follow surface contours where possible.

Splice connectors shall be compatible with the cable material. Splices shall not be made except at splice points shown on the plans.

Penetrations by cables through fire-rated elements shall be fire-stopped in accordance with "Basic Electrical Materials and Methods" of these special provisions.

Cable shields shall be bonded to ground at only one point in each circuit. Components shall be connected to wiring systems and to ground as shown on the plans and as recommended by the manufacturer.

All cables shall be identified in accordance with "Electrical Identification" of these special provisions.

FIELD QUALITY CONTROL

Copper Cable Testing.--Cables shall be inspected for physical damage and tested for continuity and shorts. Cable segments shall be tested for faulty connectors, splices, terminations, and the integrity of the cable and its component parts. Written test reports shall be submitted to the Engineer.

Optical Fiber Cable Testing.--All visual and mechanical inspections and field tests, including optional procedures, stated in NETA ATS, Section 7.25 shall be performed to verify physical condition and proper installation. The Contractor shall certify compliance with test parameters and manufacturer's written instructions. Malfunctioning cables shall be replaced and retested. Written test reports shall be submitted to the Engineer.

PAYMENT

Full compensation for signal system conductor and cable shall be considered as included in the contract lump sum prices paid for various items of systems work and no separate payment will be made therefor.

10-4.__ TELEPHONE SYSTEM

GENERAL

The telephone system shall consist of the Operation and Maintenance Center (OMC) telephone system and the tunnel emergency system. The telephone system shall be furnished, installed, and tested in conformance to the details shown on the plans and these special provisions. The OMC telephone system shall include a Private Branch Exchange (PBX) in the OMC Building, backboards, termination blocks, jacks, wire and cable, and telephones. The tunnel emergency system shall include backboards, termination blocks, jacks, wire and cable, and telephones. Conduit and raceway shall conform to "Raceways and Boxes" of these special

provisions. Ductbank shall conform to "Underground Ducts and Vaults" of these Special provisions.

SUMMARY

Scope.--Office telephones shall be installed at the OMC. Emergency telephones shall be installed in the Fire Telephone Cabinets (FTC) at intervals through the tunnel. In addition, one emergency telephone shall be installed on the approach roadway in each direction as shown on the plans. Telephone cables shall be installed in the ductbank between the OMC and the tunnel and shall terminate on the backboard in the equipment chambers.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the telephone system as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Manufacturer's technical data for each type of product in the telephone system.
B. Interconnection diagram showing all instruments and wiring.
C. Operation and Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods".

QUALITY ASSURANCE

Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. The system and components shall comply with NFPA 502. All system components shall be UL Listed.

DEFINITIONS

Distribution Circuit: A circuit from the network interface device to a telecommunications outlet.

Main Distribution Frame (MDF): Backboard and terminal blocks for distribution and station circuits.

Fire telephone cabinet (FTC) houses fire extinguisher, emergency telephone and manual pull station.

SYSTEM COMPONENTS

PBX.--The PBX shall conform to the following design criteria:

A. Capacity of 200 stations expandable to 800.
B. Capacity to support up to 50 Central Office lines.
C. Unit contained within a wall-mounted cabinet.
D. 120 V(ac) power.
E. 1700 BTU/hour maximum.
F. Standard PBX features shall be supported including ring-down, call forward, conference call, and power fail transfer functions.

Audio Recorder.--Audio recorder shall be digital with 145 hours of recording capability. Recordings shall be downloadable to computer. The Contractor shall make available audio circuits at 0 dBm level for input to voice recording equipment. Recording circuits shall be available for all emergency telephone conversations. The Contractor shall provide terminations at the MDF for recording all emergency telephone conversations and radio system announcements. The audio recorder shall have an FCC Part 68 compliant telephone interface. The recorder shall provide time and date stamping to enable easy retrieval of messages.

Other Components.--Telecommunications outlets shall be standard RJ-45 jack mounted in electrical box with a flush mounting wall plate in the OMC Building. Jacks for emergency telephones shall be RJ-11. Wall plates shall be designed for telephone service and shall match those indicated for power receptacle outlets in same spaces for materials and finish. Wall plates for wall telephone units shall include provision for support of unit.

Backboards shall be 20 mm, fire-proofed interior grade plywood. Backboards shall be the size indicated on plans. Backboards shall be painted black.

Emergency telephones will be State-Furnished in conformance with the provisions in "Materials" of these special provisions.

Wall mount and desk telephones shall be standard, single-line beige telephones and shall be installed in the OMC at all jack locations as shown on the plans. Telephones shall be compatible with the PBX system.

Standard punch-down blocks shall be used for termination blocks for the main distribution frame in the OMC and in the equipment chambers. Termination blocks for incoming distribution cable and cable routed through the tunnel shall include isolation and surge suppression. Signal Amplifiers shall be installed in the telephone cable system if required to ensure that emergency telephones are functional.

INSTALLATION

Wire and cable shall conform to "Signal Conductors and Cable" of these special provisions.

Coordination.--The Contractor shall coordinate the ordering and installation of telephone company circuits through the State.

PBX.--The PBX shall be installed in the OMC Building as shown on the plans and in accordance with the manufacturer's recommendations. The PBX shall be programmed as shown on the plans and as specified in these special provisions.

Telephones.--Telephones shall be secured with anti-tamper screws.

The telephones shall be programmed as follows:

A. Tunnel emergency telephones shall ring directly to the Oakland TMC.
B. Telephones in the OMC control room shall be capable of picking up the tunnel emergency phones.
C. Telephones in the equipment chambers shall not allow outgoing long distance calls.
D. Loss of AC power to the PBX shall initiate power failure transfer of calls to the OMC Control room.

Connections.--

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in conformance with "Electrical Identification" of these special

provisions. The telephone system backboard shall be identified with the legend "Telephone." Identification labels shall be provided to indicate location of telephones served from each termination block.

Grounding.--Cable shields and equipment shall be grounded according to system manufacturer's written instructions to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.

FIELD QUALITY CONTROL

Testing.--Test results shall be documented in writing and submitted to the Engineer prior to final acceptance of the telephone systems. The following field quality control testing shall be performed:

A. Test continuity of each circuit pair loop.
B. Test operation of each phone.
C. Test operation of PBX.

1. Verify operation of all telephones including tunnel and roadway emergency phones.
2. Confirm programming operation as specified.
3. Verify PBX functions.
4. Confirm transfer of incoming line on loss of power.
5. Verify operation of Audio Recorder.

DEMONSTRATION AND TRAINING

The factory-authorized service representative shall perform the demonstration and train Department's maintenance personnel to adjust, operate, and maintain telephone equipment including the following:

A. Procedures and schedules for troubleshooting, servicing, and maintaining equipment.
B. Review data in maintenance manuals.
C. Training shall be scheduled with the Engineer with at least seven days advance notice.
D. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

Telephone system will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for telephone systems shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the telephone systems, complete in place, including wiring, testing, and demonstration and training, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ CCTV SYSTEM

GENERAL

The closed circuit television (CCTV) system, including cameras, mounting, power supplies, media converters, software, switchers, servers, patch panels, wire and cable, testing and training for all CCTV equipment furnished and installed in the tunnel and at the Operation and Maintenance Center (OMC) Building for traffic and security surveillance, shall conform to the provisions in Section 86 "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

SUMMARY

Scope.--Color digital CCTV cameras shall be furnished and installed in the tunnel, approach roadways and at the OMC. Each camera shall have a pan, tilt, and zoom unit that can be controlled from the OMC or from the Oakland TMC. An Ethernet switcher shall be provided in the OMC to allow the video to be viewed at the OMC and at the TMC. A video recorder shall be provided to record the video of all cameras in the system. Two workstations with video control software shall be provided at both the OMC and at the Oakland Traffic Management Center (TMC).

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the telephone system as shown on the plans and as specified in these special provisions. The submittals shall include the following:

A. Manufacturer's technical data for each type of product in the CCTV system, including data on features, ratings, and performance.
B. Shop drawings for television equipment, including plans, elevations, sections, details, and attachments to other work, plan views of device locations and routing of raceway connections, and wiring diagrams showing power, signal, and control wiring, differentiating between manufacturer-installed and field-installed wiring.
C. Coordination plans drawn to scale coordinating locations of television equipment, showing ceiling suspension assembly members, method of attaching mounting brackets to tunnel and building structure, and location of items requiring installation coordination including lighting fixtures, tunnel fans, radio antennas and other tunnel or building features.
D. Operation and Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.
E. Warranties specified in these special provisions.

QUALITY ASSURANCE

The CCTV system shall be installed by an installer who is a certified representative of the television equipment manufacturer, for both installation and maintenance of units required.

Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. The system and components shall comply with NFPA 70 and 47 CFR 15, 17, and 76.

Outdoor installation shall comply with ANSI C2 and the National Electrical Safety Code.

Shop Testing.--Prior to installing the CCTV system equipment the Contractor shall test the equipment as recommended by the manufacturer to verify compliance of the system operation with these special provisions.

PROJECT CONDITIONS

Environmental Limitations.--Outdoor equipment shall be capable of operating continuously under the following service conditions:

A. Temperature: -12ºC to +50ºC.
B. Relative Humidity: 5 to 100 percent.
C. Weather: Protect connections and equipment to prevent entry of moisture due to rain or fog.

Indoor equipment shall be capable of operating continuously under the following service conditions:

A. Temperature: 0ºC to 40ºC.
B. Relative Humidity: 0 to 95 percent.

WARRANTY

A warranty for the television system and components shall be provided and signed by the manufacturer and installer agreeing to correct system deficiencies and replace components that fail in materials or workmanship. The warranty shall be two years from the date of system in service.

SYSTEM COMPONENTS

All materials provided shall be compatible with the existing Caltrans CCTV Surveillance system at the Oakland TMC.

Cameras.--Cameras shall provide a single digitized video stream with a built-in IP server and shall meet the following parameters:

A. 6.3 mm CCD imager.
B. IR filter
C. Sensitivity: 0.4 lux
D. MJPEG
E. NTSC
F. 480 TVL resolution
G. Auto Tracing Color Balance
H. Auto Iris Lens Drive and Direct Drive Lens control
I. Video Performance: up to 15fps at CIF resolution with MJPEG
J. Network Protocol: Internet IP, TCP

An external power supply shall provide the required operating voltage and be within specified parameters for ac supply voltages within the range of 105 to 130 V.

The camera shall have an RS 422 connection to provide control of pan, tilt, and zoom functions. The control format shall be capable of operating at 4800, 9600 or 19,200 baud.

The zoom lens shall have a variable speed of 0 to 200 degrees per second, with a maximum optical zoom of 16x and a digital zoom of 8x. The focal range shall be 4 mm to 64 mm and the aperture shall be f/1.4 maximum.

The pan speed shall be 6 degrees per second and the tilt speed shall be 3 degrees per second minimum. The pan and tilt unit shall have the capability of preset positions. The pan and tilt unit shall be UL Listed.

Environmental Housing.--The camera shall be installed in an environmental housing unit. The housing unit shall be suitable for mounting with a pan and tilt unit. The unit shall be provided with a sunshield for cameras mounted external to the tunnel. The housing shall be equipped with a 120 V AC outlet. The enclosure shall be equipped with a blower and a heater for environmental control. The unit shall provide housing for the camera, power supply and media converter.

Network Switch.--The network switch shall be an Ethernet switch with a capacity of 48 10/100 ports and two GBIC based Gigabit Ethernet ports. The network switch shall have 4MB memory architecture shared by all ports, and 64 MB DRAM and 16 MB flash memory. The switch shall meet IEEE 802.3 full duplex on 10Base-T, and IEEE 802.3u on 100Base-T ports.

Internal power supply shall support input voltages between 100 and 240 V AC.

Advanced IP routing shall be provided with data security to protect the system from tampering and from unauthorized use.

The switch shall be provided with built-in web-based management software to provide a web-based management interface through a standard web browser.

Codec.--An IP codec shall be provided to allow real-time video and control data to be transmitted over an Ethernet data network. The codec shall provide an interface between the network switch and PC for viewing video and control of PTZ units. The video format shall be user configurable H.261 or MJPEG.

Workstation.--The workstation processor shall consist of two processors with 800 MHz front side bus and 1ML2 cache, with 128 MB RAM minimum. The operating system shall be provided with 512 MB ECC 400 MHz DDR2 ECC registered memory standard, 4MB flash memory, web browser software, and Ethernet network interface card. The operating system provided shall be identical to the existing TMC workstation operating system. VGA graphic support shall be provided with minimum 64MB memory, dual monitor capability. The hard drive shall be 7200 RPM 80GB minimum.

I/O ports shall include: 8 Standard USB ports, 2 Serial ports, 1 parallel port, keyboard, mouse, RJ-45, stereo line-in (minijack), speakers and line-out (minijack) and headphone (minijack – front); and IEEE 1394a PCI Controller.

Removable storage shall include 1.44 MB FDD; CD-RW/DVD-ROM; DVD+RW. The monitor shall be a 540 mm Flat Panel LCD, color monitor, with a height-adjustable stand. The keyboard shall be QWERTY standard.

Software.--IP webserver software shall be provided to enable viewing video images on any PC in any standard web browser environment. Webserver software shall support RS 422 serial

data to control PTZ units through the PC. PTZ control shall be accomplished by on-screen commands. The webserver shall provide high quality, high frame rate video and shall be compatible with MJPEG compression. The webserver shall be compatible with VGA video resolutions.

Controller software shall be provided for a system with multiple points of PC control. Software shall have a graphical user interface. Software shall enable configuration of all network devices and parameters for delivery of video, for PTZ control, and for recording. Controller software shall provide on-screen display of camera and monitor titles.

Network Video Recorder software shall support digital storage of video recordings on a PC server. Recorder shall provide digital storage of video recordings. Video recorder shall support MJPEG video standards and TCP communication protocols. Recorder software shall allow playback while recording, and playback to PC monitor. Recorder software shall provide time and date stamping for authentication and verification purposes.

Signal Transmission Components.--A media converter and transceiver shall be provided including video transmitter and receiver to allow transmission of video and two-way data over a pair of optical fibers for the tunnel cameras. The media converter shall convert twisted pair Ethernet to transmission over a fiber optic cable and shall be compatible with MJPEG digital video. The fiber optic transceiver shall be compatible with RS-422 data encoding. The data channel shall support pan, tilt and zoom control of camera. The media converter shall be mounted in camera housing. The fiber optic transmitter and receiver for data channel shall be rack mountable in 483 mm EIA rack. The unit shall be capable of transmitting a distance up to 25 miles without repeaters. The transmitter shall provide output power of –16 dB and the receiver shall have a sensitivity of –30 dB.

The Contractor shall supply and install a floor-mounted patch panel rack as shown on the plans. The rack shall be a standard EIA 483 mm rack with EIA mounting hole spacing. The rack shall be manufactured of aluminum alloy and painted black.

The Contractor shall supply and install a fiber optic patch panel in the patch panel rack. The patch panel shall have capacity for termination of up to 144 fibers. Fiber optic connectors shall be SC type. The patch panel shall have space for printed labels for each port. The patch panel shall have a removable clear poly-carbonate tinted front door. A jumper management panel for wire management shall be provided and installed above the patch panel. Fiber from the cameras shall be terminated at the patch panel.

INSTALLATION

Coordination.--The Contractor shall coordinate installation of equipment in the Oakland TMC with TMC staff.

Wiring Installation.--Wire and cable shall conform to "Signal Conductors and Cable" of these special provisions.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in accordance with "Electrical Identification" of these special provisions.

Grounding.--Cable shields and equipment shall be grounded according to system manufacturer's written instructions to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.

Cleaning.--Paint splatters and other spots, dirt, and debris shall be removed. Scratches and marred finishes shall be touched up to match original finish. Units shall be cleaned thoroughly using methods and materials recommended by the manufacturers.

Camera Installation.--Cameras shall be installed at locations as shown on the plans, setting pan and-tilt unit stops to suit final camera position and to obtain the optimum field of view required for camera.

FIELD QUALITY CONTROL

Manufacturer's Field Service.--A factory-authorized service representative shall inspect field-assembled components and connections and supervise pretesting, testing, and adjustment of the CCTV system equipment.

Pretesting.--After aligning and adjusting the system, components, wiring, and functions shall be pretested to verify that they comply with specified requirements. Malfunctioning or damaged items shall be replaced, and the system shall be retested. The equipment shall be prepared for acceptance and operational testing.

