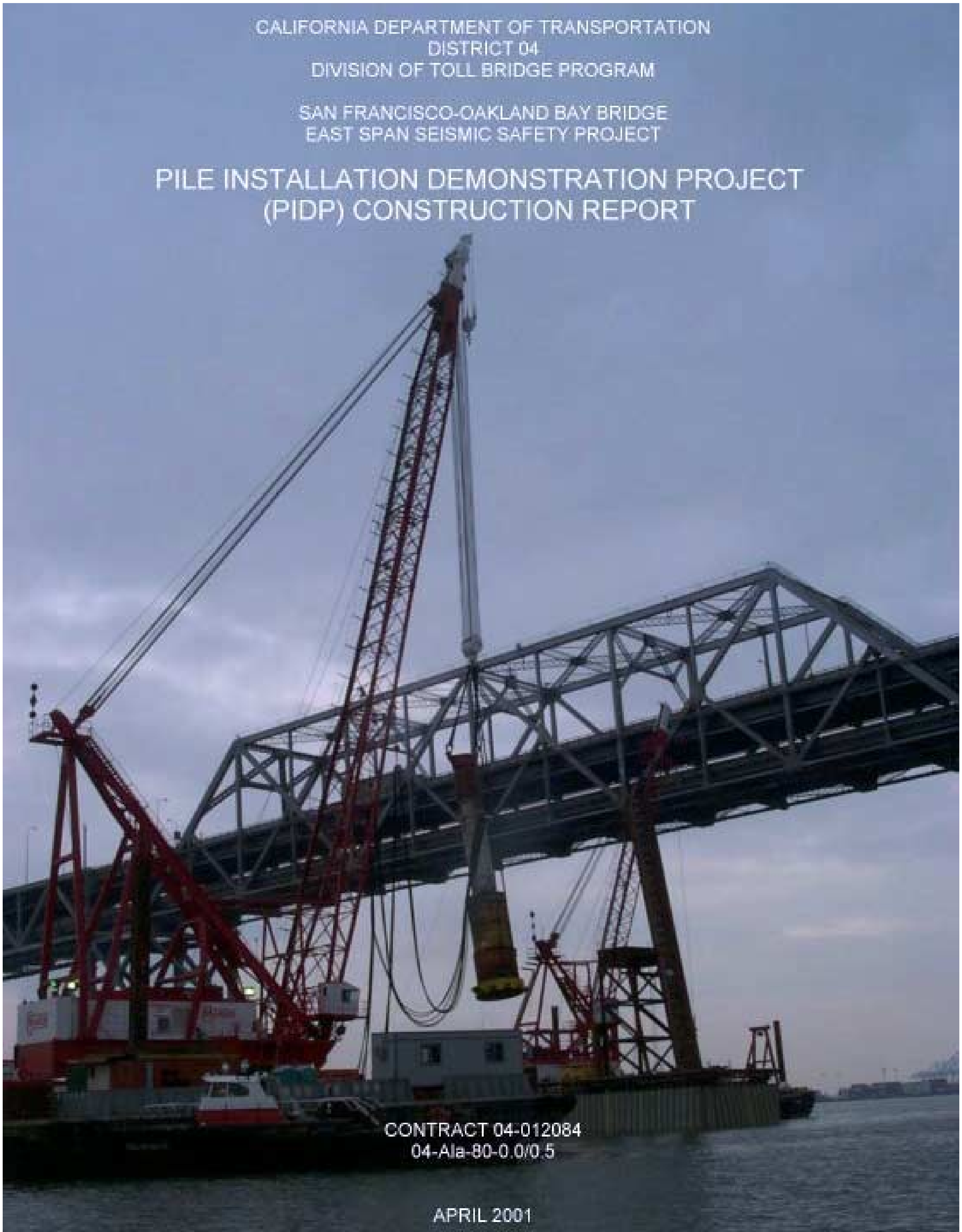
CALIFORNIA DEPARTMENT OF TRANSPORTATION
DISTRICT 04
DIVISION OF TOLL BRIDGE PROGRAM

SAN FRANCISCO-OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

PILE INSTALLATION DEMONSTRATION PROJECT (PIDP) CONSTRUCTION REPORT



CONTRACT 04-012084
04-Ala-80-0.0/0.5

APRIL 2001

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1. INTRODUCTION

On December 15, 2000 Caltrans completed a Pile Installation Demonstration Project (PIDP) for the new eastern spans of the San Francisco-Oakland Bay Bridge (SFOBB). The work entailed driving three 2.4 m diameter steel pipe piles at two different locations adjacent to the existing eastern span of the SFOBB (Figure 1). Each pile was composed of four sections and had a total completed length of approximately 107 m. Pile wall thickness varied from 40 mm to 70 mm. The individual pile sections were connected using complete joint penetration welds, and ultrasonic testing (UT) was performed on 100% of the weld volume.

The primary objectives of the PIDP included the following:

- Collecting geotechnical data pertaining to soil resistance and set up.
- Investigating several constructibility questions regarding handling, driving, and welding of large diameter pipe piles.
- Gathering information necessary to obtain the required environmental permits and investigate the effectiveness of various proposed underwater sound pressure mitigation techniques.

The PIDP contractor (Manson and Dutra, Joint Venture) drove the first three sections of each pile with a 500 kJ hydraulic hammer, and the final section was driven with a 1700 kJ hydraulic hammer. Pile run, the penetration caused by the weight of the first pile section and the hammer, ranged from 6 to 15 meters. Estimated soil resistance to driving (SRD) was generally within the range predicted with a maximum SRD between 50 and 75 MN for piles 1 and 2 at an initial penetration of 90 m. Soil set up occurred rapidly and resulted in a significant SRD increase. During the three to five day welding delays, SRD increased by a factor of 2 to 3. Restrikes performed on piles 1 and 2 also confirmed the rapid increase in soil resistance. Blow counts per quarter meter (bpqm) for the restrikes on pile 1 increased from 54 after 2 days to 144 after 9 days. Restrikes were performed using the 1700 kJ hammer at full energy after the pile had reached specified tip elevation.

The Contractor was able to place and drive the piles within the tolerances specified. The batter angle of 1:6 was maintained. It should be noted, however, that a significant amount of effort and expense went into the construction of a template strong enough to withstand the forces involved. The 500 kJ hammer was able to drive the piles to a penetration of 70 m, and was able to restart a pile at a depth of 45 m after a 5 day delay. Specified tip elevations were achieved using the 1700 kJ hammer with bpqm less than 55.

Quality control and quality assurance protocols developed to assure the structural integrity of the welded pile joints were stringent, and the contractor experienced some difficulty qualifying UT personnel due to an inability of several technicians to pass a newly required qualification test that was developed by Caltrans. This test is based upon AWS D1.5, Section 6. Estimated times to complete the weld process, particularly for the thicker sections, were found to be overly optimistic. The contractor used a Gas Shielded Flux Cored Arc Welding ($FCAW_G$) system with two welding machines on a