Testing.--The Contractor shall schedule tests after pretesting has successfully been completed and system has been in normal functional operation for at least 14 days. The Contractor shall notify the Engineer at least 10 days prior to testing. Operational system tests shall be performed to verify that system complies with the requirements specified in these special provisions. Tests shall include all modes of operation. Test results shall be recorded and submitted to the Engineer.

The Contractor shall correct deficiencies identified by tests and observations and retest.

DEMONSTRATION AND TRAINING

A factory-authorized service representative shall perform the demonstration and train the Department's maintenance personnel to adjust, operate, and maintain CCTV equipment, as follows:

A. Train Department's maintenance personnel on procedures and schedules for troubleshooting, servicing, and maintaining equipment.
B. Demonstrate methods of determining optimum alignment and adjustment of components and settings for system controls.
C. Review data in maintenance manuals.
D. Schedule training with the Department with at least seven days advance notice.
E. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

CCTV system will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for CCTV system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the CCTV system, complete in place, including wiring,

software, testing, and demonstration and training, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ RADIO REBROADCAST SYSTEM

GENERAL

Radio rebroadcast system, including furnishing and installing of the radio rebroadcast system equipment shall conform to the provisions in Section 86 "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions. Radio rebroadcast system shall include antennas, fiber optic and coaxial cables, signal transmission, amplifiers, termination equipment, testing and training.

SUMMARY

Scope.--Antennas shall be installed at the Operation and Maintenance Center (OMC) Building to provide a path for VHF and UHF signals into the tunnel. RF signals shall be transmitted over fiber optic cable to the south equipment chamber. Bi-directional amplifiers shall amplify the signal prior to be transmitted into the tunnel over the tunnel antenna system. AM and FM antennas mounted at the tunnel portal shall take entertainment radio signals off-air for retransmission into the tunnel. An emergency override system shall provide the ability to override the entertainment radio signals and broadcast pre-recorded or live emergency messages over the tunnel antenna system.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and the requirements specified herein.

Product data.--The submittals shall include complete details, information, and drawings for the telephone system as shown on the plans and as specified in these special provisions. The submittals shall include the following:

A. Manufacturer's technical data including detailed manufacturer's specifications for each component in the radio rebroadcast system, including data on features, ratings, and performance.
B. Signal strength calculations, prepared for the system to be installed. Calculations shall be prepared for the path out of the tunnel and the path into the tunnel to verify system performance. Calculations shall be prepared using the signal strength from the base station, measured at the site of the OMC Building for each channel to be rebroadcast into the tunnel.
C. Shop drawings of radio equipment, including plans, elevations, sections, details, attachments to other items, and plan views of equipment locations and routing of raceway connections.
D. Shop wiring diagrams of power and signal wiring, differentiating between manufacturer-installed and field-installed wiring.
E. Coordination plans drawn to scale and coordinating locations of radio equipment, including slotted coaxial cable antenna hangers and method of attaching hangers to

building structure, and location of items requiring installation coordination including lighting, access panels, and other architectural features.

F. Maintenance data to be included in the maintenance manuals shall conform to "Basic Electrical Materials and Methods" of these special provisions.

QUALITY ASSURANCE

All electrical equipment shall be UL listed. The system and components shall comply with NFPA 70, NFPA 780, and all applicable FCC requirements. Outdoor installation shall comply with ANSI C2, "National Electrical Safety Code."

The AM radio rebroadcast system shall meet CFR Title 47 Part 15 Subpart C Sections 15.211 and 14.221 requirements. The FM radio rebroadcast system shall meet CFT Title 47 Part 15 Subpart C Sections 15.211 and 15.239 requirements.

Shop Test.--Prior to installing the radio rebroadcast system equipment the Contractor shall test the equipment as recommended by the manufacturer. The system shall be tested to verify compliance of the system operation with these specifications.

PROJECT CONDITIONS

Environmental Limitations.--Outdoor equipment shall be rated for continuous operation under the following service conditions:

A. Temperature: -12ºC to +50ºC.
B. Relative Humidity: 5 to 100 percent.
C. Weather: Protect connections and equipment to prevent entry of moisture due to rain or fog.

Indoor equipment shall be rated for continuous operation under the following service conditions:

A. Temperature: 0ºC to 40ºC.
B. Relative Humidity: 0 to 95 percent.

Project Performance Criteria.--AM radio stations are considered to be local if its reception at the portal has a signal strength within 40 dB below the average of the stronger stations or greater than 10mV/m. FM radio stations are considered to be local if its reception at the tunnel portal has a signal strength within 40 dB below the average of the stronger stations or greater than 700 uV/m.

VHF/UHF Rebroadcast System shall be configured to meet the following system signal strength criteria:

A. Measured signal strength in the tunnel: -90 dB minimum
B. Measured signal strength 50' from the OMC Building: -10 dB nominal

WARRANTY

A warranty for radio system and components shall be provided, consisting of a written warranty, signed by the manufacturer and installer agreeing to correct system deficiencies and to replace components that fail in materials or workmanship. The warranty period shall be two years from the date of system in service.

SYSTEM COMPONENTS

VHF/UHF Repeater Amplifiers.--Repeater amplifiers shall receive, amplify and transmit radio signals in their frequency range. Bi-directional Amplifiers shall have the following features:

A. Minimum 60 dB gain in each direction; Gain shall be programmable.
B. Input Impedance: 50 ohms.
C. RF Output Power: 5W minimum.
D. Noise: 9 dB maximum.
E. FCC Type Accepted.
F. Power Supply: 120 V AC.

Frequencies (MHz) to be rebroadcast are shall be as follows:

	Agency	Output	Input
UHF			
	CO Trunked	482.4750	485.4750
		482.0625	485.0625
		488.2250	491.2250
		488.2500	491.2500
		488.2750	491.2750
	TAC1	488.8625	491.8625
	CWMA	488.8875	491.8875
	Pacifica PD	488.7375	491.7375
	HMB PD	488.3875	491.3875
VHF			
	Fire Control 1B	154.3400	159.0750
	Fire Control 21B	154.4450	160.0650
	FMA	154.2800	154.2800

Repeater amplifiers shall be provided with integral preselect filters, and shall be housed in a wall mount, painted steel enclosure rated in accordance with NEMA standards.

Repeater Amplifiers shall be installed in the tunnel antenna system if required to meet the performance criteria based on the Contractor's signal strength calculations.

AM/FM Rebroadcast System.--The AM radio rebroadcast system shall have provisions to rebroadcast up to 21 channels. The FM radio rebroadcast system shall have provisions to rebroadcast up to 35 channels.

The AM radio amplifier shall provide sufficient RF power to each channel to produce a signal in the tunnel with field strength of 2mV/m. FM field strength in the tunnel shall be 10uV/m.

The AM and FM rebroadcast sub-systems shall include channelized receivers and converters, power splitters and override function to allow broadcast of messages in the tunnel. Each station shall have an individual processor module. Modules shall be interchangeable and programmable in frequency. Failure of one processor shall not affect the remaining stations.

AM System Criteria: The input stage shall have an automatic gain control of 40dM minimum, a minimum sensitivity of -80 dBm for EIA 12 dB SINAD, an input impedance of 50 ohms and a selectivity of at least -20 dB at 15 kHz and greater than -40 dB at 40 kHz from the

selected station. Output converters shall have an output impedance of 50 ohms, a spurious and harmonics signals level of 60 dB below the carrier minimum, a maximum RF output of 0 dBm and a minimum adjustable output range of 10 dB.

FM System Criteria: The input stage shall have an automatic gain control of 40dM minimum, a minimum sensitivity of -80 dBm for EIA 12 dB SINAD, an input impedance of 50 ohms and a selectivity of at least -20 dB at 150 kHz and greater than -40 dB at 250 kHz from the selected station. Radio channel spacing shall be 400 kHz. Output converters shall have an output impedance of 50 ohms, a spurious and harmonics signals level of 60 dB below the carrier minimum, a maximum RF output of 0 dBm and a minimum adjustable output range of 10 dB.

Emergency Override.--The Emergency Override system shall accommodate both prerecorded and live messages to be broadcast over the AM/FM radio system in to the tunnel. The system shall have capabilities to allow local or remote control.

The emergency override system shall consist of a digital voice recorder and an override system controller. Two independent audio channels shall be provided to allow different messages to be broadcast in each bore. Each channel shall have the capability to record up to ten continuously repeating messages. Messages shall be entered into memory either by a microphone or by a cassette recorder provided for this purpose.

Multicoupler.--Coupling of radio transmissions shall isolate one transmission from the other by means of filters or isolators to reduce intermodulation and interference effects through the multicoupler.

Tunnel Antenna System.--The tunnel antenna system shall consist of slotted coaxial cable and a bare copper counterpoise installed in the tunnel as shown on the plans. Three antennas shall be installed in each tunnel bore. Counterpoise shall be installed in conformance with "Grounding and Bonding" of these special provisions.

Antenna hangars shall be used to provide 50 mm minimum (150 mm maximum) clearance between the tunnel wall and the antenna. Hangars shall be nylon self-locking or stainless steel.

Antenna shall have a 50 ohm termination at the far end of the tunnel. Antenna jacket shall be fire retardant, low smoke and fume, and shall be non-halogenated.

Slotted coaxial cable shall meet the following parameters:

A. Corrugated copper outer conductor.
B. Nominal size: 22 mm.
C. Input impedance: 50 ohms.
D. Attenuation at 800 Mhz: 1.6 dB per 30 m max.
E. Solid copper inner conductor.
F. Coupling loss at 6 m at 800 Mhz: 68 +/- 10 dB.
G. Typical VSWR: 1.3:1.

VHF/UHF Antennas.--Omni antennas shall be mounted on the OMC building to provide a path in and out of the tunnel. Antennas shall be constructed from aluminum and shall be mounted on the buildings as shown on plans. Antennas shall be aligned to maximize signal strength. Antennas shall not extend more than 2.5 m above the building parapet.

AM/FM Off-Air Antennas.--The AM antenna shall be a ferrite loop stick omni-directional assembly with lightning protection. The FM Antenna shall be omni-directional whip and have a frequency range from 88 to 108 MHz. Antennas shall be grounded in accordance with NEC

Section 810-21. The coupling and pre-amplification unit shall include the impedance match required to maximize performance and minimize noise for an output impedance of 50 ohms. Type N couplers shall be used.

AM/FM antennas shall be surface mounted on the outer tunnel wall at the tunnel entry portal on the northbound lanes.

Transmission Equipment.--Fiber Optic Interface Unit shall convert RF signals to light signals for transmission. Optical transmission shall be at 1550 nm. Allowable RF link gain shall be -2db to +2dB maximum. A fiber optic interface module shall be installed at the BDA and shall convert light signals to RF. Fiber optic path loss shall be 10 dBo maximum. The RF noise floor shall be -132 dBm.

Miscellaneous Materials.--Miscellaneous materials including cable hangars, grounding kits, wall feed-through assemblies and all other materials shall be provided for a complete and operating system.

INSTALLATION

Coordination.--The Contractor shall coordinate layout and installation of radio equipment and system components with other construction in the tunnel, including light fixtures, tunnel jet fans, fire-suppression and detection system components. The Contractor shall coordinate layout and installation of radio antenna and building penetration with other construction including connection to radio counterpoise.

Grounding.--Grounding shall be provided in accordance with NEC Article 250 and as recommended by the manufacturer. All equipment and antennas installed in the OMC Building shall be grounded to the building ground grid in accordance with NFPA 780.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in accordance with "Electrical Identification" of these special provisions.

FIELD QUALITY CONTROL

Manufacturer's Field Service.--A factory-authorized service representative shall inspect field-assembled components and connections and supervise pretesting, testing, and adjustment of the radio system equipment.

Pretesting.--All equipment shall be inspected to verify it is properly installed, connected, and labeled and that interconnecting wires and terminals are identified. After aligning and adjusting the system, components, wiring, and functions shall be pretested to verify compliance with specified requirements. Malfunctioning or damaged items shall be replaced, and the system shall be retested.

Final Testing.--The Contractor shall schedule tests after pretesting has successfully been completed and system has been in normal functional operation for at least 14 days. The Contractor shall provide the Engineer notice in writing when the system is ready for final acceptance testing with ten days advance notice. The Contractor shall provide a proposed test procedure with the final test notice. Tests shall include field strength surveys for both tubes of the tunnel and shall include both mobile and handheld radios. The path into the tunnel and out of the tunnel shall be tested to verify system performance.

The Contractor shall correct deficiencies identified by tests and observations and retest until specified requirements are met.

Report of Tests and Inspections.--The Contractor shall submit a written record of inspections, tests, and detailed test results in the form of a test log.

All equipment, stations, and other components at which tests have been satisfactorily completed shall be tagged to indicate completion of testing.

DEMONSTRATION AND TRAINING

A factory-authorized service representative shall perform the demonstration and train Department's maintenance personnel as specified in the following:

A. Train Department's maintenance personnel on procedures and schedules for troubleshooting, servicing, and maintaining equipment.
B. Demonstrate methods of determining optimum alignment and adjustment of components and system settings.
C. Review data in maintenance manuals.
D. Schedule training with Department with at least seven days advance notice.
E. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

Radio Rebroadcast system will be measured as a lump sum.

PAYMENT

The contract lump sum price paid for radio rebroadcast system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the radio rebroadcast system, complete in place, including warranty, wiring, testing, and demonstration and training, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ TUNNEL CONTROL SYSTEMS

GENERAL

The tunnel control systems shall be furnished, installed, and tested in conformance to the details shown on the plans, and to the provisions in Section 86, "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions. The tunnel control systems include direct digital control (DDC) equipment for tunnel systems and components, including control components for units that are not supplied with factory-wired controls. Equipment includes: control equipment and associated software programming; communications and data transmission equipment and associated software programming; and electrical controls devices. The tunnel control systems shall provide the functionality specified herein and shall operate according to the sequences of operation for tunnel ventilation fans, tunnel lighting, equipment chamber heating, ventilation and air conditioning (HVAC) units, and electrical and ancillary system monitoring.

The Tunnel Control System (TCS) shall be a fault tolerant system such that a failure of any one control component or communications bus shall not degrade the performance, or impede the full operation of, the control system. All controls and monitoring functionality shall be implemented in a fully redundant processor PLC architecture and all intraspace communication busses shall be implemented as fully redundant, physically separated, fault tolerant optical fiber links.

Primary operator control and monitoring of tunnel systems and equipment will reside within the Operation and Maintenance Center (OMC) building, with secondary control and monitoring capability located at the Oakland Traffic Management Center (TMC).

SUMMARY

Scope:--Control equipment and related software programming shall be provided as shown on the plans. Equipment shall be distributed, as equivalently functioning control nodes, at each equipment chamber area, and as equivalently functioning remote I/O nodes within each cross-passage. The configuration and programming of the equipment shall provide control nodes and remote I/O nodes that will continue to function in the last commanded state or operating status, in the event of a system communication failure. The control equipment shall be connected to field devices, electrical equipment, and mechanical equipment as shown on the plans.

Network communications among the individual control nodes and the remotely located operator interface equipment shall be via redundant dedicated fiber optic cabling. The communication network shall be tolerant of a transmission media break between control nodes or operator interface units such that full communications shall be maintained between all nodes not physically isolated from the network as a result of the break.

Operator Interface Unit (OIU) equipment, software, and functional programming shall be provided at each location shown on the plans.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the tunnel control systems as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Manufacturer's technical data for each control system component furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, installation instructions, and startup instructions.
B. Shop Drawings from manufacturer detailing equipment assemblies or components and indicating dimensions, weights, loadings, required clearances, method of field assembly, and location and characteristics of each field connection.
C. Shop Drawings containing the following information for each ventilation control panel and remote I/O panel:

    1. Schematic flow diagram showing fans, lighting contactors, and other control and monitoring devices served.
    2. Each control device labeled with setting or adjustable range of control.
    3. Diagrams for all required electrical wiring. Clearly differentiate between factory-installed and field-installed wiring.
    4. Each conductor labeled utilizing identifying labels shown on the plans.

5. Details of panel faces, including controls, instruments, and labeling.
6. Written description of sequence of operation.
7. Listing of connected data points, including connected control unit and input devices.
8. Each data point labeled utilizing identifying labels shown on the plans.
9. Associated Operator Interface Unit system graphics indicating monitored systems and devices, data (connected and calculated) point addresses, and operator notations.
10. System configuration showing I/O and peripheral devices, power supplies, diagrams, and interconnections.
11. Software description and sequence of operation.
12. Control Program Listing, fully annotated to describe the function of each programming element and each functional segment.

Integrator's Qualifications.--Submit a printed certified qualification resume of the contractor or systems integrator performing the fabrication, configuration, and programming of the tunnel control system components.

Closeout Submittals.--

A. Project Record Documents: Record actual locations of control components, including all field control components and sensors. Revise Shop Drawings to reflect actual installation and operating sequences. Include all data specified in "Submittals" in final "Record Documents" form.
B. Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions. Include the following:

1. Maintenance instructions and spare parts lists for each type of control component or device.
2. Interconnection wiring diagrams with identified and numbered conductors and system components and devices.
3. Keyboard illustrations and step-by-step procedures indexed for each operator function.
4. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
5. Calibration records and list of set points or calibrated ranges.

QUALITY ASSURANCE

Installer Qualifications.--The Contractor shall engage an installer specializing in control system installations who has been certified by the DDC system manufacturer for installation, configuration, programming, and maintenance of the installed equipment.

Manufacturer Qualifications.--The Contractor shall engage a firm experienced in manufacturing control systems similar to those indicated for this Project.

System Integrator Qualifications.--The contractor or integrator shall be a certified representative of the manufacturer for design, fabrication, programming, installation, start-up, and testing of similar DDC systems.

Software Quality Assurance.--Contractor's software quality assurance program, as well as software verification and validation programs, shall be consistent with the intent and scope defined in IEEE (Institute of Electrical and Electronic Engineers) 730 - Software Quality Assurance Plans and IEEE 1012 – Standard Software Verification and Validation Plans.

Requirements shall apply to all software developed or modified under this contract, excluding copyrighted commercially available off-the-shelf applications.

SYSTEM COMPONENTS

Operator Interface Unit (OIU).-- Each OIU shall allow Operator access to all tunnel systems via the same log-in screen and shall utilize the same programming and control commands, control software programming languages, and graphical representations. Dynamic control and monitoring displays, representing tunnel systems and equipment, shall be developed in close coordination with the Department operations and engineering staff. Operator access to the tunnel control system, for the purpose of system manipulation, shall not be allowed from any device other than the dedicated OIU's. The operator's workstation provided at the TMC shall be equipped with application software compatible with the current Department systems. Operator capabilities, protected by password, at the TMC shall be identical to those provided at the tunnel OMC building.

The Operator Interface Unit (OIU) shall be a microcomputer station with printer, including the following:

A. Workstation: IBM-compatible Microcomputer shall be commutable and identical to similar systems at the district with a minimum configuration as follows:

1. Processor: Industry Standard Processor.
2. Random-Access Memory: 1 GB.
3. Cache Memory: 256 kB.
4. Graphics: Super Video Graphics Array (SVGA) color graphic adapter.
5. Monitor: Touch-screen capable 533 mm, non-interlaced, color, with maximum 0.26-mm dot pitch.
6. Keyboard: QWERTY.
7. Floppy Disk Drives: 1.44 MB.
8. Hard Disk Drive: 200.0 GB.
9. Mouse: 3 button.
10. Modem: Auto-dial, internal, minimum 56 KBaud.
11. Network Adapter: Ethernet 10/100
12. Tape Back-Up: Internal, 250 MB.
13. Operating System: Microsoft Windows XP, Professional Edition.

B. Printer: Dot-matrix type as follows:

1. Print Head: 24 pin.
2. Carriage: Wide, 132 characters per line of paper.
3. Paper Handling: Fan-fold paper, with 2 cartons containing minimum 2500 sheets each.
4. Print Speed: Minimum 120 characters per second.

C. Application software shall include the following functionality:

1. Input/output capability from operator station.
2. Operator system access levels via software password.
3. Database creation and support.
4. Dynamic color graphic displays.

5. Alarm processing.
6. Event processing.
7. Automatic restart of field equipment on restoration of power.
8. Data collection, storage, and historical trending.
9. Graphic development on workstation.
10. Maintenance management.

Operator Interface Software.--OIU software shall be updated to latest versions of manufacturer's application development software at project completion and turned over to the Department. Software shall be developed to provide the OIU units with the functionality specified herein and on the plans. Software shall be developed to extract all available diagnostic and status information from control unit equipment. OIU software used at the TMC shall be compatible with existing Department software and systems. Software shall include the following functions:

A. Touch screen operation.
B. Input/output Functionality From Operator Station:

1. Request display of current values or status in tabular or graphic format.
2. Command selected equipment to specified state.
3. Initiate logs and reports.
4. Change analog limits.
5. Add, delete, or change points within each control unit or application routine.
6. Change point input/output descriptors, status, alarm descriptors, and engineering unit descriptors.
7. Add new control units to system.
8. Modify and set up maintenance scheduling parameters.
9. Develop, modify, delete or display full range of color graphic displays.
10. Automatically archive select data even when running third party software.
11. Provide capability to sort and extract data from archived files and to generate custom reports.
12. Support two printer operations.

    a. Alarm printer: Print alarms, operator acknowledgments, action messages, system alarms, operator sign-on and sign-off.
    b. Data printer: Print reports, page prints, and data base prints.

13. Operator selectable output of screen graphical images, data trend logs, and/or alarm summary information to printer.
14. Automatic time and date stamped output of all system alarms and automatic or manual control system actions to printer.
15. Select daily, weekly or monthly as scheduled frequency to synchronize time and date in digital control units. Accommodate daylight savings time adjustments.
16. Print selected control unit database.

C. Dynamic Color Graphic Displays:

1. Utilizes custom symbols or system supported library of symbols.
2. Sixteen (16) colors.

3. Sixty (60) outputs of real-time live dynamic data per graphic.
4. Dynamic graphical display of status, monitoring, control, and diagnostic data.
5. Up to 1,000 separate graphic pages.
6. Modify graphic screen refresh rate between 1 and 60 seconds.

D. Graphic screens to be developed in conjunction with the Department staff include but are not limited to:

1. Overview of entire tunnel system, providing means to quickly select specific segment, system, or overview graphics and indicating critical system-wide operating parameters and alarms.
2. Overviews of each tunnel system, providing means to quickly select specific related graphics and indicating associated operating parameters and alarms.
3. Graphical representation of tunnel equipment configuration at each specific equipment chamber and cross-passage location, indicating status of each system component.
4. For each tunnel control system or element, provide screens showing user-configurable historical data trend logging of equipment status and monitored signal values.
5. System-wide alarm summary screen indicating date, time, and nature of alarm event and providing the means to quickly select the graphical representation screen pertaining to the affected equipment or system.
6. Communications network overview screen indicating status and diagnostic information generated by the system communications network sub-system and the remote I/O communications subsystem.

E. Operator System Access: Via software password with minimum 10 access levels at OIU.

F. Data Base Creation and Support: Changes shall use standard procedures. The control unit shall automatically check workstation data base files upon connection and verify a data base match. Minimum capabilities shall include:

1. Add and delete points.
2. Modify any point parameter.
3. Change, add, or delete English language descriptors.
4. Add, modify, or delete alarm limits.
5. Add, modify, or delete points in start/stop programs, trend logs, etc.
6. Create custom relationship between points.
7. Create or modify DDC loops and parameters.
8. Create or modify override parameters.
9. Add, modify, and delete any applications program.
10. Add, delete, develop, or modify dynamic color graphic displays.

G. Alarm Processing. Alarm shall be processed in accordance with the following:

1. All alarm conditions: time and date stamped.
2. Off normal condition: alarm and appropriate message, including time, alarmed system, point descriptor, and alarm condition.
3. Critical alarm or change-of-state: Display message, store alarm on disk for review and sort, or print.

4. All alarm points: Print on line changeable message, up to 40 characters in length, for each alarm point specified.
5. All alarm points: Display alarm reports on monitor. Display multiple alarms in order of occurrence.
6. Time Delay: Define time delay for equipment start-up or shutdown.
7. Field Programmable: Allow field programming of individual alarms.
8. Acknowledge alarms: Operator specifies if alarm requires acknowledgment.
9. Unacknowledged alarms: Continue to indicate unacknowledged alarms after return to normal.
10. Alarm notification: print automatically and display indicating alarm condition, with selectable audible alarm indication.
11. Display: Permit operator to demand sequential display of the points currently in alarm.
12. Display: Permit operator to demand sequential display of the point addresses of all on-off discrete inputs indicating current state.

H. Contractor shall provide the Department with full software rights, in accordance with the terms of the commercial provisions, to maintain and modify all application software provided under this contract. License shall be provided to adequately cover all spare I/O points, as shown on the plans.
I. Software products shall be compatible with all IBM compatible (Intel-based) computers running Windows XP- Professional or Windows 2000 – Professional.
J. Copies of all source code of developed applications shall be provided to facilitate future changes.

Control Units.--Control units shall provide full redundancy of all control functions and system communications. Control units shall be modular, comprising microprocessor-based redundant central processor unit modules with programmable nonvolatile random-access memory, power supply modules, processor communication synchronization modules, remote I/O communication network modules, input/output interface processing modules, and system communications modules. In addition to the functionality specified herein for tunnel ventilation, lighting, and HVAC controls, the Contractor shall also provide communications modules, software design, and programming to process serial data, either RS232 or RS422, from tunnel systems equipment and transmit this data via the TCS systems communications bus network to a TCS control unit in the OMC building. Systems data will be available for use by other LAN connected systems at the OMC and TMC facilities.

A. Central Processor Unit (CPU) shall meet the following requirements:

1. Industrial quality
2. Designed for hot standby, fully synchronized redundancy.
3. 2048 Input Points
4. 2048 Output Points
5. 512 Kbytes Battery-backed RAM Memory
6. Memory Protect keyswitch.
7. Background diagnostics and fault detection.

    a. Memory errors
    b. Program sweep failure.
    c. Redundancy unit and synchronization status and failures.

8. Status and Fault Code generation and transmission via system communications bus.
9. Standard ladder logic programming.
10. Program functions shall include: contacts, coils, timers, counters, mathematical functions, shift registers and word operations.
11. L.E.D. indicators for operating mode, processor status, diagnostic alerts, and serial communications.
12. Configured for use with 1 or more single bus redundantly controlled remote I/O buses.
13. Configured for use with redundant TCP/IP Ethernet system communication modules.
14. Furnished with factory provided programming and development software.

B. CPU redundancy shall provide:

1. Bumpless transfer of control from the currently primary processor to the fully synchronized back-up processor.
2. Factory engineered redundancy configuration.
3. Selection of currently operating processor.
4. Synchronization of processors through redundancy communication and bus communication modules.
5. No single point of control unit failure.
6. Choice of same or different programs running in each of the two processors, with ability to run program sections non-redundantly.

C. Redundancy Communication Modules shall meet the following requirements:

1. I/O Data shared by both processors, controlled by currently primary processor.
2. Provides manual selection of primary processor designation.
3. L.E.D. indicators for operating modes and module status.
4. Furnished with factory supplied I/O cable with built-in impedance matching.

D. Bus Communication Modules shall meet the following requirements:

1. I/O Data shared by both processors, controlled by currently primary processor.
2. Transmitter module in Rack 0, receiver module in Rack 1.
3. Transmitter module provides high-speed parallel port connection for system programmer.
4. Receiver module provides redundancy functionality in expansion racks.
5. L.E.D. indicators for operating modes, module status, and programmer port activity.
6. Furnished with factory supplied I/O cable with built-in impedance matching.

E. Stand-alone control unit node functions shall operate regardless of the system communications network status. Functions shall include the following:

1. Global communications.
2. Discrete/digital, analog, and pulse input/output.
3. Monitoring, controlling, or addressing data points.
4. Testing and developing control algorithms without disrupting field hardware and controlled environment.

F. Ethernet Communication Modules shall meet the following requirements:

1. Global system communications.
2. TCP/IP protocol.
3. RJ45 10BaseT network port. (Link to Optical Communication module)
4. Provides client/server capability to interface with host computer.
5. Provides capability to attach to LAN via third party routers.
6. Simultaneous communication with multiple other control unit nodes.
7. Factory engineered to enable processor redundancy implementation.
8. L.E.D. indicators for module status and communications status.
9. RS485 port to load application software.
10. Background diagnostics and fault detection.

    a. Communication status and errors
    b. Module failures.
    c. Programming failures.

11. Status and Fault Code generation and transmission via system communications bus.
12. Furnished with factory provided application development and management software as well as host computer interface application development software.

G. Global Communications shall meet the following requirements:

1. Broadcast point and status data onto system communication network, making that information available for use by other control units and utilizing data from other control units.
2. Broadcast serial data that is received from tunnel systems equipment.
3. Ethernet communication modules shall provide an electrical link to Optical Communication module for conversion of communications signals to fiber optic media.
4. Provide software design and programming to implement system-wide communications.

H. Remote I/O Bus Controllers shall meet the following requirements:

1. Transmit and receive any or all input/output point data via remote I/O network.
2. Provided in pairs (one in each processor rack) to implement single bus redundant remote I/O bus.
3. Factory engineered to enable processor redundancy implementation.
4. Up to 31 bus controllers per processor.
5. 153 kBaud serial data transmission rate.
6. Frequency shift keying (FSK) modulation.
7. Signal/noise ratio shall be 60dB.
8. Receives input data from connected I/O input blocks.
9. Transmits data to connected I/O output blocks.
10. Support for analog, discrete, and specialty I/O blocks.
11. Receives diagnostic and status information from remote I/O blocks.
12. Status and Fault Code generation and transmission via system communications bus.

13. L.E.D. indicators for module status and communications status.
14. Standard product of PLC manufacturer.
15. Furnished with factory supplied communication cables with built-in impedance matching resistors.
16. Twisted pair copper communication connector (Link to Optical Communication module)

I. Optical Fiber Communications Modules shall meet the following requirements:

1. Stand-alone DIN rail panel mount module.
2. Provide communication bus intrinsic safety and noise immunity.
3. Bus topology independent.
4. 1300 nm transmission wavelength.
5. Using 62.5/125 multimode optical fiber with type SC connectors.
6. Provide redundant fiber media communication paths.
7. Automatic self-healing around communication point failures.
8. Factory engineered for compatibility with provided PLC manufacturer's CPU and communication modules.
9. Fault predictive algorithm.
10. Interactive system level diagnostics and error checking that detect and locate fault conditions throughout the network.
11. Trap and Hold, and locate, intermittent communication failures.
12. Ethernet modules support TCP/IP communications in accordance with IEE 802.3 CSMA/CD network.
13. Remote I/O bus modules support native protocol of remote I/O bus controller and I/O blocks.
14. Connected to achieve fault tolerant cross-connected communications busses.

J. Serial Communications Coprocessor Modules shall meet the following requirements:

1. Provide general purpose serial communications interface to tunnel systems equipment.
2. Support for RTU MODBUS (Slave) and SNP protocols.
3. (2) built-in serial ports, RS232 and RS422/RS485.
4. 19.2 Kbps transmission rate.
5. Non-redundant operation.

K. Local I/O Modules shall meet the following requirements:

1. Provide local I/O modules as shown in the plans.
2. Discrete Inputs as shown on the plans:

    a. 120VAC or 24 VDC.
    b. Isolated or common bus.
    c. Standard product of PLC manufacturer.

3. Discrete Outputs as shown on the plans:

    a. 120VAC or 24 VDC.

b. Isolated or common bus.
c. Standard product of PLC manufacturer.

4. Analog Inputs as shown on the plans:

a. 4-20 mADC, differential
b. 0-10 VDC, differential
c. 100 Ohm Pt. RTD
d. 1-5 VDC

5. Analog Outputs:

a. 4-20 mADC, as indicated
b. 0-10 VDC, as indicated

L. Remote I/O Modules shall meet the following requirements:

1. Provide remote I/O modules as indicated in the plans.
2. 153 kBaud serial data transmission rate.
3. Frequency shift keying (FSK) modulation.
4. Discrete Inputs:

a. 120VAC or 24 VDC as indicated.
b. Isolated or common bus, as indicated.
c. Standard product of PLC manufacturer.

5. Discrete Outputs:

a. 120VAC or 24 VDC as indicated.
b. Isolated or common bus, as indicated.
c. Standard product of PLC manufacturer.

6. Analog Inputs:

a. 4-20 mADC, differential
b. 0-10 VDC, differential
c. 100 Ohm Pt. RTD
d. 1-5 VDC

7. Analog Outputs:

a. 4-20 mADC, as indicated
b. 0-10 VDC, as indicated

8. Status and Fault Code generation and transmission via remote I/O communications bus.
9. L.E.D. indicators for module status and communications status.
10. Standard product of PLC manufacturer.