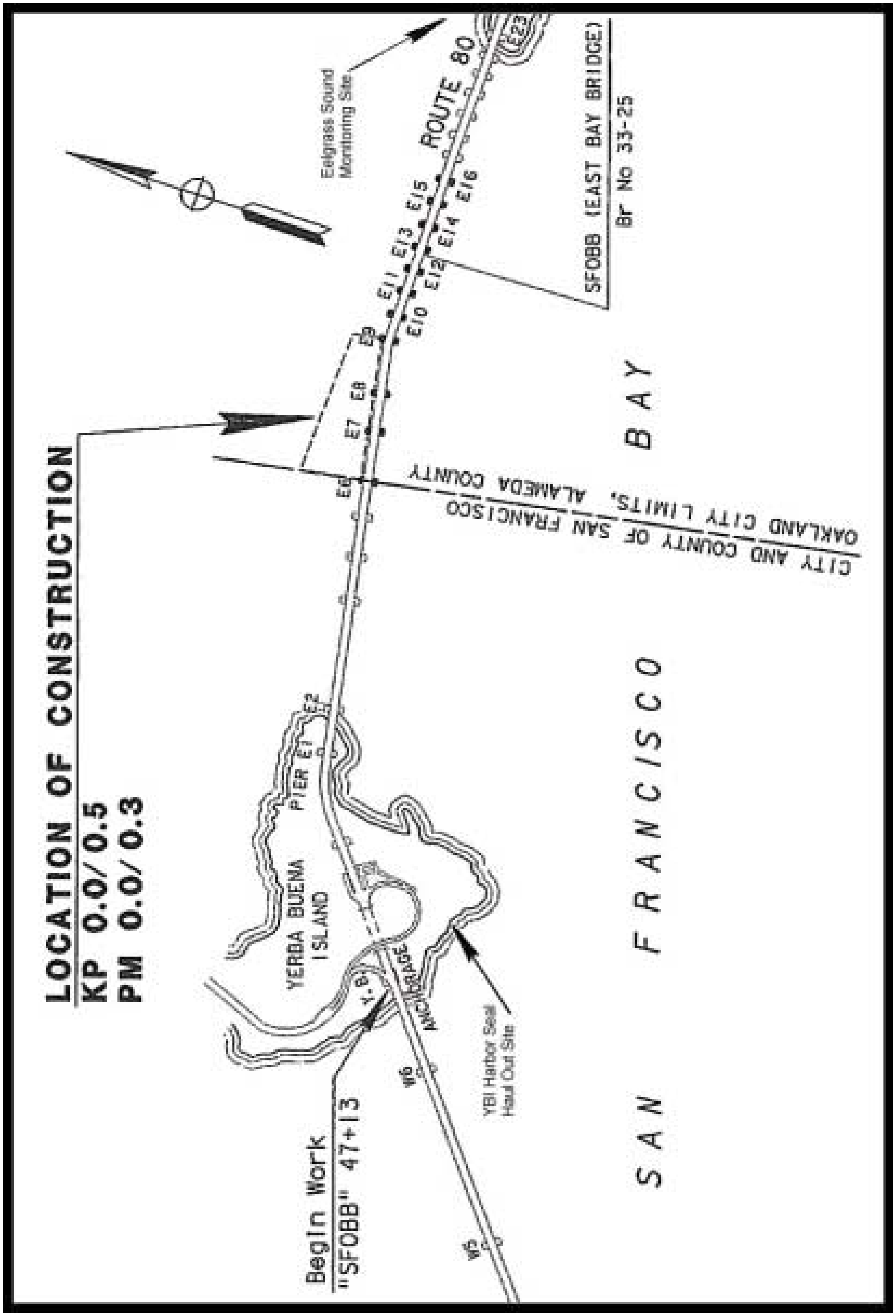

Figure 1 - PIDP Title Sheet

track to perform the 7.7 m long weld. The 70 mm thick joint took the contractor approximately 40 hrs to weld, with UT and weld repairs consuming as much as another 24 hrs depending on the initial weld quality.

As part of the environmental permitting process, Caltrans agreed to monitor the marine mammal response to pile driving, and to investigate two techniques to attenuate sound pressure in the water. Seals located at the haul out areas on Yerba Buena island were essentially unaffected by the PIDP, and the few seals and sea lions which wandered into the project limits prior to driving would leave upon commencement of driving without any noticeable signs of distress. Two types of bubble curtain were employed during driving operations to attenuate underwater sound pressure. Both curtains employed compressed air delivered to pipes at the mud line. Pile one was driven without sound attenuation. Pile two was driven with an air only bubble curtain, and pile three was driven using a fabric-encased bubble curtain. Both devices were shown to provide some sound attenuation.

The PIDP demonstrated the feasibility of using the piles presently being considered for the new SFOBB. It also provided Caltrans with a wealth of information that will be used to ensure the substructure of the new bridge is built in a cost effective and structurally sound manner while mitigating any negative environmental effects.

2. GEOTECHINICAL INFORMATION

Detailed information on the data collection and analysis pertaining to the geotechnical aspects of the PIDP and the new SFOBB East Span alignment is contained in a separate report titled “PILE INSTALLATION DEMONSTRATION PROJECT (PIDP) GEOTECHNICAL REPORT”, written by Fugro-Earth Mechanics (dated March 2001). Following is a general overview of some of the most pertinent soil profile and geologic information from the PIDP site.

2.1 PRINCIPAL GEOLOGIC FEATURES

The geology of the eastern San Francisco Bay is made up of the easterly sloping bedrock of the Franciscan Formation, overlain by layers of Holocene- and Pleistocene-age marine and alluvial sediments. There is extensive channeling within the marine and alluvial sedimentary layers.

2.1.1 FRANCISCAN FORMATION BEDROCK

The bedrock of the Franciscan Formation is primarily thickly bedded massive sandstone with thinly interbedded siltstone and claystone. In the vicinity of the PIDP test locations, bedrock is expected to be located at around El. -105 m to El. -110 m. This is well below the PIDP pile tip elevation of -102 m

2.1.2 HOLOCENE- AND PLEISTOCENE-AGE SEDIMENTS

This westerly-thinning sequence of marine and alluvial layers non-uniformly overlays the Franciscan Formation bedrock in the East Bay. The marine sediments are commonly clays and silts, while the alluvial sediments are primarily sands. Except where eroded and backfilled by past sequences of channeling, the inclination of the bedding is slight. Frequently, the marine and alluvial sediments are interlayered. The stratigraphic sequence can generally be extrapolated between borings, but the lithologic and geotechnical properties of the soils can vary significantly over short horizontal distances.

2.2 DESCRIPTION OF HOLOCENE- AND PLEISTOCENE-AGE SEDIMENTS

The soils that make up the Holocene- and Pleistocene-age marine and alluvial sediments are the following (in descending order):

- Young Bay Mud (YBM)
- Merritt-Posey-San Antonio Formations (MPSA), sometimes called Merritt Sand
- Old (Yerba Buena) Bay Mud (OBM)
- Upper Alameda Marine Sediments (UAM)
- Lower Alameda Alluvial Sediments (LAA)

2.2.1 YOUNG BAY MUD

This is typically fat clay, very soft to firm within the paleochannels, including sand layers and seams at various depths. Outside the paleochannels the surface blanket of YBM is typically soft. Near the primary PIDP location (piles 1 and 2) the YBM varies in thickness from 4.5 to 6.1 m and ranges between 10 to 20 m thick at the location of pile 3.

2.2.2 MERRITT-POSEY-SAN ANTONIO FORMATIONS

The MPSA formations are made up of a layered sequence of dense to very dense sand with stiff to very stiff sandy clay. The geophysical reflections of the MPSA sequence are generally discontinuous, suggesting limited lateral extent to individual layers. At the primary PIDP location, the MPSA is roughly 7 to 8.5 m thick and thin to non-existent near pile 3 due to proximity to a paleochannel.

2.2.3 OLD BAY MUD/UPPER ALAMEDA MARINE SEDIMENTS

These two formations have similar composition and properties with an interface difficult to ascertain and so can be treated as a combined sequence of sediments. Except where eroded by channeling, the top of this sequence is typically located at El. –17 m to El. –25 m. Borings indicate that the typical 60 m thickness of the combined sequence often includes multiple crust layers with locally higher strength. The OBM/UAM marine clays are generally very stiff to hard fat clays. The sequence includes some sand layers that are more prevalent beyond El. -65 m, but appear around El. -57 m at the PIDP locations. A 6 m thick layer of sand is present below approximately El. –68 m in the primary PIDP location. The OBM/UAM is the layered sequence from which the majority of the axial pile capacity due to skin friction was expected to be developed.

2.2.4 LOWER ALAMEDA ALLUVIAL SEDIMENTS

The LAA sequence is made up of a cap layer of very stiff to hard lean clay 3 to 10 m thick underlain by a sequence of very dense granular alluvial sediments. At the primary PIDP location, the top of the clay cap was expected to be around El. -84 m to El. -88 m with the alluvial sand layers approximately 2 to 4 m below the top of the clay cap. The PIDP specified pile tip elevation is well within the layers of LAA sands.

3. PIDP CONSTRUCTION

The separate report titled “PILE INSTALLATION DEMONSTRATION PROJECT (PIDP) GEOTECHNICAL REPORT”, written by Fugro-Earth Mechanics (dated March 2001) contains detailed information covering the drivability of the PIDP piles and the performance of the hammers used. Following is a general overview of some of the construction aspects of the PIDP (Table 1).

3.1 MARINE OPERATIONS AND EQUIPMENT

PIDP construction operations on-site mainly involved equipment and activities for the installation of a pile driving support template and, of course, the driving of the three demonstration piles.

The lifting on the PIDP was done primarily using the Derrick-24 (DB-24), which was positioned on-site using four anchors and two spud anchors. Smaller derrick barges were also used for ancillary operations not requiring the heavy-lift capacity of the DB-24. Transport of pile sections and other materials and equipment was accomplishing using a second flat-decked barge.

3.1.1 PILE TEMPLATE

The pile template consisted of a tubular-steel space frame “jacket” section with eight legs, supporting a steel frame tower with retractable yokes to laterally support the demonstration piles during driving (Fig. 2, 3, 4 and 5). The template was designed to support the vertical and horizontal loads of the pile and hammer during driving. It was strong enough to support the battered pile and to correct the batter angle during welding of the pile sections. The template was fabricated off-site, transported to the PIDP location by barge, and then submerged and positioned on the bay bottom. The location of the template was fixed by installing 864 mm diameter steel pipe piles within each leg and driving them to penetrations ranging from 18 to 30 m with the use of a vibratory hammer and an air/steam impact hammer. The template support piles were welded at the top of the template jacket.