11. Furnished with factory supplied communication cables with built-in impedance matching resistors.
12. Twisted pair copper communication connector (Link to Optical Communication module)

M. Power Supply Modules shall meet the following requirements:

1. 120 VAC supply input.
2. Sized to provide full calculated loading plus 25% spare capacity.
3. Configured to provide redundant power backup to all racks.
4. Standard product of PLC manufacturer.

N. Each stand-alone tunnel control panel shall be provided with an RS-232C serial data communication port for operator I/O devices such as industry standard portable operators terminals or portable lap-top computers.

O. Each tunnel control panel shall continuously perform self-diagnostics, communication diagnosis and diagnosis of all subsidiary equipment. Information concerning detected diagnostic faults shall be broadcast network-wide.

P. All necessary software to form a complete operating system as described in this specification shall be provided. The software programs shall be provided as an integral part of the control unit panel and shall not be dependent upon any higher-level computer for execution.

Q. Provide Uninterruptible Power Supplies (UPS) for each standalone tunnel control panel. UPS shall be capable of powering the control unit panel for a minimum of five (5) minutes and protecting panel from a restart in the event of a momentary power outage or switchover to emergency power.

R. Sensor and Control Wiring Surge Protection: Controllers and remote I/O modules shall have sensor and control wiring surge protection with optical isolation, metal oxide varistors (MOV), or silicon avalanche devices. Fuses are not permitted for surge protection.

Control Unit Software.--Control unit application development software shall be updated to latest versions of manufacturer's software at project completion and turned over to the Department. Control programming shall be designed and programmed to provide the control units with the functionality specified herein and on the plans. Contractor shall provide all software necessary to program, test, and operate the TCS.

A. Required functionality shall include:

1. Automatic response of ventilation system to fire alarm system event signaling.
2. Automatic response of the tunnel lighting system in response to measured portal luminance.
3. Automatic control of equipment chamber HVAC units.
4. Manual (operator initiated) selection and control of individual ventilation and lighting system components.
5. Monitoring and controlling of indicated field equipment and devices.
6. Broadcast of tunnel systems serial data.

B. Programming format of control unit development software shall be relay ladder logic.

C. Integrated software tool packages shall be provided to implement programming, troubleshooting, and documentation of control unit programming.
D. Software products shall be compatible and identical to similar system at the district.
E. Tools shall support both off-line and on-line programming, as well as provide the ability to obtain hard copy prints of all programming and configuration.
F. Software running on a compatible computer shall connect to the control unit PLC via high-speed parallel connection.
G. Software shall contain provisions to allow password protected remote programming access to any PLC processor on the systems communication bus.
H. Software shall support menu-driven parameterization of remote I/O blocks, as well as field device local I/O.
I. Standard product of PLC manufacturer.
J. Changes to the PLC program shall be allowed without the need to recompile and download the complete program to the PLC.
K. Contractor shall provide the Department with full software rights, in accordance with the terms of the commercial provisions, to maintain and modify all application software provided under this contract. Provide software license to support one maintenance workstation and one backup copy.

CONTROL PANELS

Tunnel Control Panels.--The contractor shall provide free-standing, single door, enclosures rated ICS 6, NEMA Type 12 and 13 for the tunnel control panels. Enclosures shall be constructed of 16 gauge steel with all seams continuously welded and smoothly finished, and shall possess integral, rolled lip framing around the door to prevent dirt, water, and other debris from falling into the cabinet when the door is opened. The enclosure doors shall be fully gasketed with glued-in-place oil resistant gaskets and shall be equipped with a screwed-down door clamp mechanism. Exterior finish shall be cabinet manufacturer's standard corrosion inhibiting, baked-on enamel finish over phosphatized surfaces. The enclosure interior surfaces and back panels shall be finished with the cabinet manufacturer's standard corrosion-inhibiting, white high-gloss baked-on enamel finish.

Remote I/O Monitoring Panels.--Wall-mounted, continuous hinge, single door, enclosures rated ICS 6, NEMA Type 12 and 13 shall be provided. Enclosures shall be constructed of 16-gauge steel with all seams continuously welded and smoothly finished. Enclosure door shall be fully gasketed with glued-in-place oil resistant gaskets and shall be equipped with a screwed-down door clamp mechanism and padlockable hasp assembly. Enclosure exterior and interior finishes shall be cabinet manufacturer's standard corrosion inhibiting, baked-on enamel finish over phosphatized surfaces.

CONTROL PANEL COMPONENTS

Fiber Optic Patch Panels.--The Contractor shall provide surface mount telecommunications outlet housings of a high-density, low-profile, design with four (4) field-configurable ports, snap-lock cover, and cable knockouts on the back. Base shall include tie-wrap anchor points at all cable entrances. Housings shall be wall mountable with screws and have mounting holes that are compatible with standard NEMA wall boxes. Patch panels shall be constructed of high-impact self-extinguishing plastic and shall be UL listed.

Terminal Blocks.--Provide channel mounted, impact and combustion resistant, self-extinguishing type terminal blocks. Terminal blocks shall be rated, as a minimum, for

continuous operation at 10A AC at 600 V AC. Terminals shall be of the tubular screw clamp type and shall be capable of accommodating two (2) #14 AWG or one (1) #12 AWG conductors. Furnish all required end plates, channel clamps, separators and other components required for installation in accordance with the manufacturer's recommendations. Terminal blocks shall each be equipped with an appropriate label which is large enough to legibly accommodate identifying numbers as shown on the plans.

Channel Mounted Circuit Breakers.--Units equipped with "tripped" indication shall be provided, rated as shown on the plans. Channel mounted breakers shall mount on the same size and type of mounting channel as the terminal blocks specified herein and shall possess terminals each capable of accommodating one (1) #14 AWG wire. Each breaker shall be equipped with an appropriate label and labeling space large enough to legibly accommodate a three-digit identifying number. Thermal-magnetic type circuit breakers with a "normal blow" tripping characteristic curve shall be provided.

Wireway.--Provide slotted type plastic wireways, with covers, of the size shown on the plans and as required for neat installation of interconnecting conductors. Wireways shall be restricted slot type to prevent accidental removal of wires and shall be constructed of rigid, non-flammable polyvinyl chloride (PVC). Wireway shall be UL recognized for continuous operation at 120 °F.

Selector Switches.--Provide industrial duty, 30 mm body, selector switch units with stackable, replaceable contact blocks. Units shall possess the number and type of contacts indicated on the plans and shall be rated NEMA Type 13, oil tight. Operator units shall be maintained with the number of positions as shown on the plans. Where shown on the plans, keylocked selector switch units shall posses identical cylinder locks employing the same master key, and shall hold the key captive in the positions indicated as 'Local' control positions. All selector switch unit contacts shall be rated for continuous operation at 10 A at 120 V AC. Surge suppression modules shall be supplied on all selector switch contacts that are wired to the DDC system.

Pushbuttons.--Provide industrial duty, 30 mm body, round button, momentary operator pushbutton units with stackable, replaceable contact blocks. Units shall possess the number and type of contacts as shown on the plans and shall be rated NEMA Type 13, oil tight. All pushbutton unit contacts shall be rated for continuous operation at 10 A at 120 V AC. Surge suppression modules shall be supplied on all pushbutton contacts that are wired to the DDC system.

Control Relays.--Provide control relays utilizing DIN rail mounted 8-pin round socket bases. Relays shall be equipped with double pole double-throw (DPDT) contacts, neon internal pilot lights to indicate coil energization, and shall be rated for operation over the temperature range of -34°C to +43°F. Control relays shall have 24 V DC coils and shall be equipped with contacts rated for continuous operation at 10 A at 120 V AC, with a resistive load. Surge suppression modules shall be supplied on all control relay coils.

24 V DC Power Supplies.--Provide regulated 24 V DC power supplies as shown on the plans.

UNINTERRUPTABLE POWER SUPPLY (UPS)

The UPS shall provide power conditioning, both voltage regulation and noise rejection, and shall be sized as shown on the plans. The power conditioning section shall be of the ferro-resonant design, with no moving parts and no tap switching while electrically isolating the secondary from the power-line side. Characteristics of the power conditioning section shall be as follows:

A. At 85 percent load, the output voltage shall not deviate by more than plus or minus 13 percent of nominal when the input voltage fluctuates between -20 to +10 percent of nominal.
B. During load changes of zero to full load, the output voltage shall not deviate by more than plus or minus 3 percent of nominal. Full correction of load switching disturbances shall be accomplished within 5 cycles, and 95 percent correction shall be accomplished within two cycles of the onset of the disturbance.
C. Total harmonic distortion shall not exceed 3-1/2 percent at full load.

CONTROL CABLE

Electronic cable for control wiring and optical-fiber cable for signal transmission shall be in accordance with "Signal Systems Conductor and Cable" of these special provisions.

INSTALLATION

Equipment shall be installed as indicated on the plans and in conformance to manufacturer's written instructions. Software shall be installed in control units and operator workstation, implementing all features of programs and appropriate to sequence of operation. The Contractor shall connect and configure equipment and software to achieve the sequence of operation specified herein.

Pre-Installation Meeting.--A pre-installation meeting shall be convened a minimum of one week prior to commencing Work of this section.

Field Measurements.--The Contractor shall verify field measurements and clearances prior to fabrication and installation of control system components

Power Line Surge Protection.--Equipment connected to AC circuits shall be protected from power-line surges. Equipment protection shall meet the requirements of IEEE C62.41. Fuses shall not be used for surge protection..

Delivery, Storage, And Handling.--Equipment and materials shall be stored inside and protected from weather.

Examination.--The Contractor shall verify that conditioned supply power is available to control units and operator workstation, and verify that field end devices and wiring are correctly and securely installed before proceeding with installation.

Coordination.--The Contractor shall verify location of control system components with plans and structural details before installation.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in accordance with "Electrical Identification" of these special provisions.

Electrical Wiring And Connections.--Electrical components shall be connected to wiring systems and to ground as indicated and instructed by manufacturer. Connectors and terminals, including screws and bolts, shall be tightened according to equipment manufacturer's published torque-tightening values for equipment connectors. Where manufacturer's torquing requirements are not available, connectors and terminals shall be tightened according to tightening requirements specified in UL 486A.

SEQUENCE OF OPERATION

Tunnel Jet Fans.--The sequence of operation for the tunnel jet fans shall be as follows:

A. During normal operations, all tunnel jet fans are off.
B. When a contact closure is received from the Fire Alarm system indicating a fire/event in the west tunnel bore, tunnel jet fans JF-1 through JF-16 are started in the forward direction (air flow southward).
C. When a contact closure is received from the Fire Alarm system indicating a fire/event in the east tunnel bore, tunnel jet fans JF-17 through JF-32 are started in the forward direction (air flow northward).
D. During automatic fire/event operations, all tunnel jet fans remain on regardless of fan or motor status until the system is reset by the control system operations personnel at the direction of the designated incident commander.
E. Tunnel jet fan direction during automatic fire/event operations can be reversed at the scene by operation of a selector switch located within a keylocked enclosure near each portal as shown on the plans. Enclosure shall be identified as "Fire Department Emergency Ventilation Direction Override Panel". The control system shall enforce a 10 second time delay prior to energizing a reversing direction contactor.
F. When a Carbon Monoxide (CO) gas concentration in excess of 50 ppm (programmable setpoint) is detected in the vicinity of any group of two tunnel jet fans, one fan in the group is started in the forward direction. If a CO gas concentration in excess of 70 ppm (programmable setpoint) is detected, both fans in the group are started in the forward direction. Tunnel jet fan operation shall continue until the concentration has again fallen to below 5 ppm.
G. If a combustion product (NOX) gas concentration in excess of 50 ppm (programmable setpoint) is detected in the vicinity of any group of two tunnel jet fans, one fan in the group is started in the forward direction. If a NO gas concentration in excess of 70 ppm (programmable setpoint) is detected, both fans in the group are started in the forward direction. Tunnel jet fan operation shall continue until the concentration has again fallen to below 5 ppm.
H. The operating status and direction of each tunnel jet fan is proven via fan mounted air flow switches. Fan and motor bearing vibration, as well as motor temperature, are continuously monitored via local transducers at each fan.
I. The tunnel control system shall create a time and date stamped log of all tunnel jet fan operations indicating individual fan status including all fan and motor related run states and alarms.

J. During emergency fire/event operation of the jet fans in one bore of the tunnel, operation of the fans in the other bore shall be limited to a maximum of 8 fans under any circumstance.

Tunnel Lighting.--The operating sequence for tunnel lighting control systems shall meet the following requirements:

A. The lighting level controls shall permit the light levels inside the tunnel to be adjusted for varying exterior light levels. Controls shall be programmed to pre-determined values for the lights to come on and stay on until the outside light level reduces to below another pre-determined value, and then turns the lights off. To account for intermittent cloud cover and other short-term transient ambient conditions, the turn on and off process shall incorporate 5 minute time delays (programmable) at each transition.
B. The South portal photosensor shall control the circuits in the East bore (northbound lanes) and the North portal photosensor shall control the circuits in the West bore (southbound lanes).
C. During darkness, the nighttime circuit only shall be energized.
D. The light levels are defined in the table:

	HIGH LEVEL Medium Level & Low Level Luminaires	MEDIUM LEVEL Medium Level Luminaires	LOW LEVEL Low Level Luminaires	NIGHT LEVEL Nighttime Luminaires
Turn-On	558 fc (6000 lux)	232 fc (2500lux)	4.7 fc (50 lux)	1.9 fc (20 lux)
Turn-Off	502 fc (5400 lux)	209 fc (2250 lux)	1.9 fc (20 lux)	4.7 fc (50 lux)

Leech Water Sump Pump.-- Pump start/stop and level alarm setpoints shall be as shown on the tunnel controls plans. The sequence of operations for the leech water sump shall meet the following requirements:

A. During normal operations both pumps are off.
B. When a liquid level reaches the first separately programmed setpoint, one pump is started and operated until the level decreases below the "off" setpoint.
C. If the liquid level is sensed to increase above a second, separately programmed on setpoint, the second pump is started and run until the level decreases below a second separately programmed "off" setpoint.
D. The initially started pump is alternated each time a pump start is mandated by rising level.
E. Sump level is sensed continuously by a locally mounted level transducer.

South Chamber HVAC constant volume unit HV-1.--The sequence of operations shall meet the following requirements:

A. During normal operation, the control system shall start and run the unit Variable Frequency Drive (VFD) continuously at low speed and modulate outside and return air damper (DMPR 1) to minimum position. (The low speed setpoint shall be adjusted during balancing to achieve one-half the design airflow).
B. Outside air damper minimum position initial setpoint (programmable) shall be set to 20% open. The setpoint shall be adjusted during balancing to achieve the required minimum outside air flow (94 L/s) with the VFD operating at low speed.

C. Room temperature control shall be accomplished by modulating the outside air damper and the return air damper (DMPR 1) to maintain room temperature cooling setpoint (initially programmed to 23.9 deg. C). When measured room temperature is greater than the second cooling setpoint (initially programmed to 29.4 deg. C), the VFD speed is commanded to maximum. Fan shall run for a minimum time period (initially programmed to 5 minutes) after motor speed change. When the temperature again falls below the room temperature heating set point (initially programmed for 15.6 deg. C), sequence the electric heating stages to maintain the setpoint.
D. A smoke detector in the supply air duct shall stop the supply fan and signal an alarm when combustion products are detected in the air stream.

South Chamber Pressurization Control.--The sequence of operations shall meet the following requirements:

A. During normal operation, the controls system shall maintain a positive pressure inside the chamber by modulating the fire/smoke dampers (DMPR 2 and DMPR 3) to maintain a programmable setpoint (initially programmed to 0.025 kPa).
B. During initial balancing, adjust the differential pressure setpoint to achieve a positive 0.025 kPa pressure differential while HV-1 outside air damper is at the minimum position.

South Chamber HVAC Fire/Event Operation.--The sequence of operations shall meet the following requirements.

A. When a contact closure input is received from the Fire Alarm system indicating a fire/event in one of the tunnel bores, the control system shall override normal HVAC system operation and close the fire/smoke damper serving the incident tunnel and open the damper on the non-incident tunnel.

Center Chamber HVAC constant volume unit HV-2.--The sequence of operations shall meet the following requirements:

A. During normal operation, the control system shall start and run the unit VFD continuously at low speed and modulate outside and return air damper (DMPR 1) to minimum position. (The low speed setpoint shall be adjusted during balancing to achieve one-half the design airflow).
B. Outside air damper minimum position initial setpoint (programmable) shall be set to 20% open. The setpoint shall be adjusted during balancing to achieve the required minimum outside air flow (94 L/s) with the VFD operating at low speed.
C. Room temperature control shall be accomplished by modulating the outside air damper and the return air damper (DMPR 1) to maintain room temperature cooling setpoint (initially programmed to 23.9 deg. C). When measured room temperature is greater than the second cooling setpoint (initially programmed to 29.4 deg. C), the VFD speed is commanded to maximum. Fan shall run for a minimum time period (initially programmed to 5 minutes) after motor speed change. When the temperature again falls below the room temperature heating set point (initially programmed for 15.6 deg. C), sequence the electric heating stages to maintain the setpoint.
D. A smoke detector in the supply air duct shall stop the supply fan and signal an alarm when combustion products are detected in the air stream.