SUMMARY OF PILE INSTALLATION SEQUENCE

Pile Installation Demonstration Project
SFOBB East Span Seismic Safety Project
04-012084   04-Ala-80-0.0/0.5

PILE	Segment	A		B (Splice AB)					C (Splice BC)					D (Splice CD)				
	activity	stabbing	driving	stabbing	welding	UT	weld repair	driving	stabbing	welding	UT	weld repair	driving	stabbing	welding	UT	weld repair	driving
1	start	0915, 10/19/00 Th	0810, 10/23/00 M	1745, 10/27/00 F	2200, 10/27/00 F	1345, 10/29/00 Sun	2100, 10/29/00 Sun	1605, 10/30/00 M	1215, 10/31/00 Tu	1600, 10/31/00 Tu	1000, 11/02/00 Th	1845, 11/02/00 Th	1400, 11/04/00 Sat	0740, 11/05/00 Sun	1245, 11/05/00 Sun	0140, 11/08/00 W	n/a	1050, 11/09/00 Th
	stop	1045, 10/19/00 Th	1042, 10/23/00 M	1815, 10/27/00 F	1030, 10/29/00 Sun	2130, 10/29/00 Sun	1500, 10/30/00 Sun	1753, 10/30/00 M	1250, 10/31/00 Tu	0800, 11/02/00 Th	1500, 11/02/00 Th	0630, 11/04/00 Sat	1550, 11/04/00 Sat	0950, 11/05/00 Sun	1700, 11/07/00 Tu	1330, 11/08/00 W	n/a	1300, 11/09/00 Th
2	start	1500, 11/02/00 Th	0900, 11/03/00 F	1600, 11/09/00 Th	2130, 11/09/00 Th	0300, 11/11/00 Sat	0700, 11/11/00 Sat	0850, 11/12/00 Sun	1800, 11/12/00 Sun	0040, 11/13/00 M	0430, 11/15/00 W	n/a	1050, 11/15/00 W	0800, 11/16/00 Th	1300, 11/16/00 Th	1330, 11/18/00 Sat	1525, 11/18/00 Sat	see note below
	stop	1730, 11/02/00 Th	1055, 11/03/00 F	1740, 11/09/00 Th	2130, 11/10/00 F	0600, 11/11/00 Sat	2130, 11/12/00 Sun	1130, 11/12/00 Sun	2107, 11/12/00 Sun	1830, 11/14/00 Tu	0630, 11/15/00 W	n/a	1348, 11/15/00 W	1100, 11/16/00 Th	0530, 11/18/00 Sat	1520, 11/18/00 Sat	1700, 11/18/00 Sat	see note below
3	start	0830, 12/01/00 F	n/a	1840, 12/01/00 F	2305, 12/01/00 F	2240, 12/02/00 Sat	0035, 12/03/00 Sun	1120, 12/03/00 Sun	2150, 12/03/00 Sun	0445, 12/04/00 M	0525, 12/06/00 W	0800, 12/06/00 W	1010, 12/07/00 Th	1800, 12/07/00 Th	0245, 12/08/00 F	0900, 12/10/00 Sun	1100, 12/10/00 Sun	1100, 12/11/00 M
	stop	1006, 12/01/00 F	n/a	1920, 12/01/00 F	1710, 12/02/00 Sat	0020, 12/03/00 Sun	0930, 12/03/00 Sun	1327, 12/03/00 Sun	0130, 12/04/00 M	0130, 12/06/00 W	0730, 12/06/00 W	2230, 12/06/00 W	1205, 12/07/00 Th	2300, 12/07/00 Th	0500, 12/10/00 Sun	1045, 12/10/00 Sun	1700, 12/10/00 Sun	1730, 12/11/00 M

NOTE: Driving of Pile 2D was initially begun on 11/19/00 Sun at around 0845, with the MHU 500T. At around 1639 on 11/19/00 Sun, the hammers were switched and driving of 2D was done with the MHU 1700T. There were hammer malfunctions that precluded completion of the drive of 2D on 11/19/00 Sun. Driving of 2D was resumed on 11/20/00 M, at around 0930 and completed around 1130.

PILE	Retap No.	Date
1	1	11/11/00
	2	11/20/00
	3	12/12/00
2	1	11/21/00
	2	12/12/00
3	1	12/13/00

Table 1 - Summary of Pile Installation Sequence

Figure 2 - Pile Template Installation

Figure 3 - Pile Template after the completion of driving at piles 1 and 2

Figure 4 - Pile Template during the driving of pile 3

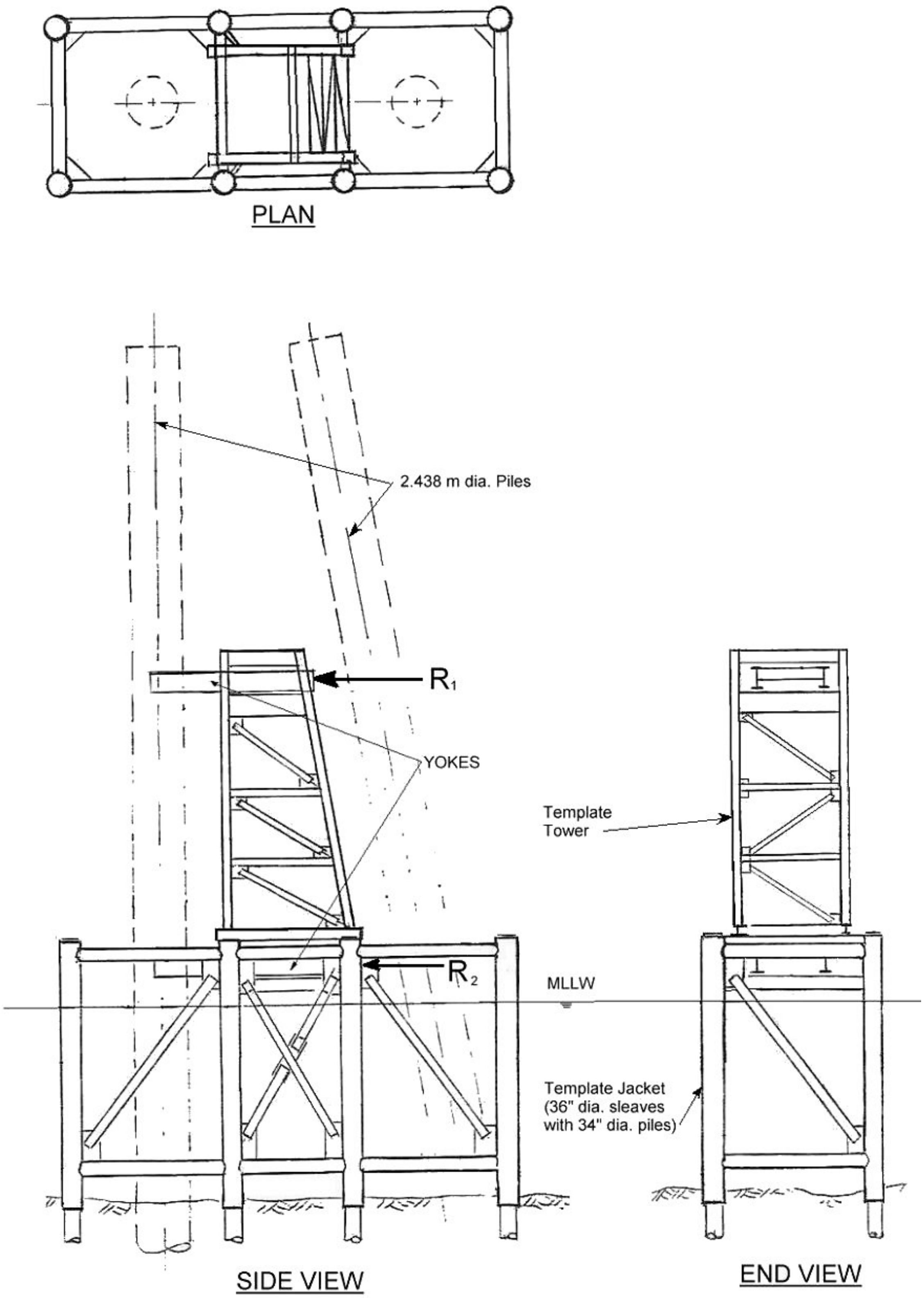

Figure 5 - Pile Template

3.1.2 PILE HANDLING

Pile sections were supported off the deck of the transport barge by cradles. Lifting of each pile section was accomplished by use of a lifting device which included two hydraulic rams, extended through 80 mm diameter holes cut about 200 mm below the upper edge of the piles. Two steel trunions were temporarily welded to the outside of the lower portion of each of the piles to serve as pivots in a tipping saddle as the piles were lifted (Fig. 6). The tipping saddle allowed the piles to rotate up without the lower edge of the pile coming into contact with the deck of the barge. In the interest of time, this trunion detail was accepted for the PIDP despite the special provisions requiring that all temporary welds would be performed parallel to the axis of the pile. The Contractor suggested that he would not use this method to tip the pile again. He would instead use a tipping chair where there would be no need to attach temporary trunions to the pile. As this is possible, no change in the temporary weld specifications is anticipated for the new SFOBB.

When placed into the template, the position of the battered piles was controlled through adjustment of the yokes in the template tower.

3.1.3 PILE HAMMERS

The hammers used for the PIDP were a Menck MHU 500T and a Menck MHU 1700T (Fig. 7 and 8). These are dual-action hydraulic hammers with maximum rated energy of about 550 kJ and roughly 1870 kJ, respectively, when operated above water. The underwater operation capability of these hammers was not used during the PIDP.

The Menck hammers and hydraulic systems are accompanied on-site by instrumentation providing detailed information on hammer performance and operating parameters, such as hammer stroke, impact velocity (and energy), mechanical efficiency, and blow rate, for instance. Each hammer rested in its own specially designed cradle, which served a similar purpose to the pile tipping saddle described above.

The hammers were lifted and positioned for pile driving using the DB-24, without the use of leads. The MHU 500 and hydraulic systems and accessories for both hammers were stored on the DB-24, while the MHU 1700 was stored on its own barge that was only towed to the jobsite when needed.

3.2 WELDING AND WELDING INSPECTION

The PIDP piles consisted of 2.4 m OD pipe piles fabricated in four sections. Sections ranged from 24.5 to 29 m in length (Fig. 9). The wall thickness varied from 40 mm near the bottom of the pile to 70 mm at the top. The wall thicknesses of the pipe sections at each field splice location were the same. The contract required that each pile section be fresh headed after driving by cutting off the top 1.5 m before splicing the next section. The pile sections, cover plates and two extra sections of pipe for welding

Figure 6 - Trunion and Tipping Saddle

Figure 7 - MHU 500 and two Power Packs on deck of DB-24

Figure 8 - MHU 1700 Driving Pile 3

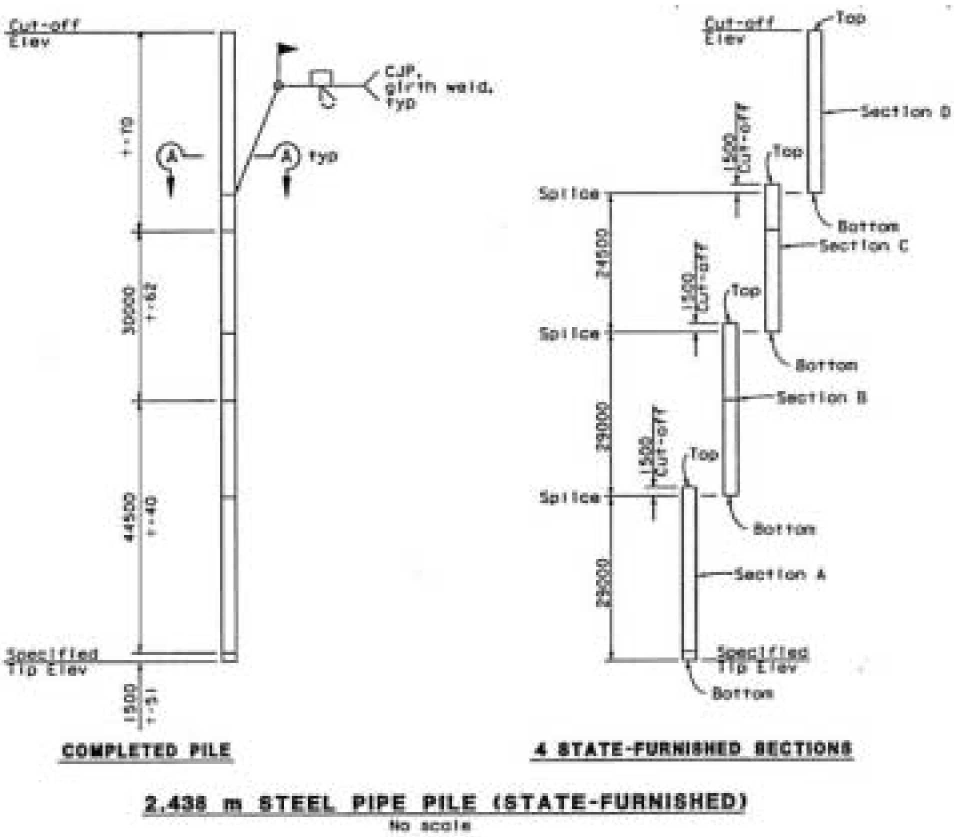

Figure 9 - Pile Details

qualifications were fabricated by Eaton Metal Products on a separate contract for the State. Discussions of the fabrication of the pipe pile sections can be found in the separate report titled "PID Welding Report 04-012081", by OSM. This report is included in the Appendix.

3.2.1 GIRTH WELD

The pile sections were furnished to the Contractor at Pier 96 in San Francisco. The Contractor then delivered the piles to the Dutra yard in Alameda while they prepared to qualify their welders and weld joint details.

The pile splices were specified to be field welded to the requirements of AWS D1.1-98 "Structural Welding Code -- Steel" except that the Procedure Qualifications were to conform to AWS D1.5-95 or AWS D1.5-96 "Bridge Welding Code". The splices were required to be complete joint penetration single bevel butt welds with backing.

The Contract required that the joints should be preheated to 150 C (300 degrees F) in accordance with the Special Provisions and AWS D1.1, Table 3.2. This preheat was achieved using electrical resistance heating mats. However, as noted below, this temperature requirement affected the way the joints were constructed.

Proposal for use of proprietary $FCAW_G$ system

The Contractor hired a Welding Consultant to provide the welding system, prepare the Welding Quality Control Plan, and train welders to use the consultant's welding system. The welding consultant's system was a CO_2 shielded $FCAW_G$ system of his own design (Fig. 10 and 11). The welding consultant began demonstrating this proprietary welding system and training the Contractor's welders on smaller piles at the Redwood City Lonestar Cement terminal about the first of August. The welds on these piles were found to be flawed and subsequently repaired. The Contractor's welders continued to train on the machines in Manson's Richmond yard until the middle of September, when the welding consultant performed the first PQR for this contract.

Based upon their experience, the welding consultant proposed a non-standard joint detail to perform the complete joint penetration girth weld (Fig. 12). This detail was intended to improve the ease of connecting (stabbing) two sections of the pile together in the field. This detail included a 3 mm spacer between the 13 mm backing plate and the pile plate. The welding consultant proposed to use a T-12 wire.

When the consultant attempted to assemble the two full-sized mock up pieces (2.4 m dia., 600 mm long, 70 mm thick), they found that the backing plate/stabbing guide created as many problems as it solved. While the stabbing effort was simplified, the gap between the backing plate and the lower pile section increased when the joint was preheated to the required temperature resulting in a failure to achieve the proper joint geometry. In some locations the gap exceeded 6 mm when preheating was complete. This fit-up difficulty was attributable to the additional hoop restraint on the pipe pile by the stabbing guide/backing bar related to the lack of provision for thermal expansion of the upper pipe. The Contractor requested permission to proceed with the PQRs with this geometry and the State granted this request.