Center Chamber Pressurization Control.--The sequence of operations shall meet the following requirements:

A. During normal operation, the control system shall maintain a positive pressure inside the chamber by modulating the fire/smoke dampers (DMPR 2 and DMPR 3) to maintain a programmable setpoint (initially programmed to 0.025 kPa).
B. During initial balancing, adjust the differential pressure setpoint to achieve a positive 0.025 kPa pressure differential while HV-1 outside air damper is at the minimum position.

Center Chamber HVAC Fire/Event Operation.--The sequence of operations shall meet the following requirements:

A. When a contact closure input is received from the Fire Alarm system indicating a fire/event in one of the tunnel bores, the control system shall override normal HVAC system operation and close the fire/smoke damper serving the incident tunnel and open the damper on the non-incident tunnel.

North Chamber HVAC constant volume units HV-3 and HV-4.--The sequence of operations shall meet the following requirements:

A. During normal operation, the control system shall start and run the unit VFD continuously at low speed and modulate outside and return air dampers to minimum position. (The low speed setpoint shall be adjusted during balancing to achieve one-half the design airflow).
B. Outside air damper minimum position initial setpoint (programmable) shall be set to 20% open. The setpoint shall be adjusted during balancing to achieve the required minimum outside air flow (94 L/s) with the VFD operating at low speed.
C. Room temperature control shall be accomplished by modulating the outside air damper and the return air damper (DMPR 1) to maintain room temperature cooling setpoint (initially programmed to 23.9 deg. C). When measured room temperature is greater than the second cooling setpoint (initially programmed to 29.4 deg. C), the VFD speed is commanded to maximum. Fan shall run for a minimum time period (initially programmed to 5 minutes) after motor speed change. When the temperature again falls below the room temperature heating set point (initially programmed for 15.6 deg. C), sequence the electric heating stages to maintain the setpoint.
D. A smoke detector in the supply air duct shall stop the supply fan and signal an alarm when combustion products are detected in the air stream.

North Chamber Pressurization Control.--The sequence of operations shall meet the following requirements:

A. During normal operation, the controls system shall maintain a positive pressure inside the chamber by modulating the fire/smoke dampers to maintain a programmable setpoint (initially programmed to 0.025 kPa).
B. During initial balancing, adjust the differential pressure setpoint to achieve a positive 0.025 kPa pressure differential while HV-1 outside air damper is at the minimum position.

North Chamber HVAC Fire/Event Operation.--The sequence of operations shall meet the following requirements:

A. When a contact closure input is received from the Fire Alarm system indicating a fire/event in one of the tunnel bores, the control system shall override normal HVAC system operation and close the fire/smoke damper serving the incident tunnel and open the damper on the non-incident tunnel.

Cross Passage Ventilation.--The sequence of operations shall meet the following requirements:

A. When motion is detected in the cross passage, the control system shall start the cross passage fan and shall start a cycle timer (programmable time period) and run the fan until the time period has expired.
B. When a contact closure input is received from the Fire Alarm system indicating a fire/event in one of the tunnel bores, the control system shall close the damper serving the incident tunnel and open the damper on the non-incident tunnel.

FIELD QUALITY CONTROL

Interconnection Verification.—Contractor shall verify signal integrity and interconnections between the control system and the field instruments and devices. All signal interconnections shall be individually physically verified for proper terminations and noted on the pre-commissioning checklist.

Factory Tests And Inspections.--Factory testing specified herein shall not preclude any additional standard tests normally performed by the Manufacturer or Integrator for similar equipment. Contractor shall notify Department in writing, not less than 14 days prior to proposed start date, of all scheduled factory test dates. Notification shall include nature and sequence of testing and indicate expected test duration. Observations and test results recorded during the tests shall be clearly documented and submitted to the Department for record prior to shipping the equipment to the site.

PLC system components shall be factory tested for complete and correct operation, sequencing, interlocking, communications, diagnostics, alarming and logging in accordance with the requirements outlined herein and on the plans. All field functions shall be simulated in the factory for the purposes of this testing. Control system components shall be subjected to a burn-in test, at 60° Centigrade, for a minimum of 96 hours.

Final Testing.--The Contractor shall submit procedures and criteria for certification of control system functionality to the Engineer at least 30 days prior to commencement of formal testing.

The testing plan shall include the following elements:

A. Detailed definition of responsibilities, accountabilities, and deliverables by each party within the commissioning process.
B. System and equipment commissioning scope of work list.
C. Pre-Commissioning Checklist: Checklist shall include the procedure and certification to provide individual verification of all installed system components. The Contractor shall verify that the submittal information matches installed components. The contractor shall

review complete system installation, cleaning, and initial settings and verify that system is ready for operations.

D. Pre-Operation Checklist: Checklist shall include the procedure and certification to provide verification, by system or equipment, of system setpoints, operating strategies, and required pre-operational component adjustments and testing such as correct fan rotation and component operation.

E. Functional Performance Test Plan: The contractor shall provide test plans which will include a test calendar, a detailed sequence and schedule, and a step-by-step procedural description of all required tests which clearly indicates planned actions and the anticipated corresponding equipment response or sequence of responses. The test plans shall include a comprehensive tunnel system component and equipment list that provides a test verification signoff field for each item. Performance tests shall verify that all components, sub-systems, and systems comprising the tunnel control system function in accordance with the contract documents.

F. Acceptable System Performance Standards: Definition of test durations, test criteria, and acceptable operational functionality and performance criteria for each of the planned functional tests.

A factory-certified manufacturer's field service representative shall assist in testing of the tunnel control systems. Test results shall be recorded and submitted to the Engineer in writing.

The Contractor shall correct deficiencies indicated by the tests and completely retest work affected by such deficiencies. The Contractor shall verify by the system test that the total system is in conformance with the requirements specified in these special provisions.

DEMONSTRATION AND TRAINING

The Contractor shall be responsible for training coordination and scheduling and for ensuring that training is completed on all equipment in accordance with “Basic Electrical Materials and Methods” of these special provisions. Contractor shall provide:

A. Six (6) copies of an operator's manual describing all operating and routine maintenance service procedures to be used with the TCS.

B. Instruction to the Department's designated representatives in these procedures during the start-up and test period and following project completion. The instruction shall consist of on-site, project specific training as detailed below.

C. On-site training shall be performed by an engineer familiar with the specific design of the system provided for this project. On-site training shall be separated into an initial session that will occur at or prior to project completion and a second session that will occur 1-2 months after project completion. The instruction shall consist of both hands-on and classroom training at the jobsite.

MAINTENANCE SERVICE

During the warranty period the Contractor shall provide a 24-hour emergency service number where a qualified automation service engineer familiar with the installed system may be reached.

MEASUREMENT

The tunnel control system will be measured on a lump sum basis.

PAYMENT

The contract lump sum price paid for tunnel control systems shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the tunnel control systems, complete in place, including software programming, training and testing, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ TUNNEL CONTROLS FIELD DEVICES

GENERAL

Tunnel controls field devices shall consist of furnishing, installing, and testing of field devices and components associated with the tunnel control systems, including control components for units that are not supplied with factory-wired controls, in conformance to the details shown on the plans and to the provisions in Section 86 "Signals, Lighting and Electrical Systems" of the Standard Specifications and these special provisions. Tunnel controls field devices shall include components to monitor tunnel jet fan status and tunnel portal lighting level, and components to monitor and control heating, ventilation, and air conditioning (HVAC) systems and equipment within the tunnel equipment chambers and cross passages.

SUMMARY

Scope.--Control panels, shown on the plans as field interface panels (FIP), shall be installed at each cross passage throughout the tunnel. Control panels, shown on the plans as fire department emergency override panels shall be installed at both the north and south portals. Each of these control panels shall be equipped with, and connected to, components and field devices as shown on the plans, in conformance with the requirements herein and in "Tunnel Control Systems" of these special provisions. Field devices for bearing temperature, jet fan vibration, and both forward and reverse air flow shall be installed at each tunnel jet fan and shall be connected to the associated cross passage FIP. Field devices for measuring ambient lighting levels shall be installed at both the north and south portal entrances. Field devices for control and monitoring of HVAC equipment and systems shall be installed within each equipment chamber and at each cross passage. Field devices for monitoring tunnel air flow shall be mounted in both tunnel bores near the portal entrances.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the tunnel control field devices as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Manufacturer's technical data for each type of product specified, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, installation instructions, and startup instructions.

B. Shop drawings from manufacturer detailing equipment assemblies and indicating dimensions, weights, loadings, required clearances, method of field assembly, components, and location and size of each field connection.
C. Wiring diagrams detailing wiring for power, signal, and control systems and differentiating clearly between manufacturer-installed and field-installed wiring.
D. Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions. Maintenance data shall include the following:

1. Maintenance instructions and spare parts list for each type of control component or device.
2. Interconnection wiring diagrams with identified and numbered conductors and system components and devices.
3. Inspection period, cleaning methods, cleaning materials recommended, and calibration tolerances.
4. Calibration records and list of set points or calibrated ranges.

E. Field test reports: procedure and certification of control component functionality.
F. Project record documents that record actual locations of control components, including control units and sensors. Shop drawings shall be revised to reflect actual installation and operating sequences.

QUALITY ASSURANCE

Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. All device and component installations shall comply with NFPA 70 and NFPA 502. All tunnel control field devices and components shall be UL Listed.

DEVICES AND COMPONENTS

Indoor Control Panels.--Enclosures for indoor control panels shall consist of wall-mounted, continuous hinge, single door, enclosures rated ICS 6, NEMA Type 4. Enclosures shall be constructed of 16-gauge steel with all seams continuously welded and smoothly finished. Enclosure door shall be fully gasketed with glued-in-place oil resistant gaskets and shall be equipped with a screwed-down door clamp mechanism and padlockable hasp assembly. Enclosure exterior and interior finishes shall be cabinet manufacturer's standard corrosion inhibiting, baked-on enamel finish over phosphatized surfaces.

Outdoor Control Panels.--Surface-mounted or flush mounted, continuous hinge, single door, enclosures rated ICS 6, NEMA Type 4X shall be provided as shown on the plans. Enclosures shall be constructed of 16-gauge stainless steel with all seams continuously welded and smoothly finished. Enclosure door shall be fully gasketed with glued-in-place oil resistant gaskets and shall be equipped with a quarter-turn door clamp keylocked cylinder mechanism.

Terminal Blocks.--Terminal blocks shall be channel-mounted, impact and combustion resistant, self-extinguishing type terminal blocks. Terminal blocks shall be rated for continuous operation at 10 A at 600 V AC. Terminals shall be of the tubular screw clamp type and shall be capable of accommodating two (2) #14 AWG or one (1) #12 AWG conductors of the type specified herein. Terminal blocks shall be furnished with all required end plates, channel clamps, separators and other components required for installation in accordance with the manufacturer's recommendations. Terminal blocks shall each be equipped with an appropriate

label which is large enough to legibly accommodate the identifying numbers as shown on the plans.

Wireway.--Wireways shall be slotted type plastic wireways, with covers, of the size specified on the plans for neat installation of interconnecting conductors. Wireways shall be restricted slot type to prevent accidental removal of wires and shall be constructed of rigid, non-flammable polyvinyl chloride (PVC). Wireway shall be UL recognized for continuous operation at 49°C.

Selector Switches.--Selector switches shall be industrial duty, 30 mm body, selector switch units with stackable, replaceable contact blocks. Units shall possess the number and type of contacts indicated on the plans and shall be rated NEMA Type 13, oil tight. Operator units shall be maintained with the number of positions as shown on the plans. Keylocked selector switch units shall possess identical cylinder locks employing the same master key, and shall hold the key captive in the positions indicated as 'Local' control positions in locations as shown on the plans. All selector switch unit contacts shall be rated for continuous operation at 10 A at 120 V AC.

Pushbuttons.--Pushbuttons shall be industrial duty, 30 mm body, round button, momentary operator pushbutton units with stackable, replaceable contact blocks. Units shall possess the number and type of contacts shown on the plans and shall be rated NEMA Type 13, oil tight. All pushbutton unit contacts shall be rated for continuous operation at 10 A at 120 V AC.

Pilot lights shall be industrial duty, 22 mm body, round dome lens, L.E.D. type pilot lights. Units shall be rated NEMA Type 13, oil tight as defined by NEMA 250 and shall operate at 120 V AC primary supply voltage. Lens color shall be as shown on the plans.

Channel-Mounted Circuit Breakers.--Channel-mounted circuit breakers shall be thermal-magnetic type circuit breakers with a "normal blow" tripping characteristic curve. Circuit breakers shall be equipped with "tripped" indication and rated as shown on the plans. Channel mounted breakers shall mount on the same size and type of mounting channel as the terminal blocks specified herein and shall possess terminals each capable of accommodating one (1) #12 AWG wire. Each breaker shall be equipped with an appropriate label and labeling space large enough to legibly accommodate the identifying number shown on the plans.

Control Relays and Signal Light Contactors.--Control relays shall use DIN rail mounted 8-pin round socket bases. Relays shall be equipped with double pole double-throw (DPDT) contacts, neon internal pilot lights to indicate coil energization, and shall be rated for operation over the temperature range of -35°C to +43°C. Control relays shall have 120 V AC coils and shall be equipped with contacts rated for continuous operation at 10 A at 120 V AC, with a resistive load.

Time Delay Relays.--Time delay relays shall use DIN rail mounted 11-spade square socket bases and possess two independent double-throw contacts rated for operation at 10 A at 120 V AC. Relays shall provide either "delay on make" or "delay on break" functionality as shown on the plans, and shall possess a time delay setting that is field adjustable from 1 second to 10 minutes. Time delay relays shall be equipped with LED internal pilot lights to indicate coil energization, shall be rated for operation over the temperature range of -18°C to +43°C and the humidity range of 45 to 85 percent relative humidity.

24 V DC Power Supplies.--Regulated 24 V DC power supplies shall be provided as shown on the plans.

Sensors.--Electronic sensors shall be vibration and corrosion resistant, and shall be mounted as shown on plans.

Resistance Temperature Detector (RTD)**.--**Each RTD shall be platinum with a tolerance of plus or minus 0.2 percent at 0ºC, and shall be encapsulated in epoxy and series 300 stainless steel.

Differential Pressure Transmitters.--Differential pressure transmitters shall be provided with integral sensing elements. The instrument over-pressure rating shall be 300 percent of the operating pressure. The sensor and transmitter assembly accuracy shall be plus or minus 2 percent of full scale. The transmitter shall be a 2-wire, loop-powered device. The transmitter shall produce a linear 4 to 20 mA DC output corresponding to the required differential pressure measurement.

Photo-Sensor Devices.--The photometric interface shall be solid state, with output 0 to 10 V DC signal in proportion to the illuminance level measured by the photosensor. The operating range shall be 0 to 1000 fc (0 to 10,761 lx). The supply power shall be 24 V DC, 60 mA. Housings shall be DIN rail (35mm) mounted indoor-rated housings, with mounting orientation insensitive. The ambient operating temperature shall be -20°C to +50°C.

The photosensor shall have the following features: photometric curve, microprocessor-based, automatic range adjusting from 1 to 1000 fc (0 to 107,607 lx). Digital signal output to photometric interface shall be in proportion to measured illuminance level. Housing shall be impact resistant, ultraviolet-light-resistant, NEMA 5 and watertight outdoor housing. Ambient operating temperature: -50°C to +60°C. Sensor shall be line-powered by photometric interface over polarity insensitive output signal conductors.

Airflow Status Inputs for Fans.--Airflow status inputs for fans shall be differential-pressure switches with adjustable range of 0 to 50 mm W.G.

Control Cable.--Electronic cable for control wiring and optical-fiber cable for signal transmission shall be in accordance with "Signal Systems Conductor and Cable" of these special provisions.

INSTALLATION

Equipment shall be installed as shown on plans in accordance with all manufacturer's written instructions. The Contractor shall connect and configure devices and components to achieve the sequence of operation specified in "Tunnel Control System" of these special provisions.