Figure 10 - Proprietary FCAW system

Figure 11 - Proprietary FCAW system

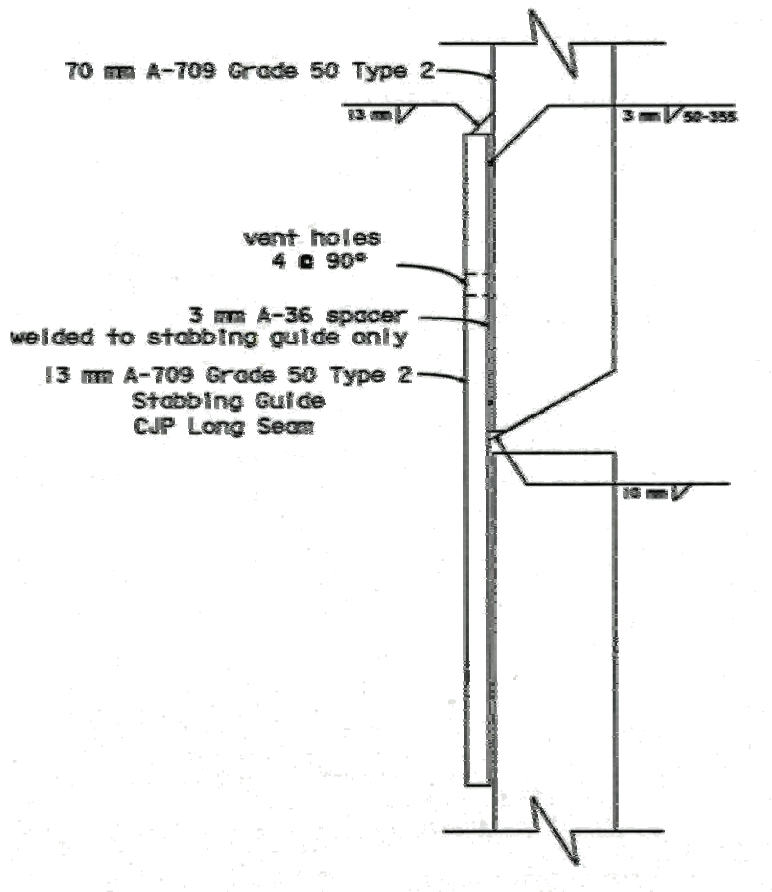

Figure 12 - Weld Detail with Spacer Plate

The consultant attempted several Procedure Qualification Records (PQRs) using this detail. The consultant chose to prepare PQRs and Welding Procedure Specifications (WPSs) for procedures using two different wire types, as well as a Shielded Metal Arc Welding (SMAW) procedure for use in repairs. In order to complete the root of the weld, the Contractor chose to use a welding procedure which called for the first several passes to be welded using a SMAW process and then continue the filler passes and cap passes using the $FCAW_G$ procedure. All of these PQRs and the qualification of some welders were attempted at the same time on this set of mock-up pipe sections. This endeavor took more than two days, working 24 hours per day, to perform. After completion of the Radiographic testing of this joint, the Contractor informed the Resident Engineer that this PQR showed numerous rejectable indications. The welding consultant decided against further use of the 3 mm spacer plate (Fig. 13).

The Contractor then cut the mock-up pieces apart and attempted a new PQR for the girth weld. This attempt was performed on the same mock-up pieces about two weeks after the first PQRs. The welding consultant attempted two PQRs: SMAW through the whole weld depth for use in repairs and SMAW for the first 10 passes and $FCAW_G$ for the last 89 passes for the production weld. The radiographic and mechanical tests on the production weld PQR passed. However, when the welding consultant submitted the tabular values for the essential variables (current, voltage, travel speed, heat input, etc.) to which each pass of the PQR was welded, they failed to conform to the requirements of the Contract. The PQR was rejected and the Contractor chose to replace the welding consultant with their own forces.

Use of commercially available $FCAW_G$ system

The Contractor brought in their own welding engineer and four new semi-automatic Lincoln $FCAW_G$ welding machines. The guns were fixed on a tracked buggy assembly (Fig. 14 and 15). The Contractor proceeded to run a Maximum-Minimum Heat Input PQR in accordance with AWS D1.5 section 5.12.2. Because the joint detail which the Contractor chose had standard features, they were able to perform these PQRs on flat 1-inch thick plate instead of the full sized pipe. By running a Maximum-Minimum Heat Input PQR, the Contractor was able to use a wider range in their essential variables for the final WPS than was permitted with the previously attempted PQRs. The Contractor used a T-9 wire for this attempt and the production welds. The final WPS, written based on this third PQR, was approved within two weeks of the start of welding.

Upon completion of the girth weld PQR and WPS, a full-sized mock-up was welded. This mock-up was completed in approximately 45 hours using four welders alternating on two welding machines with two machines as backups. The gap between the backing plate and the lower section of pipe varied from 0 to 4 mm after the upper section was pre-heated to about 210 C while the lower section was maintained at 150 C. Fit-up of the pile segments was achieved by heating the lower section to the minimum preheat temperature (or higher) then stabbing the upper section at ambient temperature and heating the upper section after the pile had been secured using wedges and strongbacks (Fig. 16). This procedure was adjusted as necessary to achieve a fit

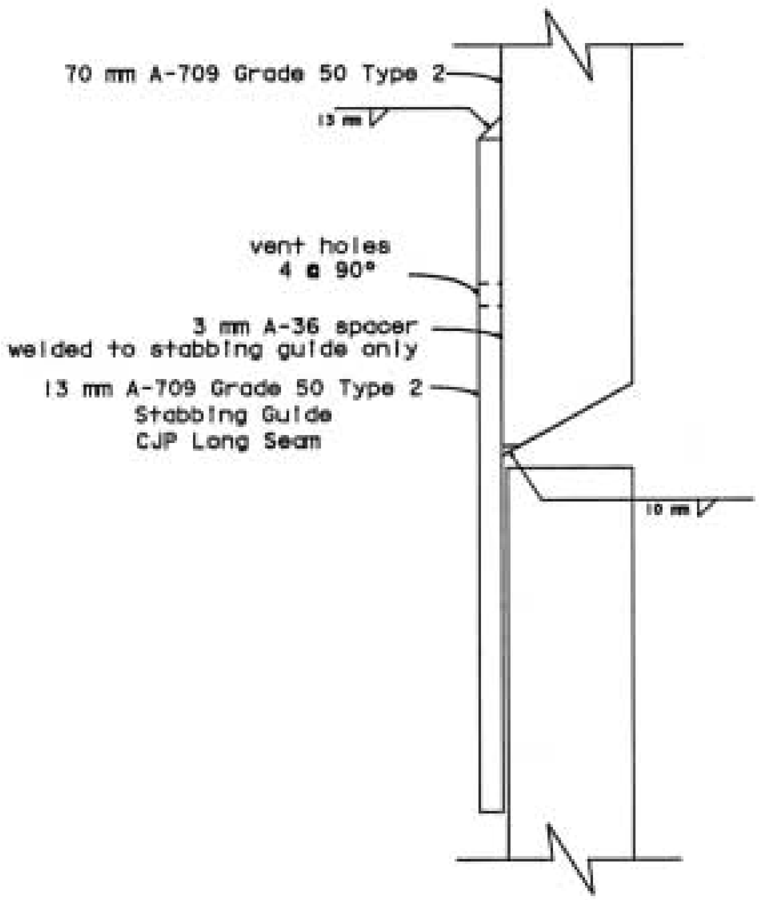

Figure 13 - Weld Detail As Built

Figure 14 - Preparing to weld the Mock-up

Figure 15 - Welding the mock-up

Figure 16 - Pile fit-up

where the final gap was generally less than 4 mm on the production piles. The Contractor chose to use only two welders in order to minimize the restart regions and minimize the related grinding. The Contractor's crew consisted of four welders using two alternately operating the $FCAW_G$ guns and two cleaning and making repairs.

The Contractor's welders continued to adjust their methods for placing the weld metal. The first pile was a plumb pile and was relatively easy to weld, however the first weld (1A-1B) contained the third most reported defects of the nine welds (see Table 2). Weld 1A-1B took about 36.5 shift hours to weld and 18 shift hours to repair. In placing weld 1B-1C the welders tried to increase production by increasing deposition rate. However this proved to be counterproductive, as the weld was found to have more defects attributable to lack of fusion and/or slag inclusions. This weld required the placement of almost twice the weld metal of the 1A-1B weld and took 40 hours to place and 36 hours to repair. On the third weld, the welders slowed down and paid greater attention to interpass cleaning and repairs at the start and stop regions. This effort allowed the Contractor to produce weld 1C-1D with no rejectable indications. This last weld took only 52 shift hours to complete despite placing about 230% of the weld metal placed in 1A-1B.

The first two joints on pile 1 were welded using a dragging angle on the $FCAW_G$ gun. This was found to contribute to the lack of fusion in the joint. The Contractor chose to weld the rest of the joints using a pushing angle on the gun.

The second and third piles were battered (sloped) at the rate of 1h : 6v (9.5 degrees from vertical). Due to the slope, the joints were welded uphill, both of the welders starting from the bottom.

3.2.2 STABBING GUIDES

The stabbing guide/backing plate consisted of a 13 mm plate extending from 175 mm above the bottom of the 30-degree bevel to 100-200 mm beyond the bevel (Fig. 17). The lower end of the stabbing guide was cut to a miter to ease stabbing. The upper end of the stabbing guide was welded with a 10 mm fillet weld 175 mm from the root of the girth weld to facilitate the use of the 45 and 70 degree transducers for the Ultrasonic inspection of the girth weld.

The Contractor used several approaches to welding the backing plate/stabbing guides to the bottom end of the pile sections.

First, they tried to weld the longitudinal seam of the backing plate after attaching the backing plate to the pile with the 10 mm fillet weld, using a V-beveled groove weld with the pile as a backing plate and a back gouged double V-beveled groove weld on the remainder of the backing plate which extended from the end of the pile. The Contractor found that there were difficulties in this method due to the thermal expansion (contraction) and shrinkage and they abandoned the method.

The Contractor also tried the above method using two parallel welds. This method too, was abandoned in part due to the additional restraint applied to the backing plate. This

SUMMARY OF WELDING AND REPAIR TIME

Pile Installation Demonstration Project
SFOBB East Span Seismic Safety Project
04-012084 04-Ala-80-0.0/0.5

Pile Section	Wall Thickness (mm)	Welding Time (hr)	Theoretical Length of Welded Passes (mm)	Length of Rejectable Indications (mm)		Rejection Percentage (%)	Repair Time Required (hr)
				Root Geometry	Slag Inclusions/ Lack of Fusion		
1A-1B	40.0	36.5	559232	1725	819	0.455	18.0
1B-1C	62.0	40.0	1080160	0	6985	0.647	36.0
1C-1D	70.0	52.0	1302309	0	0	0.000	0.0
2A-2B	40.0	24.0	559232	3366	356	0.665	14.5
2B-2C	62.0	42.0	1080160	0	0	0.000	0.0
2C-2D	70.0	40.5	1302309	0	25	0.002	1.5
3A-3B	40.0	18.0	559232	0	521	0.093	9.0
3B-3C	62.0	44.5	1080160	0	1499	0.139	14.5
3C-3D	70.0	50.0	1302309	0	152	0.012	6.0
Totals		347.5	8825103	5090	10357	0.175	99.5

Note: Weld times do not include preheating or cooling time.

Table 2 - Summary of Welding and Repair Time

Figure 17 - Stabbing Guide

additional restraint caused the forces applied to the second weld by the weld shrinkage to crack the base metal of the backing plate adjacent to the weld.

Finally, the Contractor determined that the best way to install the backing ring was to fabricate it to the size of the pre-heated pile and to weld the longitudinal seam before installation. The pile was then heated in the storage yard and the backing ring was inserted cold into the pile and then heated itself. When the backing ring was tight to the pile the 10 mm circumferential fillet weld was placed and the whole assembly was cooled down again before loading onto the pile transport barge.

3.2.3 TEMPORARY WELDS AND CUTTING

The pile sections came from the fabricator with all of the ends cut square. All of the cut ends met the straight edge requirements of API 2B, but they required beveling of the bottom end of the upper pile as preparation for the girth weld joint. This 30 degree bevel was made using thermal cutting methods (Fig. 18). Some of these joints were cut with irregularities that were then ground out and repaired in the process of welding the joint. This was a cause of fit-up difficulties particularly in the root opening. Performing these repairs during the weld also required additional time. If the joint geometry had been known at the time the pile order was placed, the fabricator could have added the bevel to the bottom ends.

Upon completion of the driving of each of the lower three sections of pile, 1.5 m was cut off to fresh head the piles before the splice weld was made. These cuts all met the straight edge requirements of API 2B. Pile section 1D was cut off in the field to provide additional mock-up sections. This cut was made somewhat unevenly, which caused some irregularities in the pile stresses as determined by Fugro using their Pile Dynamic Analyzer (PDA).

In order to secure the pile segments upon stabbing and maintain the weld geometry, a set of wedges and strongbacks were temporarily welded to the face of the pile (Fig. 16). The Contractor took care to provide that these components would secure the pile and keep the stresses applied to the root passes of the weld by the movement of the DB-24 on the waves from cracking the initial passes of the weld. These wedges and strongbacks were removed entirely after the root passes were completed and the upper pile segment was adequately secured to the lower segment.

3.2.4 FIELD WELDING ENCLOSURE

To successfully perform the welding in the field the Contractor designed and constructed a portable welding shack or enclosure on a temporary platform on the pile driving template (Fig. 19). This enclosure was necessary to keep the rain and significant marine winds from affecting the welding process. At the same time the enclosure had to provide proper ventilation and safe working conditions for the welding team. Lastly, the enclosure had to fit around both plumb and battered piles on the same template and had to be able to be removed before the driving of each section of pile.

A pair of modified storage boxes was used to form the body of the enclosure. Each box had one long side removed completely. The top (roof) and bottom had an oval cut into the edge facing the missing side and these open sides were then butted together for

Figure 18 - Pile Cut-off

Figure 19 - Welding enclosure at pile 3

each splicing event to make a double-width room. The butt joint was then weather sealed to prevent water and wind penetration. The upper pile section was lowered through the hole that was formed by the oval in the roof to meet up with the lower pile section that rose through the ovals cut in the floor and the steel plates that made up the temporary platform for the work. Flashing was placed around the pipe to seal the holes against unwanted water penetration. Ventilation was provided by the installation of fan units below the upper flashing in the roof, as well as the back wall of the enclosure. The doorways also had to be shielded from drafts that resulted with the entry or exit of welding and inspection personnel.

Flash burns from radiation that was reflected off the enclosure walls were one difficulty that was encountered. Fireproof shielding that minimized the reflections was found to be necessary. The personnel that regularly worked in the enclosure also found it necessary to apply heavy sun-screen to exposed skin and then wore clothing on the back of their heads in addition to using the hoods and eye protection devices that are standard in this industry. With multiple welding units working in this confined space the placement of the lights, machines, power chords, leads and support and QC/QA personnel all created additional logistic problems that had to be dealt with.

3.2.5 ULTRASONIC INSPECTION

The PIDP was the first project to include in its welding quality control specifications the requirement that, “Prior to performing ultrasonic type NDT, personnel performing ultrasonic NDT will be required to verify their qualifications by both written and practical examinations” that are administered by the State. These examinations test the applicants knowledge of the requirements of AWS D1.5, Section 6 as described in the Information Handout provided during the bidding phase.

The subcontractor charged with performing the ultrasonic testing (UT) on the welds got a slow start at getting their UT technicians qualified and found the exam to be more difficult and time consuming than they had anticipated. The specification requires the passing of a written exam prior to taking the practical exam. The practical exam is a rigorous process of reviewing the UT inspectors’ skills on a set of test plates with known weld defects, including their equipment preparation and defect documentation techniques. Prior to the completion of the last attempted PQR, only one UT technician had qualified. One inspector was not adequate since the UT inspection required on each 7.7 m long weld is very extensive, requiring up to 12 man-hours to complete (an average of 10 man-hours). A second inspector passed the exams in time to help with the inspection of piles 2 and 3. The overall passing rate for these exams was less than 20%. This rate is typical for the administration of similar tests by other organizations.

The pile sections as delivered to the project by Eaton Metals were not perfectly round and did not match exactly. However, they were fabricated to very close tolerances, exceeding API 2B requirements. The farthest out of round measured after delivery was only 7 mm (Table 3). Despite the high quality pile sections delivered, when two sections were stabbed together, a gap of up to 4 mm existed between the backing plate and the lower sections of the pile at the time that the root passes were placed. Due to this gap,

Pile Roundness Measurements
PIDP
04-012084
04--Ala-80-0.0/0.5

Date: 8/18/00
Taken by: MP Woods
J Gramlick
MG Vilcheck
DJ Bennett

Largest out-of-round measurement in mm			
Pile	Section	Top	Bottom
1	a	round	
	b	-4	-4
	c	0	-2
	d	+4	+2
2	a	-7	+2
	b	round	
	c	round	
	d	+5	-4
3	a	-5	0
	b	0	-3
	c	-3	-6
	d	-3	-6

Note: Round shows less than 2 mm deviation.

Table 3 - Pile Roundness

interpretation of the UT results was difficult. The squirt through of the weld metal into this gap caused many of these locations to be incorrectly interpreted as rejectable indications by the UT technicians (Table 2). This difficulty was addressed with very careful logging of the root gap and pile to backing plate locations and dimensions.

3.2.6 AUTOMATED ULTRASONIC INSPECTION

A separate NDT firm provided two demonstrations of their Automated Ultrasonic Testing (AUT) system, including one on the pile mock-up. Their system consisted of multiple transducers set up to run back and forth across the weld and around the pile on a tracked buggy. The information from these transducers was delivered to a laptop PC which had various gates used to determine the size of the flaw.

In order for the NDT firm to have used their AUT system on the PIDP welds, the firm and its operators would still have had to qualify under the Caltrans UT inspector qualification verification exams.

Two major advantages to this system became apparent in the demonstrations. First, while manual UT took at least 5 man-hours to inspect one of the welds, the AUT was able to complete the inspection (including set up) in under 2.5 hours. Secondly, the AUT provides the ability to record the size and location of the weld flaws electronically, such that the information can be reviewed at a later time by other UT technicians or State engineers.

The major drawback to this system is that it does not conform to the processes specified in AWS D1.5, section 6. The AUT system must instead be approved by the Engineer under AWS D1.5, Annex VII. Similarly to the UT inspection, the reporting of flaws, particularly in the root area of the weld, did not always reflect a flaw, but often, just a root geometry problem and the associated squirt through. This problem could be addressed using careful mapping of the root geometry prior to welding the joint.