Power Line Surge Protection.--Equipment connected to AC circuits shall be protected from power-line surges. Equipment protection shall conform to the requirements of IEEE C62.4 1. Fuses shall not be used for surge protection.

Delivery, Storage, And Handling.--Equipment and materials shall be stored indoors and protected from weather.

Examination.--The Contractor shall verify that supply power is available to control units and operator workstation, and verify that field end devices and wiring are correctly and securely installed before proceeding with installation.

Coordination.--The Contractor shall verify location of exposed control sensors with plans and structural details before installation. Sensors shall be located a minimum of 1.5 m above floor.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in conformance with "Electrical Identification" of these special provisions.

Electrical components shall be connected to wiring systems and to ground in accordance with manufacturer’s written instructions. Connectors and terminals, including screws and bolts, shall be tightened according to equipment manufacturer's published torque-tightening values for equipment connectors. Where manufacturer's torquing requirements are not available, connectors and terminals shall be tightened according to tightening requirements specified in UL 486A.

FIELD QUALITY CONTROL

Interconnection Verification:--Tests shall verify signal integrity and interconnections between the control system and the field instruments and devices. All signal interconnections shall be individually verified for proper terminations prior to commencing operational tests. A checklist shall be maintained to document the verification of each interconnection. The completed checklist shall be submitted as part of the final test report.

Testing.--Field instrument and device testing shall be performed in conjunction with the testing specified for "Tunnel Control Systems" of these special provisions. Tests shall verify proper functionality of each field device and component. Results of field instruments and device testing shall be included with reports specified for tunnel control systems.

Retesting.--The Contractor shall correct, repair, or replace any deficiencies indicated by the tests and perform retest.

Final Testing.--The Contractor shall perform final testing on the tunnel controls field devices in conformance with the following requirements:

A. Test and adjust instruments and system components to the specified range and operational settings.
B. Replace damaged or malfunctioning instruments, devices and equipment found during testing.
C. Demonstrate compliance with all specified requirements.
D. Adjust, calibrate, and fine tune instruments and equipment to achieve range and functionality of operation specified.

Report of Tests and Inspections.--The Contractor shall submit to the Engineer a written record of inspections, tests, and detailed test results in the form of a test log, on the successful completion of tests. All equipment, stations, and other components at which tests have been successfully completed shall be tagged to indicate completion of testing.

PAYMENT

Full compensation for tunnel controls field devices shall be considered as included in the contract lump sum price paid for tunnel control system and no separate payment will be made therefor.

10-4.__ SYSTEMS AND EQUIPMENT COMMISSIONING

GENERAL

Commissioning of systems and equipment shall conform to these special provisions. The commissioning process shall be defined by the Commissioning Agent (CA) and shall executed by the Contractor in the presence of the Commissioning Agent, Test Engineer and the commissioning team.

SUMMARY

Scope.--The systems and equipment to be commissioned include:

A. Mechanical systems, including:

1. Variable frequency drives
2. Jet fans
3. Leach water treatment systems
4. Equipment chamber heating and ventilation units
5. Cross Passage pressurization fans

B. Fire protection systems, including:

1. Fire protection system stand-pipe system

C. Electrical systems, including:

1. Lighting systems
2. Medium Voltage Switchgear
3. Electrical metering, monitoring, and control systems
4. Motors
5. Medium voltage interrupter/automatic transfer switchgear
6. Medium voltage transformers
7. Low voltage (less than 600 volts) Transformers
8. Primary power system cabling
9. Secondary power system cabling
10. Breaker trip sequencing coordination study
11. Ground fault systems
12. Service switchboard
13. Circuit breaker panelboards
14. Motor control centers
15. UPS systems and battery capacity test
16. Transit voltage surge suppression (TVSS) systems

D. Special systems, including:

1. Fire detection and alarm system
2. Security access system
3. Closed circuit television (CCTV) systems
4. Traffic systems
5. Environmental monitoring systems
6. Tunnel control systems
7. CO2 monitoring and control systems
8. Smoke evacuation system and integration

E. Audio visual systems, including:

1. Variable message signs
2. Changeable message signs
3. Extinguishable message signs

F. Communications systems, including:

1. Telephone systems
2. Data systems
3. Fiber optic systems
4. Radio rebroadcast systems

DEFINITIONS

A. Commissioning: The process to certify to the Department that systems, equipment, mechanical, electrical, controls, and special systems function together properly to meet performance requirements and design intent as shown in a composite manner in the contract documents.
B. Commissioning Plan: The overall document prepared by the Test Engineer, approved by the Commissioning Agent and executed by the Contractor or their subcontractor. The commissioning plan outlines the organization and accountabilities, scheduling, documentation, pertaining to the overall commissioning process.
C. Pre-commissioning Checklist: Checklist prepared by the Test Engineer, initialed and monitored by the Commissioning Agent and approved by the Resident Engineer. Checklist shall be by system or equipment to verify submittal information, installation match, and assure that all systems and equipment are ready for continuous operation and final testing. Review complete system installation, cleaning and initial settings and verify systems are ready for operations. This document shall incorporate manufacturer equipment site packing slip, installation instructions, system readiness checkout list, manufacturers start-up plan and system operational checkout. Checklist shall include verification of system set points, operating strategies, required component testing, correct rotation, damper positions, prior to functional test. The Contractor shall review and sign-off the checklist prior to continuing with the commissioning process.
D. Functional Performance Testing: Verification criteria developed by the Test Engineer, initiated and monitored by the Commissioning Agent and accepted by the Resident Engineer. The full range of checks and tests shall be carried out to determine if components, sub-systems, systems, and interfaces between systems function in

accordance with the contract documents. In this context, "function" includes all modes and sequences of control operation, all interlocks and conditional control response, and all specified responses to emergency conditions. The Contractor is fully responsible for operation and performance of systems and equipment throughout the commissioning process until acceptance of contract and turnover.

E. Systems: Group of components and equipment functioning as a unit or performing a common function, such as the tunnel ventilation system including jet fans, fan monitoring instrumentation, motor control centers, variable frequency drives, and controls.

F. Acceptable Performance: A component or system shall be able to meet specified design parameters and criteria under actual load conditions for duration of time as indicated within the functional test criteria as determined by technical specifications and outlined by the Test Engineer for final approval by the Resident Engineer with recommendation from the Commissioning Agent.

H. O&M Manuals: Operations and Maintenance manuals as defined in "Basic Electrical Materials and Methods" of these special provisions.

I. Training: Equipment and systems training as defined in "Basic Electrical Materials and Methods" of these special provisions.

I. Submittals: The Commissioning Agent will receive two copies of the normal submittals for equipment to be commissioned from the Resident Engineer. The Commissioning Agent shall review submittals applicable to systems being commissioned for compliance with commissioning needs, concurrent with the Resident Engineer's reviews. The Commissioning Agent shall forward one copy to the Resident Engineer for integration of comments and retain one copy. Contractor shall forward two additional copies of contract clarifications, changes, and communications that relate to commissioned equipment and systems to the Resident Engineer for the Commissioning Agent's use.

J. Data for Commissioning: The contractor shall receive a written request from the Resident Engineer, prepared by the Commissioning Agent, requesting specific information needed about each piece of commissioned equipment or system. Typically this shall include detailed manufacturer installation and start-up checklists, operating, troubleshooting, and maintenance procedures, full details of required testing, fan and pump curves, full factory certified test reports, and full warranty information, including all responsibilities of the Department to keep the warranty in force clearly identified. In addition, the installation and checkout materials that are shipped with the equipment and field checkout sheet forms to be used by the factory or field technicians shall be submitted to the Resident Engineer for the Commissioning Agent. The data request may be made prior to normal submittal procedures.

K. Areas of Conflict: Where provisions of this section conflict with technical requirements elsewhere in these special provisions, the technical requirements shall take precedence.

ABBREVIATIONS

CA	Commissioning Agent
Cx	Commissioning Plan
DDC	Direct Digital Controls
DE	Design Engineer
HVAC	Heating Ventilating and Air Conditioning
O&M	Operations and Maintenance
RE	Caltrans Construction Resident Engineer
TAB	Testing, Adjusting and Balancing Engineer/Firm

TE Testing Engineer

COMMISSIONING TEAM

The commissioning team shall consist of the Department's representatives; Commissioning Agent; Testing Engineer; Contractor's Testing, Adjusting and Balancing Engineer; Contractor; subcontractors; manufacturers; and project design professionals in accordance with their contractual agreements with the Department. It is the intent that all members shall work together as a team to fulfill their contractual responsibilities and meet the objectives of the contract documents and the Department, and make the project turnover and commissioning process seamless.

Commissioning Agent.--The Department will directly contract for Commissioning Agent services for all pre-construction services and during construction work. The Commissioning Agent shall represent the Department through the commissioning process. The Commissioning Agent shall report directly to the Resident Engineer, to review the work of the Contractor in the development and execution of the commissioning program.

The Department will directly contract for the Test Engineers and other Testing agencies as required to verify conformance of work, systems and equipment commissioning in accordance with the requirements of the contract documents. The Commissioning Agent shall oversee and coordinate the Testing agencies work for commissioning.

The Commissioning Agent shall formally communicate with the Contractor via the Resident Engineer. It is expected, however, that informal communication and coordination will be conducted directly with the Contractor and subcontractors who will keep records of all contacts and send copies of all records to the Resident Engineer through normal channels.

The Commissioning Agent shall be independent and not financially associated with the Engineer of Record, the Contractor, or any of the subcontractors, prior to engaging in the contract.

The Commissioning Agent, Test Engineer, or their subcontractors are not authorized to modify, add to, or revoke the requirements of the project contract documents.

The duties of the Commissioning Agent shall be as follows:

A. Develop the commissioning plan with the Contractor, Testing Engineer, TAB, and design engineers.
B. Initiate, monitor, review and recommend all commissioning documentation, forms, data sheets and performance criteria for systems and equipment to be commissioned.
C. Monitor, review and recommend the Contractor's systems start-up plans and schedules.
D. Witness and verify satisfactory completion of equipment and component tests, systems and inter-systems functional performance tests.
E. Monitor, review and recommend specified documentation including completed start-up and functional testing documentation prepared and forwarded by Contractor and Test Engineer.
F. Review the tunnel controls test plans, procedures, and reports submitted by Contractor.
G. Monitor and approve with design engineer, testing, adjusting, and balancing work and the final report.
H. Coordinate via the Resident Engineer, the participation of Department personnel involved with equipment, component, and systems performance verification and required training.
I. When commissioning has been successfully completed, recommend system or equipment acceptance to the Department.

Test Engineer.--The Commissioning Agent shall perform test verification and commissioning as required in this section and elsewhere in the contract documents, through the Test Engineer who shall be a subcontractor to the Commissioning Agent. Testing Engineer shall work in concert with the Contractor's subcontractors.

The Test Engineer shall be independent, not be financially associated with the Resident Engineer of Record, the Contractor, or subcontractors, prior to engaging in the contract.

The duties of the Test Engineer shall be as follows:

A. Report to the Commissioning Agent in the collection and assembly of subcontractor or supplier information required for development of a complete commissioning plan. The Test Engineer shall review the commissioning plan that includes activities to be performed, sequence, scheduling, documentation and verification procedures, and confirm in writing to the Commissioning Agent any known areas of conflict or areas requiring clarification with the final commissioning plan, installed systems or design features.
B. Review all functional performance tests, results, and documentation required by the contract documents for all equipment and systems as performed by subcontractors and suppliers. Confirm review in writing through the Commissioning Agent to the Resident Engineer. Include a list and description of any known areas of conflict or areas requiring clarification.
C. Coordinate with the Contractor to develop schedules for all start-up and testing; integrate testing into the master construction activity schedule and coordinate all subcontractor testing with Contractor as required. Forward schedule to all subcontractor testing firms as required. Forward schedule to Commissioning Agent for inclusion in commissioning plan.
D. Develop test procedures following equipment manufacturer's recommendations, where applicable, and design engineer's format and intent detailed within the specifications. Test procedures shall fully describe system configuration and steps required for each test, appropriately documented so that another party can repeat the tests with virtually identical results.
E. Develop pre-commissioning checklist, pre-functional (operational) checklist and functional test procedures for Commissioning Agent approval, including an integrated cross-functional matrix.
F. Develop, with the Contractor, in the presence of the Commissioning Agent, test procedures and forms for documentation of all equipment tests, system functional tests, and related cross system functional tests.
G. Develop with the Contractor system integration matrixes, performance standards and compliance responses.
H. Submit test procedure schedule, procedures, forms, and other documentation to the Commissioning Agent and design engineer for review and approval no later than 90 calendar days after approval of the contract.
I. Coordinate directly with Contractor on subcontractors' specific responsibilities and contractual obligations.
J. Provide qualified personnel for participation in commissioning tests.
K. Observe and document the start-up and initial testing of equipment by the Contractor and subcontractors and all final tests of equipment and systems. Forward all completed start-up functional test documentation to the Commissioning Agent for review within 5 workdays of successful completion of each activity.

L. Observe and document all integrated system testing such as, but not limited to, HVAC, tunnel ventilation, tunnel lighting, fire alarm, emergency power, life safety, traffic control, and CCTV system. Forward all completed start-up functional test documentation to the Commissioning Agent for review within 5 workdays of successful completion of each activity.
M. Document inconsistencies or deficiencies in system operations and systems compliance. Develop and submit detailed reports for Commissioning Agent review describing these inconsistencies or deficiencies and their resolution within 24 hours of such observation or occurrence.
N. Coordinate the required Commissioning Agent and design engineer testing participation and approval process and procedures, after verifying that pretests and check-off lists have been satisfactory conducted and documented and final tests are ready to be performed.
O. Review operating and maintenance data provided by the various Subcontractors and suppliers submitted to the Commissioning Agent for verification and conformance to requirement of contract documents.
P. Obtain all documentation from tests and assemble a final test report to be submitted to the design engineer and Commissioning Agent for review prior to final submittal to Resident Engineer. The Commissioning Agent shall review the report format and recommend to Resident Engineer approval.

Testing, Adjusting and Balancing Engineer/Firm (TAB).--The Contractor shall perform HVAC testing adjusting and balancing, as required in this section and elsewhere in the contract documents, through a subcontractor or directly with a TAB. The TAB shall be hired by the Contractor through the Commissioning Agent and shall work in concert with the Contractor's Subcontractors. The TAB shall communicate through the Contractor to the Resident Engineer or Commissioning Agent.

The duties of the Testing, Adjusting and Balancing Engineer/Firm (TAB) shall be as follows:

A. Review all Mechanical specifications and drawings to affirm design meets or exceeds all codes, regulations, and standards for safe operations and acceptable indoor air quality.
B. Review design and submittals for development of TAB scope of work, schedule, phasing and execution plan. Plan shall be forwarded to Resident Engineer for the Commissioning Agent review and recommendation. TAB shall coordinate schedule and phasing with Contractor.
C. Submit through the Contractor to Commissioning Agent all forms, formats, standards, and procedures to be employed for testing and balancing the HVAC equipment and mechanical systems.
D. Perform and compile all test data and submit to Resident Engineer for Commissioning Agent to review and make recommendations.
E. Notify Resident Engineer and Commissioning Agent immediately when issues arise beyond the TAB ability to perform their work, or when design questions arise or installation concerns are identified. TAB shall maintain log of all issues, deficiencies or incidents, as well as corrective action and submit to Resident Engineer and Commissioning Agent.
F. Develop all general balancing procedures and submit to Commissioning Agent for approval prior to starting work.
G. Verify controls interface and operation with the HVAC systems, control strategies, sequence of operation and ability to perform in accordance with the design intent.

H. Submit initial and final test results and balance log to Resident Engineer for Commissioning Agent for review and comments prior to proceeding or final approval.
I. Analyze performance, data, trend-logs and develop comments and recommendations to be forwarded to the Commissioning Agent for follow though and resolution.
J. Provide training in accordance with these special provisions.

Special Testing Firm/Engineer.--Resident Engineer and Commissioning Agent shall determine requirements for Special Testing Firms/Engineers based on project size, complexity and potential risk to the Department.

Special Testing Firms/Engineers shall be hired by the Contractor through the Commissioning Agent as required by the project, and may include, but not limited to, testing of the following: tunnel DDC system, smoke control and fire alarm system, traffic systems, communication, security, CCTV, and electrical testing.

The duties of the Special Testing Firms/Engineers shall be determined by the Commissioning Agent and Resident Engineer.

Contractor.--The Contractor shall be hired directly by the Department, shall support and assist in the development of the commissioning plan, and shall execute the testing procedures in accordance with the commissioning plan. The Contractor shall work in concert with the Commissioning Agent throughout the commissioning process.

It is the Contractor's ultimate responsibility and accountability to schedule and execute the commissioning plan.

The commissioning duties of the Contractor shall include the following:

A. Execute the Commissioning plan through the operation of equipment and systems by their subcontractors.
B. Be solely responsible for the operations, testing, and results during the Commissioning process for systems and equipment to perform in accordance with the contract documents.
C. Attend weekly Commissioning meetings called by the Resident Engineer or Commissioning Agent to develop or implement the Commissioning plan. Invite subcontractors as appropriate to expedite Commissioning process.
D. Notify Commissioning Agent in writing that equipment and systems are ready for beginning the pre-commissioning checklist work.
E. Sign-off pre-commissioning checklist and certify in writing to Commissioning Agent to start pre-functional checklist.
F. Develop start-up plans in accordance with manufacturer's recommendations and as a function of pre-functional checklists.
G. Sign-off pre-functional "operational" checklists, assure equipment and system operation start-up and design point initial settings are ready for functional testing and that all systems and equipment operate. Certify in writing to Commissioning Agent that equipment and systems are operational ready for functional performance testing.
H. Provide all manufacturer's data, manuals and material, checklists, warrantees, and brochures to Commissioning Agent for developing commissioning plan.
I. Provide final approved submittals and all requests for information to Commissioning Agent for equipment and systems being commissioned. Keep the Commissioning Agent informed on status of all systems and equipment to be commissioned.
J. Execute Department training in accordance with the special provisions.

K. Develop and maintain master schedule. Work with Commissioning Agent for the inclusion of scheduling elements of commissioning plan.
L. Develop Operations and Maintenance data and procedures manual in accordance with the special provisions.
M. Maintain inventory, secure and protect required spare parts and specialty tools in accordance with the technical specifications until transferred to the Department.
N. Professionally maintain shop drawings and single-line diagrams in as-installed condition, to be included in the O&M manual and used during the Commissioning process and Department staff training.
O. Maintain as-built drawings and system single-line schematics and diagrams for all systems that are installed, to be included in the O&M manual and used during the Commissioning process and Department staff training.
P. Maintain all data and information in CD-ROM format for Department use, following the Department requirements for integration into their data management system.

COMMISSIONING PLAN

The commissioning plan shall be prepared by the Commissioning Agent with support from the Test Engineer and shall detail the implementation of the commissioning process. It shall include the requirements that each party involved in the commissioning process will have to accomplish, including sequence, acceptance criteria, scheduling, documentation requirements, and verification procedures.

The commissioning plan shall incorporate the aforementioned information to be collected (and submitted) by the Test Engineer and design engineers after the mechanical and electrical subcontracts are issued, furnishing details of the equipment to be installed and including the approved controls sequences submittal from the design engineer and Controls subcontractor. Test Engineer, TAB, and design engineer information shall be submitted to Commissioning Agent no later than 90 days prior any cable, equipment, or systems installations and presented at the initial commissioning meeting.

The commissioning plan shall include the following:

A. Design and contractor project team data and information
B. Detailed responsibilities, accountabilities and deliverables by each party within the commissioning process.
C. System and equipment commissioning scope of work list.
D. Detailed procedures for the test to be performed by each party in the commissioning process as developed by the Test Engineer for each listed piece of equipment and system.
E. Pre-commissioning checklists and system pre-functional checklists developed by the Test Engineer.
F. Detailed checklists for performance testing as developed by the Test Engineer, manufacturer and design engineer.
G. Test Engineers, design engineers and TAB report forms that will be used to submit test data and results with acceptance criteria.
H. Calibration data for test equipment to be used during the Commissioning process.
I. Sequence and schedule of procedures.
J. Other items as may be specified in these special provisions.

The commissioning plan procedures for performance tests and verification shall include, but are not limited to, the following:

A. Testing, adjusting, and balancing performance.
B. Verification of all equipment and system performance.
C. Verification of the performance of subsystems consisting of combinations of equipment (e.g. communications modules, remote I/O modules, and interconnecting transmission media).
D. Verification of the performance of the automatic controls in all modes.
E. Verification of the performance of the tunnel lighting systems as a whole.
F. Verification of the performance of the ventilation systems as a whole.
G. Verification of the performance of all life safety devices and systems that interface with the ventilation systems.
H. Operational testing shall also be a function of time or duration for each system or equipment as defined by the Commissioning Agent and RE within the commissioning plan.
I. Corrective action plan for all noted deficiencies identified by the TE, DE, TAB or others during their respective work within the commissioning process.

The intent of mechanical, electrical, communications, control, and life safety systems commissioning is to verify delivery to the Department of systems and equipment which are fully functioning in accordance with project documents and which the Department personnel are fully trained and equipped to operate, maintain and troubleshoot. Additionally, the Department shall have supporting documentation to enable the Department staff to maintain systems and equipment in accordance with manufacturers recommendations and design engineers' intent to sustain operations over the life of the system or equipment. The following information shall be included:

A. General information, identifying project location and address
B. Building or chamber type, occupancy and fire rating
C. Building or chamber square footage and number of stories
D. Project team member information: company name and address, discipline, phone number, fax, email, emergency 24/7 phone number.

COMMISSIONING PROCESS

No later than 120 days prior any cable, equipment, or systems installations, The Contractor shall provide the Commissioning Agent with all drawings, addendums, requests for information and specifications and the construction schedule by trade.

An initial scope meeting shall take place no later than 90 days prior any cable, equipment, or systems installations. The agenda shall include:

A. Introductions
B. Flow of documents
C. Submittal data
D. Shop drawings and single line diagrams
E. Lines of reporting and communication defined
F. Responsibilities reviewed
G. Start up plan and checklist data requirements

The Commissioning Agent, with the Test Engineer, shall develop the draft commissioning plan, due no later than 60 days prior any cable, equipment, or systems installations, including:

A. Preliminary schedule developed for review
B. Equipment and system list of items to be commissioned
C. Checklist elements defined
D. Testing elements defined
E. System and equipment integration matrix developed

Team members shall make periodic visits to the site, in accordance with their contract, to witness equipment and system installation, and monitor project schedule and progress, and shall include:

A. Observations, conflicts or areas needing clarification shall be documented and forwarded to the Commissioning Agent for discussion and follow up with the Contractor. Commissioning Agent shall maintain observation logs and response.
B. Progress construction meetings, attended by the Contractor, Resident Engineer, TE and others, shall be called by the Commissioning Agent to review project status, change orders, requests for information, schedule, etc. Commissioning Agent shall maintain minutes for the record.
C. Specific routine construction commissioning weekly meetings shall be scheduled 60 calendar days prior to any system or equipment start up. Other meetings may be required and called by the Commissioning Agent to resolve specific commissioning issues. Contractor shall coordinate subcontractor participation as required.

Contractor shall operate equipment and systems and conduct all tests in presence of the Commissioning Agent to demonstrate compliance with specified requirements.

The Contractor shall notify the Commissioning Agent, Test Engineer, and the design engineer, in writing, 7 calendar days prior to tests scheduled under requirements of this Section unless specified otherwise.

Testing shall be conducted under design operating conditions as defined within the specifications and accepted by the Resident Engineer.

The Contractor shall provide 5 copies of all test reports to the Commissioning Agent.

Functional performance testing shall be completed and accepted by the Resident Engineer through the Commissioning Agent as a condition of acceptance of contract.

All elements of systems shall be tested to demonstrate that total systems satisfy all requirements of these special provisions. Testing shall be accomplished on hierarchical basis. Each piece of equipment shall be tested for proper operation, followed by each subsystem, followed by entire system, followed by interfaces to other major systems.

Contractor shall provide all special testing of materials and test equipment.

A copy of the Commissioning Agent approved commissioning plan and functional performance test results for each system or piece of equipment shall be included within each copy of the Operations and Maintenance manuals.

DOCUMENTATION

In accordance with the draft commissioning plan, the Contractor shall provide the specific material and information identified required for the preparation and development of the commissioning plan.

The Contractor shall provide the Commissioning Agent all documentation from the equipment manufacturer on factory testing or certifications, shipping orders and information, delivery checkout lists, installation requirements, pre-startup and startup checklists, and warranty

requirements. The Test Engineer shall provide the Contractor with a summary matrix of information required.

The Contractor shall provide the Commissioning Agent two approved copies of the equipment submittals that will be required for the preparation and development of the commissioning plan.

The Contractor shall provide Commissioning Agent with all shop drawings that will be required for the preparation and development of the commissioning plan.

Contractor shall provide to Commissioning Agent all system sequences of operations from the controls subcontractor and an all-points list that will be required for the preparation and development of the commissioning plan, functional testing and performance trending.

Products and Reports.--The Commissioning Agent shall provide regular reports to the Resident Engineer, with increasing frequency as construction and commissioning progresses. Standard forms shall be developed and referenced in the Commissioning plan.

The Commissioning Agent shall regularly communicate with all members of the Commissioning team, keeping them apprised of commissioning progress and changes through progress reports.

The final commissioning report shall be developed by the Commissioning Agent for the Resident Engineer, summarizing the commissioning efforts and evaluating the process.

Pre-commissioning Checklist.--The pre-commissioning checklist shall include the following:

A. Submittal approvals
B. Model verification
C. Manufacture installation checklist
D. System checklist
E. Deficiencies documentation
F. Contractor certification and notification
G. Acceptance

Pre-functional Checklist.--The pre-functional checklist shall include the following:

A. Installation checklist
B. Manufacturer start-up programs
C. Fire and emergency power response matrix
D. Fire alarm sequence flow chart or diagram
E. Tab initial report
F. Deficiencies documentation
G. Contractor certification notification
H. Acceptance

Functional Performance Testing.--The functional performance testing checklist shall include the following:

A. Relationship matrix
B. Sequence of operations and control
C. Control logic
D. Forms and standards with acceptance criteria

E. Progress reports
F. Tab final report
G. Fire and emergency power response matrix
H. Fire alarm sequence flow chart or diagram
I. Testing plan, approach, and methodology
J. Test methods
K. Coordination and scheduling
L. Deficiencies documentation
M. Seasonal or deferred testing
N. Final acceptance

PHASING AND SCHEDULE

Commissioning Agents final commissioning plan shall be completed prior to commissioning any electrical, equipment, or systems installations.

The Commissioning Agent shall work with the Contractor to schedule the commissioning activities. The Contractor shall integrate the commissioning into the master schedule. All parties shall address scheduling issues as they arise, make necessary modifications and notifications in a timely manner, in order to maintain both master and commissioning schedule.

Commissioning Phasing and Sequencing.--The Contractor shall coordinate phasing and sequencing and integrate the commissioning plan within the master schedule. Tasks shall include, but not limited to, the following:

A. Detailed manufacture pre-submittal information
B. Final submittals obtained and reviewed
C. Specific design intent summaries including sequence of operations, control strategies, and basis of design.
D. Initial commissioning scope meeting
E. Start of construction observation
F. Pre-commissioning checklist developed and approved
G. Start up and check out plans from manufacturers and Contractor
H. Forms and formats developed and approved
I. Pre-functional checklist developed and approved
J. Start up and check out plans execution
K. Function test procedures approved
L. TAB certification
M. Functional performance testing execution
N. Flush-out or cleaning period
O. Performance period
P. O&M documentation review and verification
Q. Training
R. End of warranty training
S. Seasonal or delayed testing

ACCEPTANCE PROCEDURES

Contractor shall execute the commissioning plan, sign off that both the pre-commissioning and pre-functional checklists have been completed and the Commissioning Agent has accepted the functional test results and results have been approved by the Resident Engineer.

Prior to functional performance testing of each system, the Test Engineer and Contractor shall observe and verify that the components and systems being tested are installed in accordance with the contract documents and sign off the pre-commissioning and pre-functional checklists.

Commissioning Agent, upon receipt of the Contractor certification and notification readiness form, shall start the functional testing process.

Test Engineer-witnessed Contractor's tests shall include the following procedures:

A. Verification that systems and equipment have been cleaned and prepared for start up.
B. Verification of systems for proper installation, adjustment, calibration, and readiness to function as specified.
C. Verification that system elements have been installed properly and that all connections have been made correctly.
D. Adjustment and verification of proper operation of all discrete elements and sub-systems.
E. Complete start-up and operational tests, with documentation submitted to Commissioning Agent within 5 workdays of each activity, prior to starting final functional acceptance tests.
F. Submittal of copies of all test reports and records to the design engineer and Commissioning Agent within 5 workdays of such testing.

The objective of functional performance tests shall be to demonstrate that the system is operating and complying with specified performance requirements. Resident Engineer-witnessed functional performance tests shall include the following procedures:

A. Tests shall be performed on a complete system basis. Each function shall be demonstrated to the Resident Engineer and the Commissioning Agent, in accordance with the Test Engineer's written test procedure developed to demonstrate conformance to the contract documents.
B. Test shall be witnessed and signed off by the design engineer, Test Engineer and Commissioning Agent upon satisfactory completion.
C. Testing program shall be conducted in accordance with prior approved procedures and shall be documented as required in these special provisions.
D. The Resident Engineer, design engineer and Commissioning Agent shall be notified at least two weeks prior to date of functional performance tests.

The functional performance test checklist contained in the approved commissioning plan shall be used to document the results of the functional performance testing process.

The functional performance testing process shall be accomplished for all equipment, subsystems, systems, and system interfaces, with a separate checklist for each to ensure that documentation specific to each is complete. The Contractor shall execute all testing procedures.

Each system shall be operated through all modes of system operation including every individual interlock and conditional control logic, all control sequences, both full- and part-load conditions, and simulation of all abnormal conditions for which there is a specified system or controls response. Contractor shall operate systems and equipment throughout this testing and verification process.

Temporary upsets of systems, such as distribution fault, control loss, set-point change, equilibrium upset, and component failure shall be imposed at different operation loads to determine system stability and recovery time. All data shall be logged for recording in the O&M Manual.

When the functional performance of all individual systems has been proven, the interface or coordinated responses between systems shall be checked.

CORRECTIVE MEASURES

If acceptable performance cannot be achieved, then the Contractor shall carry out necessary corrective measures. Every check or test for which acceptable performance was not achieved shall be repeated after the necessary corrective measures have been completed until acceptable performance is achieved. Corrective measure accountability shall be as directed by the Resident Engineer. Unless it is found to be a design issue, Contractor shall correct the deficiency at no additional cost to the State.

PERFORMANCE PERIOD

Contractor shall provide within the master schedule a 30-day period to have all commissioned equipment and systems operate under normal operating conditions. Commissioning Agent and Test Engineer shall monitor performance in accordance with these special provisions.

The performance period in this section shall apply to all commissioned equipment and systems. During this period, Contractor shall operate and maintain equipment and systems being verified.

Upon successful completion of Resident Engineer-witnessed functional performance tests, a performance period consisting of 30 consecutive calendar days shall commence on the first day following the last approved performance test and shall be completed prior to final acceptance of the project. In event of failure to meet standard of performance during any initiated performance period, it is not required that one 30 calendar day period expire in order for another performance period to begin.

The Test Engineer shall develop a written performance period testing plan and verify and document over time under normal conditions the performance of the commissioned equipment, systems and related systems, utilizing manual recording, automated tracking and tunnel control system trend logs as appropriate, and including:

A. Identification of systems and equipment that will be tested and set up acceptance criteria with approval of the Commissioning Agent.
B. Development, with the Commissioning Agent's approval, of sampling strategies based on likelihood and impact of failures; i.e., not all issues in all equipment need to be monitored.
C. Determination with the Commissioning Agent's approval, acceptable output and documentation to verify compliance with the acceptance criteria, such as sampling rate of trend logs, which points to graph together, graph type (time series, scatter plot) or tabular outputs needed, and defining how the trend graphs will be developed, such as by DDC or other means.
D. Graphs titled or annotated listing and describing the performance issue being displayed, clearly showing the point identity of each graph line, with date, time, values and units clearly identifiable.

    1. The Y-axis shall be scaled to provide as much resolution as possible and two Y-axes used for multiple points with large variances in their numerical ranges.
    2. The time window shall be narrowed to provide clear resolution, but wide enough to verify that compliance is not an anomaly in time.

3. Multiple time windows shall be used for the same issue as needed and requested by the Commissioning Agent.
4. Electronic data behind each graph shall be archived so re-graphing or reformatting can be accomplished or points used to add to another graph.