3.3 SURVEYING

In order to install the piles in the correct locations, the Contractor used GPS to get the derrick barge and template close to the correct position. To finally locate the template piles, they used a total station set up on a reference point on one of the nearby piers of the East spans of the SFOBB. They used the total station to locate the first corner template pile, and then drove the pile. Next, they installed the template and turned it to the correct alignment and shot in the location for the opposite corner template pile and drove the pile. They then used a level to grade the template. The reference points for the construction of the SFOBB East Span Seismic Safety Project (ESSSP) have been established on each of the existing piers of the east spans.

4. SOUND ATTENUATING SYSTEMS AND MONITORING

The Special Provisions of the PIDP specify the use of two sound attenuating systems for the purpose of attenuating noise generated during pile-driving operations. The first system specified was an air bubble curtain system. The second sound attenuation system specified was one consisting of a full-water-depth fabric curtain with a contained aerating mechanism.

Air bubble curtain

The air bubble curtain system was exactly what the name implies. A curtain of air bubbles was generated around the pile to provide sound attenuation during driving. The bubbles were emitted from a submerged piping system surrounding the pile template.

The piping system was made up of three 4” diameter PVC pipes mounted side-by-side, 6” apart, on top of a beam frame. The frame was sized so that the pipes formed an octagonal ring around the template, 100 feet across the flats. Two rows of holes (0.04” in diameter) were drilled into the lower third of the PVC pipes to allow generation of the air bubbles. The beam frame support of the piping system was a 100’ square constructed of beams bolted together rather than welded to facilitate easier shipping and field erection. Additional beams (41.5’ long) were installed diagonally across each of the corners of the square frame, providing the octagonal form for the piping ring (Fig. 20 and 21). The piping ring was attached to the beam frame by pipe clamps fitted to a unistrut that was welded to the top of the upper beam flange.

The bubble curtain system was fabricated and assembled off-site, then transported to the pile-driving site using a barge-mounted crane. The ring was then fully submerged on the bay floor so that it encircled the pile-driving template. In operation during the driving sessions for installation of Pile 2, air was supplied to the bubble ring through a hose from a 1600 cfm compressor located on a barge at the water’s surface.

Aerating mechanism contained in fabric curtain

The full-water-depth fabric curtain with contained aerating mechanism, used during the driving of Pile 3, was essentially an air bubble curtain contained within a fabric curtain. This system (Fig. 22 and 23) was supplied by Gunderboom, Inc. and is described below. The fabric curtain itself consisted of two layers of water-permeable material 33’-8” in height and 226’ in length enclosing the perimeter of the pile-driving template. The top of the fabric curtain was connected to a turnbuckle, which was connected to a bracketed hoop attached to outrigger beams at the top of the template. The bottom of the fabric curtain was secured to the lower portion of the template by bolting to the upturned flanges of a beam that was welded to lower template outrigger beams near the bay floor. There were two piping systems incorporated into the Gunderboom. The first was similar in concept to the air bubble curtain previously described, but with 3” diameter PVC pipe, instead of 4” diameter pipe. This set of three pipes extended around the perimeter of the template and was clamped to a unistrut attached to a beam, which was in turn welded to the template outriggers inside the fabric curtain. The second piping system consisted of a single 3” diameter PVC pipe installed between the two layers of fabric of the curtain, nested between the flanges of the beam to which the fabric was bolted. As with the air bubble curtain, the pipes of both of these piping systems had 0.04” diameter holes drilled into the lower third of the pipes to allow for air bubble emission.

The Gunderboom system was assembled and attached to the pile-driving template off-site. The template with Gunderboom attached was then transported by barge to the pile

Figure 20 - Air Bubble Curtain under construcion in Dutra Yard

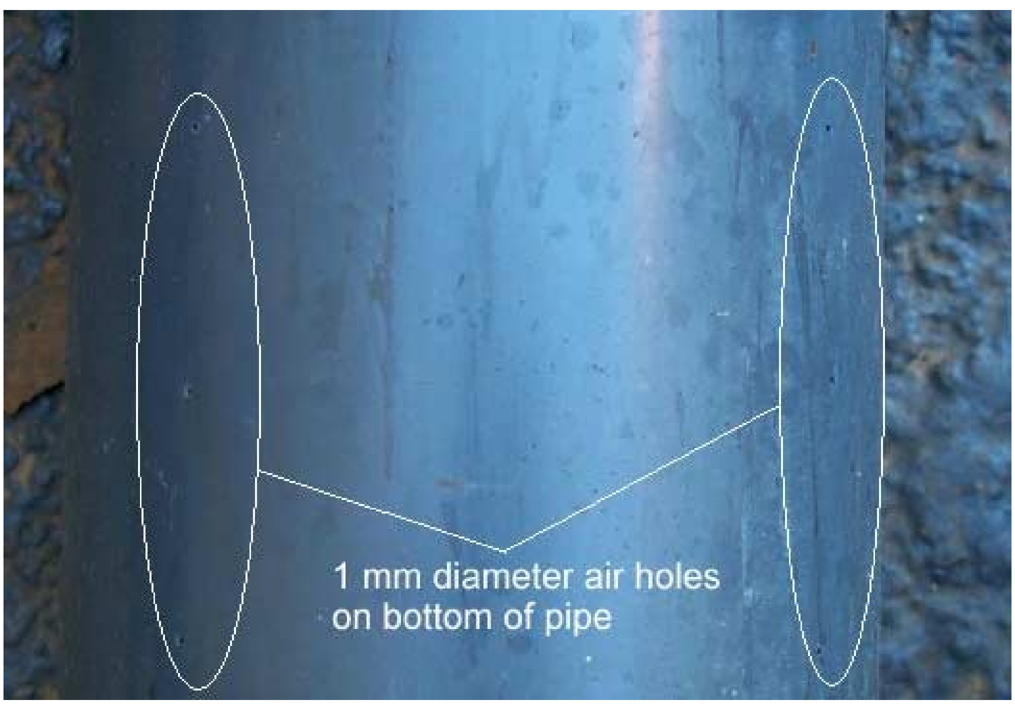

Figure 21 - Air Bubble Curtain pipe

Figure 22 - Gunderboom Assembly in Yard

Figure 23 - Gunderboom during driving of pile 3

location. During operation, air was fed into the Gunderboom piping systems from a 1600 cfm compressor located on the pile-driving template.

Sound Attenuating Systems -- General

Qualitatively, it can be stated that both the air bubble curtain and the Gunderboom showed effectiveness in attenuating the waterborne noise produced by the driving of the demonstration piles. Beyond this, however, it is difficult to make a true quantitative assessment of the effectiveness of each of these systems based on the limited data obtained from the subcontractor tasked with performing the sound monitoring for this project. During driving of pile 1, it was found that several small fish (anchovies) were being severely impacted by the shock wave developed by the pile driving. Many of these fish were stunned or killed and eaten by the local Gull population. In the process of driving piles 2 and 3 with the additional attenuation devices, it was discovered that both attenuation devices noticeably reduced the kill rate when in use. The Gunderboom appeared to be slightly more effective in this manner.

5. MARINE MAMMAL MONITORING (MMM)

Marine mammal monitors were stationed at various locations around the pile driving operation and at the nearby Harbor Seal haul-out site at Yerba Buena Island in accordance with the requirements of the Contract. The purpose of the monitors was to evaluate the response of the pinnipeds (harbor seals and sea lions) to the pile driving and to prevent their harassment due to the start of pile driving.

A Marine Mammal Safety Zone (MMSZ) was established at the beginning of the contract and was to be adjusted based upon sound pressure levels (SPLs) recorded during driving. This was not completed properly, based on the State's analysis of the limited data obtained from the subcontractor tasked with performing the waterborne sound monitoring for this project. The State had a consultant spot check the SPLs and from this data we were able to determine that a 500 m MMSZ is approximately correct for the hammers operating at maximum energy.

The MMM team stopped driving from occurring on two occasions where there were sea lions within the 500 m MMSZ. The sea lions then left the area and pile driving was allowed to begin. Two of the sea lions that were observed were swimming quickly away from the MMSZ. These were the only pinnipeds apparently incidentally harassed.

The harbor seal haul out monitoring appeared to show that there was no correlation between the pile driving and the number of seals at the haul out. The number of seals at the haul out appeared to be affected most by the tide and the presence of small boats and wakes.

Further discussions of the effects of the PIDP upon the marine mammals can be found in the "Marine Mammal Monitoring of the San Francisco-Oakland Bay Bridge Pile Installation Demonstration Project: September-December 2000", prepared by Philip Thorson, Ph.D. and Karin Wagner of SRS Technologies, (dated January 5, 2001).

6. CONCLUSIONS

The PIDP was a very short contract. Because the pile segments were State furnished, the contract time did not include the 5-6 months of lead-time that would be included in a typical construction project. The Contractor was given 132 days to obtain the Pile Hammers; receive the pile segments; mobilize a marine fleet; qualify welding procedures and welders; qualify UT inspectors; organize and execute Marine Mammal Monitoring (MMM) and Sound Attenuation Effectiveness Monitoring (SAEM) plans; install the piles and sound attenuation systems; and complete the MMM and SAEM reports.