E. The Contractor shall set up trends in the DDC to ensure there will be no loss of data.
F. Data shall be analyzed and graphs adjusted by adding or deleting points or zooming in on a narrower time frame to clearly illustrate the issue. All data shall be submitted in an indexed binder, including a summary of the analysis listing all known areas that do not meet the acceptance criteria or are of concern.
G. Daily activities and conditions that may be useful in interpreting performance, such as tunnel activities and weather.
H. All system alarms, system failures, equipment failures, software failure, software errors, corrective actions and causes of alarms or failures, classified as to type of failure or alarm. A table listing the issue type and number of occurrences shall be submitted to the Commissioning Agent.
I. Records of all maintenance and adjustment operations performed on all commissioned systems.
J. The Test Engineer may review performance during the performance period to identify and correct problems as early as possible. All such corrections shall be documented with date and time and submitted to the Commissioning Agent within 24 hours of correction.
K. Corrections may or may not interrupt the timing of a performance period for a piece of equipment, system or issue, at the discretion of the Commissioning Agent.

The documentation of the planning and execution of the Performance Period tasks shall be assembled into a report and submitted to the Commissioning Agent within 5 working days of the end of the performance period.

Five to seven working days after submission of the report, a review meeting with the Commissioning Agent shall be held. At the meeting the report shall be reviewed and corrective actions, retest duration, and performance verification procedures shall be determined for issues where acceptance criteria was not met.

Additional testing shall be performed at no added cost to the State.

If equipment or systems operate so as to demonstrate continuing compliance with specified requirements for a period of 30 consecutive calendar days from commencement date of performance period, it shall be deemed to have met the standard of performance.

Equipment and systems will not be accepted and final payment will not be made by the Department until standards of performance and reliability are met.

Equipment warranties shall not start until standards of performance and reliability are met.

Upon Contractor's completion of the requirements of the commissioning plan, the successful completion of the performance period, and receipt of the required documentation, the Commissioning Agent shall provide the Department with a statement of acceptable performance. Receipt of the acceptable performance statement by the Department shall be a condition of acceptance of contract.

OPERATIONS AND MAINTENANCE DATA MANUAL

The Contractor shall compile O&M manuals for each piece of equipment or tunnel operating system in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions

TRAINING AND DEMONSTRATION

Training of, and demonstration to, Department personnel shall be a part of the commissioning process and essential for the proper operation of the equipment and systems. The Contractor shall coordinate with Commissioning Agent for the training and instruction of Department personnel in accordance with these special provisions.

COMMISSIONING RECORD REQUIREMENTS

The Commissioning Agent shall compile, organize and index the following commissioning data by equipment into labeled, indexed and tabbed, three-ring binders and deliver it to the Department for approval, to be included with the O&M manuals. Three copies of the manuals shall be provided. The format of the manuals shall be:

Tab 01 Commissioning Summary Report
Tab 02 Issues Log (log of commissioning findings and resolution)
Tab 03 Commissioning Plan
Tab 04 Commissioning Progress Reports
Tab 05 Submittal Reviews
Tab 06 O&M Manual Reviews
Tab 07 Summary Training Record
Tab 08 Design Narratives
Tab 09 Functional Testing Schedule
Tab 10 System / Equipment # 1, as follows:

1. Sequence of Operation for Equipment #1
2. Colored separator sheet
3. Functional Test Record and any approvals (filled out test procedures). Include trend logs if conveniently separated by equipment; otherwise include trend logs and analysis for all equipment in a separate Tab.
4. Colored separator sheet
5. Construction Checklist (filled out)
6. Colored separator sheet
7. Startup Report
8. Colored separator sheet
8 Training Record

Tab 11 System / Equipment # 2, etc.: repeat as per System / Equipment # 1
Tab xx Trend Log Analysis

The summary report shall include an executive summary, list of participants and roles, brief building description, overview of commissioning and testing scope, and a general description of testing and verification methods. For each piece of commissioned equipment and system, the report should contain the disposition of the Test Engineer regarding the adequacy of the equipment, documentation and training meeting the contract documents in the following areas:

A. Installation, including equipment meeting the equipment specifications
B. Functional performance and efficiency
C. Equipment O&M manual documentation
D. Operator training

All outstanding non-compliance items shall be specifically listed. Recommendations for improvement to equipment or operations, future actions or commissioning process changes shall also be listed. Each non-compliance issue shall be referenced to the specific functional test, inspection, trend log or other record where the deficiency is documented. The functional performance and efficiency section for each piece of equipment shall include a brief description of the verification method used, such as manual testing, DDC trend logs, or data loggers, and include observations and conclusions from the testing.

All other acquired documentation such as logs, minutes, reports, or communications will be retained by the Resident Engineer.

RESPONSIBILITIES AND COSTS

The Department will select and hire under a separate contract, the Commissioning Agent, the Test Engineer, and any Special Testing Firms/Engineers. All costs associated with these groups will be the responsibility of the Department, except where the Resident Engineer declares the Contractor has caused unreasonable delays or extra work due to the Contractor's or subcontractors' failure to perform tasks and complete work in a timely manner. In the latter case, the Contractor will be responsible for the extra expenses of these groups.

The Contractor shall be responsible for hiring, managing, and compensating (as a part of the base bid contract) all other commissioning and support personnel as specified in these special provisions and as may be necessary to complete the commissioning scope of work within the scheduled time.

The Contractor is fully responsible for the cost and performance of the technical specifications testing scope leading up to the final commissioning process, and shall provide reasonable office space for the Commissioning Agent and Testing Engineer at no additional cost to the Department.

PAYMENT

Full compensation for commissioning systems and equipment, including testing, training, documentation, reports and manuals, shall be considered as included in the contract prices paid for the various items of work involved and no additional compensation will be allowed.

10-4.__ INTRUSION DETECTION SYSTEM

GENERAL

The intrusion detection system shall include furnish and installation of devices for intrusion detection at doors in the tunnel and the Operation and Maintenance Center (OMC) in conformance with the details shown on the plans and to the requirements specified in these special provisions. Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions. The intrusion detection system shall consist of:

A. Detectors for roll-up doors.
B. Detectors for single and double doors.
C. Connection to I/O points in the Direct Digital Control (DDC) system.
D. Wire and cable.

SUMMARY

Scope.--Intrusion detectors shall be used for single, double and roll-up doors as shown on the plans. Intrusion detectors shall provide alarms to OMC Control Center and to the Oakland Traffic Management Center (TMC) through the DDC system.

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product data.--The submittals shall include complete details, information, and drawings for the intrusion detection system as shown on the plans and as specified in these special provisions. The submittals shall include the following:

A. Manufacturer's technical data for each type of product specified, including operating characteristics, furnished specialties, and accessories.
B. Shop drawings showing the following:

    1. Wiring diagrams showing typical wiring schematics.
    2. Operation and maintenance data for intrusion detectors for inclusion in Operation, and maintenance manuals in compliance with "Basic Electrical Materials and Methods" of these special provisions.

QUALITY ASSURANCE

The installation shall comply with NFPA 70, "National Electrical Code."

SYSTEM COMPONENTS

The intrusion detection system components shall be capable of withstanding a corrosive environment due to environmental conditions without mechanical or electrical damage or degradation of operating capability. System components subjected to corrosive fumes, vapors, and wind-driven salt spray in coastal zones, shall be provided with NEMA 250, Type 4X enclosures.

Door Detectors.--Door detectors shall consist of high security balanced magnetic switches. The switch shall contain Form C biased reed contacts, wired in single pole, double throw (SPDT) configuration. Door switches shall be surfaced mounted and UL listed.

Roll-up Door Detectors.--Roll-up door detectors shall consist of high security balanced magnetic switches. The switch shall contain a minimum of three Form C biased reed contacts, wired in SPDT configuration. Switches shall be track mounted and UL listed.

INSTALLATION

Pathway elements intended for cables shall be examined prior to installing cable. Raceways, cable trays, and other elements shall be checked for conditions affecting installation in accordance with NEC requirements. Installation shall proceed only after unsatisfactory conditions have been corrected.

Cables shall conform to "Signal Systems Conductor and Cable" of these special provisions. PVC insulation shall not be used in the tunnel.

Grounding.--Cable shields, drain conductors, and equipment shall be grounded to eliminate shock hazard and to minimize ground loops, common-mode returns, noise pickup, cross talk, and other impairments.

FIELD QUALITY CONTROL

Testing.--Testing of the intrusion detection system shall include the following:

A. Inspection: units and controls shall be verified that they are properly labeled and interconnecting wires and terminals are identified.
B. Pretesting: The Contractor shall align and adjust system and perform pretesting of all components, wiring, and functions to verify compliance with the requirements specified in these special provisions. Deficiencies shall be corrected by replacing malfunctioning or damaged items with new items.
C. Manufacturer's Field Services: A factory-authorized service representative shall inspect field-assembled components and perform system pretesting, testing, and adjustment.
D. Operational Tests: Tests shall be scheduled after pretesting has been successfully completed. Operational system tests shall be performed to verify compliance with the requirements specified in these special provisions. All modes of system operation and intrusion detection shall be tested. The Contractor shall methodically test for detection of intrusion and for false alarms in each zone of intrusion detection. False alarms shall be tested by simulating activities outside indicated detection patterns.
F. Report: a written report of observations, inspection, and tests shall be prepared.
G. Retesting: Deficiencies shall be corrected and the system shall be retested until the total system meets the requirements of these special provisions.
H. When the system is ready for final acceptance testing, the Contractor shall provide the Engineer, in writing, at least seven days advance notice.

Identification.--All system components, wiring, cabling, and terminals shall be identified with permanent labeling in conformance with "Electrical Identification" of these special provisions.

DEMONSTRATION AND TRAINING

A factory-authorized service representative shall perform the demonstration and train Department's maintenance personnel as specified in the following:

A. Procedures and schedules for troubleshooting, servicing, and maintaining equipment.
B. Review data in maintenance manuals.
C. Training shall be scheduled with the Engineer with at least seven days advance notice.
D. Training shall conform to "Basic Electrical Materials and Methods" of these special provisions.

MEASUREMENT

Intrusion detection system will be measured on a lump sum basis.

PAYMENT

The lump sum contract price paid for intrusion detection system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing

all the work involved in furnishing and installing the intrusion detection system, complete in place, including cabling, testing, and training, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.

10-4.__ SEISMIC MONITORING ELECTRICAL SYSTEM

GENERAL

This work shall consist of installing the seismic monitoring system in accordance with the details shown on the plans, these special provisions, the provisions in Section 86, "Signals, Lighting, and Electrical Systems," of the Standard Specifications and, the Standard Plans. The work shall include furnishing all labor, materials, equipment and services required to construct and install the complete seismic monitoring system.

SUMMARY

Scope.--The seismic monitoring electrical system shall consist of seismic sensor enclosures, a seismic recorder enclosure, a global positioning system (GPS) timing antenna, and associated interconnect cabling to facilitate seismic monitoring within the tunnel structure. In addition to the required interconnect cabling, the system also requires supply power and high-speed telephone circuits. Installation of seismic sensors and the seismic recorder will be performed by California Geological Survey (CGS).

SUBMITTALS

The Contractor shall submit equipment list and drawings in conformance with the provisions in Section 86-1.04, "Equipment List and Drawings," of the Standard Specifications and as specified in these special provisions.

Product Data.--The submittals shall include complete details, information, and drawings for the seismic monitoring system as shown on the plans and as specified in these special provisions. The submittals shall also include the following:

A. Manufacturer's technical data for each component furnished, indicating dimensions, capacities, performance characteristics, electrical characteristics, finishes of materials, installation instructions, and startup instructions.
B. Shop drawings from manufacturer detailing equipment assemblies and indicating dimensions, weights, loadings, required clearances, method of field assembly, components, and location and size of each field connection.
C. Wiring diagrams detailing wiring for power, signal, and control systems and differentiating clearly between manufacturer-installed and field-installed wiring.
D. Maintenance data to include in the maintenance manuals in conformance with the provisions in "Basic Electrical Materials and Methods" of these special provisions.

Product data shall be submitted for the following:

A. Seismic Sensor Enclosures – each type
B. Seismic Sensor Cable
C. RS485 Cable
D. Telephone (ISDN) cable

QUALITY ASSURANCE

Electrical components, devices, and accessories shall be listed and labeled as defined in NFPA 70, Article 100. The system and components shall comply with NFPA 70, and NFPA 502. All system components shall be UL Listed.

STATE FURNISHED MATERIALS

The Contractor is directed to Section 8-1.01, "State Furnished Materials," of the Special Provisions. The following materials will be furnished to the Contractor for installation:

FBA Pigtails.
Seismic Sensor mounting plates.
GPS Timing Antenna (CGS Installed)

SYSTEM COMPONENTS

Seismic Sensor Enclosure.--The Contractor shall furnish and install, at the locations shown on the plans, NEMA type 4X, wall-mount enclosures for use as Seismic Sensor Enclosures. Sensor enclosures shall be mounted in the center of recessed blockouts. It is critical that the enclosures be mounted smooth/flat and plumb. Enclosures shall not be used as junction boxes for any cabling other than the sensor cables for that enclosure.

Cabling.--Cable shall meet the following requirements:

A. Seismic Sensor Cables: Contractor shall furnish and install, at the locations indicated on the plans, 4-pair, #22AWG, twisted shielded pair cables running from each seismic sensor to the seismic recorder. Stranded copper, individually shielded pairs, overall shield, and individual #22AWG drain wires. A cable conforming to these requirements is also needed from the Seismic Recorder Enclosure to the GPS Timing Antenna junction box. Cable spools shall be of sufficient length to allow cables to be installed without splices. Conductor color code:

   1. 1st pair – red, black
   2. 2nd pair - white, brown
   3. 3rd pair – blue, violet
   4. 4th pair – yellow, orange

B. A high speed telephone digital subscriber line (DSL) data link is required to terminate on the communications backboard near the seismic recorder.

C. A junction box shall be installed at the location shown on the Plans, at an accessible location within 75 feet of the GPS Timing Antenna. This junction box shall be the same type enclosure as the Seismic Sensor Enclosures without venting or sensor mounting plates. A 4-pair, RS485 cable is required from the Seismic Recorder Enclosure to the GPS Timing Antenna junction box.

Conduit.--Conduit and raceway shall conform to "Raceways and Boxes" of these special provisions.

Miscellaneous Materials.--Miscellaneous materials shall meet the following requirements:

A. Pull Ropes: Pull ropes shall be nylon or polypropylene with a minimum tensile strength of 225 kg.
B. Anchorage Devices: Anchorage devices shall be corrosion resistant stainless steel toggle bolts, wood screws, bolts, machine screws, studs, expansion shields, and expansion anchors and inserts. Anchorage devices shall be installed in accordance with Manufacturer's recommendations.
C. Nameplates: Nameplates shall be provided in conformance with "Electrical Identification" of these special provisions. Equipment shall be identified with nameplates on the cover of each seismic enclosure.

INSTALLATION

Equipment shall be installed as shown on the plans to comply with manufacturer's written instructions.

Delivery, Storage, And Handling.--Equipment and materials shall be stored indoors and protected from weather.

Examination.--The Contractor shall verify that conditioned supply power is available to seismic recorder, and shall verify that enclosures, mounting plates, and interconnect cabling are correctly and securely installed before proceeding with installation.

ACCESS AND CONTRACTOR ASSISTANCE

Contractor shall coordinate with the Engineer to provide CGS personnel with the means and equipment to safely access and perform work at all recorder, sensor, and antenna locations after all Contractor installed equipment, conduit, and cabling is complete. Work shall include the transportation of equipment on the job site, traffic control, and movement of stored materials or parked vehicles. CGS will be responsible for installation at the following locations:

A. Recorder Location
B. Seismic Sensor Locations:
C. GPS Antenna Location:

FIELD QUALITY CONTROL

Testing.--After the complete installation of the seismic monitoring electrical system by both the Contractor and CGS personnel, the complete system will be tested by CGS personnel in the presence of the Engineer to demonstrate that it is working properly. Any problems associated with the equipment installed by the Contractor shall be adjusted, replaced, or repaired and the complete system shall be retested. If problems occur with State installed equipment, it will be replaced or repaired as required and retested, all at the State's expense. The Contractor shall provide 120 VAC, single phase, 60 Hz power for each sensor and recorder location for the duration of the testing.

MEASUREMENT

Seismic monitoring electrical system will be measured on a lump sum basis.

PAYMENT

The lump sum contract price paid for seismic monitoring electrical system shall include full compensation for furnishing all labor, materials, tools, equipment and incidentals and for doing all the work involved in furnishing and installing the seismic monitoring electrical system,

complete in place, as shown on the plans, as specified in the Standard Specifications and these special provisions, and as directed by the Engineer.