It was shown on the PIDP that:

- The marine equipment chosen by the Contractor appeared to perform satisfactorily
- The pile support template performed adequately.
- The Contractor was able to maintain the pile locations and a 1h:6v batter acceptably. The deviations in location for the pile appeared to be related only to the precision with which the template was located.
- The location and direction of the pile head should be carefully monitored and corrections made to maintain the alignment using a template such as the one chosen by the Contractor.
- The methods of handling and driving the piling chosen by the Contractor were adequate.
- UT inspector qualification takes several weeks to perform a successful test and there is a low passing rate, so qualification must begin as early as possible in a contract.
- WPSs and welder qualifications take a great deal of time and planning. In order to develop the most effective welding plan, a Contractor would probably need to qualify several different WPSs or practice several different approaches to make most efficient use of the various welding materials.
- The welding and splicing operations took longer than planned by the Contractor. This was related both to the learning curve involved in welding the joints and the repair time.
- The Contractor made a good effort to provide a welding enclosure that was adequate to perform $FCAW_G$ in the field.
- The delays in driving, due to longer duration of pile splicing, allowed additional pile set-up, but did not cause driving difficulties for the pile hammers specified in the Contract.
- A hammer equivalent to the MHU 1700 used on this project will be necessary if there is any need to restart the piles due to equipment problems or welding difficulties when the pile tip is in the LAA sand.

- The pile batter did not appear to significantly reduce the drivability of the piles.
- Care must be taken to assure that the pile heads are cut off evenly and square to assure that the stresses applied by the pile hammer are distributed evenly to the piles.
- The waterborne sound attenuation efforts were both effective in reducing the SPLs to a point where the damage to fishes was noticeably reduced.
- MMM showed that there was a minimal effect of the pile driving upon the pinniped population in this part of the bay.

For additional conclusions with respect to the drivability and geotechnical monitoring, see the "PILE INSTALLATION DEMONSTRATION PROJECT (PIDP) GEOTECHNICAL REPORT", written by Fugro-Earth Mechanics (dated March 2001).

7. LIST OF TERMS

AASHTO	American Association of State Highway and Transportation Officials
API	American Petroleum Institute
AUT	Automated Ultrasonic Testing
automatic welding	Welding with equipment that requires only occasional or no observation of the welding and no manual adjustment of the equipment controls.
AWS	American Welding Society
bpqm	blows per quarter meter
Caltrans	California Department of Transportation
DB-24	Manson Construction Company's Derrick Barge No. 24
ESSSP	East Spans Seismic Safety Project
$FCAW_G$	Gas Shielded Flux Cored Arc Welding
GPS	Global Positioning System
LAA	Lower Alameda Alluvial Sediments
Manson/Dutra	Manson and Dutra, Joint Venture (Contractor for PIDP)
MMM	Marine Mammal Monitoring
MMSZ	Marine Mammal Safety Zone
MPSA	Merit-Posey-San Antonio Formation (Merritt Sand)
MT	Magnetic Particle Testing
OBM	Old Bay Mud
NDT	Nondestructive Testing
PDA	Pile Driving Analyzer – the analysis tool to show the pile stresses during driving
PIDP	Pile Installation Demonstration Project
PQR	Procedure Qualification Record
RTK	Real Time Kinematic
SAEM	Sound Attenuation Effectiveness Monitoring
SAW	Submerged Arc Welding
semiautomatic welding	Arc welding with equipment that controls only the filler metal feed. The advance of the welding is manually controlled.

SFOBB	San Francisco-Oakland Bay Bridge
SMAW	Shielded Metal Arc Welding (stick welding)
SRD	Soil Resistance to Driving
tack weld	a weld made to hold parts of a weldment in proper alignment until the final welds are made
temporary weld	A weld made to attach a piece or pieces to a weldment for temporary use in handling, shipping, or working on the weldment.
UAM	Upper Alameda Marine Sediments
UT	Ultrasonic Testing
WPS	Welding Procedure Specification
YBM	Young Bay Mud

8. REFERENCES

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9. APPENDIX

CALIFORNIA DEPARTMENT OF TRANSPORTATION
DISTRICT 04
DIVISION OF TOLL BRIDGE PROGRAM

SAN FRANCISCO-OAKLAND BAY BRIDGE
EAST SPAN SEISMIC SAFETY PROJECT

PILE INSTALLATION DEMONSTRATION PROJECT (PIDP) STEEL PIPE PILE FABRICATION REPORT

PURCHASE ORDER NO. 54472

EA NO. 04-012081

REPORT PREPARED BY
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Introduction

In order to meet the installation schedule for the PIDP Construction Contract, a separate contract was established for the procurement of the steel pipe piling. This procurement contract was advertised and awarded by The California Department of General Services, and it was managed and paid through the California Department of Transportation. This procurement contract included storage, shipping and off-loading of the completed materials directly to the Prime Contractor for the PDIP Construction Contract.

The procurement contract was awarded to the lowest bidder, Eaton Metal Products, Company in July 1999. Fabrication was complete in February 2000. Materials went into long-term storage at an Eaton facility until the Construction Contract was awarded. Eaton shipped the materials by rail to the Port of San Francisco where off-loading was completed by their Subcontractor, Sheedy Drayage Company. Off-loading was completed in August 2000.

Several difficulties were encountered during the fabrication of these piles. These difficulties ranged from getting materials to final inspection of the finished product. The following report will discuss these difficulties.

This project consisted of fabricating three (3 meters diameter by approximately 120 meters long) piles, extra sections for weld procedure qualification and covers for the tops of the completed piles. Each of the three piles was delivered per the State required four sections per pile, for a total of 12 pile pieces.

Eaton Company primarily performed the fabrication at Salt Lake City, Utah. The Salt Lake facility performed the rolling and seam welding of the pipe pile sections, while both the Salt Lake City and Pocatello Idaho facilities performed the girth welding of the pile members. Both plants worked concurrently on this project.

Quality Control Plan Problems

The special provisions of the project clearly indicated the requirements for the Quality Control Plan (QCP) submittal prior to the start of any welding. A pre-weld meeting was held at the fabricator facility to discuss the specifications, special provisions and drawings requirements for the project. The pre-weld meeting was very detailed as to the special requirements of this project.

The contractor's Quality Control Plan Manual (QCP) required several revisions before being accepted by the Caltrans. The following problems or discrepancies were observed during the review of the contractors Quality Control Plan and required revisions:

- The NDT firm's procedure manual required corrections and re-submittals approximately five times. The submittal package was initially missing the required documentation for personnel certification, equipment calibration documentation, and testing procedures conforming to AWS.

- The fabricators organization chart did not include information for both fabrication facilities which included all Quality control Inspectors and their assigned QC responsibilities.

- The names, qualifications, and documentation of certifications for the Quality Control Manager (QCM) and Quality Control (QC) inspection staff was not properly documented.

- The NDT forms submitted did not contain the minimum information required by the AWS code and contract special provisions.

- The non-critical repair procedures were missing vital information. The missing information included QC reviews, depth of excavation measurements, QC verification of defect removal, and proper documentation of repair information.

- The welding procedures and welder qualifications were not initially submitted in the QCP package. This variance was permitted by the Engineer to allow the contractor time to receive the actual production material for the qualification testing. The qualifications were later submitted and approved. The first welding procedure qualification test did have problems with the radiographic testing. The radiographic film and testing technique did not meet the code criteria.

Fabrication Problems

Fabrication in both Pocatello and Salt Lake City plants seemed to progress smoothly once the quality control plan submittals were approved by the Engineer. During fabrication the contractor encountered time problems with the grinding of welds for the nondestructive testing, especially for the ultrasonic testing. At this point the contractor opted for using radiographic testing in the interest of time.

In addition several nondestructive testing problems were encountered. The following nondestructive testing problems or difficulties were noted during the fabrication and testing process:

- The NDT firm did not relay the approved ultrasonic testing procedure to the technicians that performed the testing at the fabrications shop.

- The NDT firm had difficulties complying with the code criteria for ultrasonic testing of the longitudinal weld joint while contending with the curvature of the pile.

- The NDT firm had difficulties performing ultrasonic testing on the girth weld joints with transitions.

- The NDT firm initially utilized film side IQI's and were required to retest utilizing source side IQI's.

- The experience, technical knowledge and skill level of the NDT personnel performing the testing was not sufficient based upon the high number of retests that were required to meet the contract requirements.

Nonconformance Issues

Most of the nonconformance issues were related to the nondestructive testing for either the ultrasonic and radiographic testing. The nondestructive testing firm's hires did not have sufficient experience with AWS D1.1 or D1.5 code requirements.

Materials Issues

The project special provisions required the contractor to use material ASTM A709 grade 50 with additional requirements such as:

- The carbon equivalency (CE) shall not exceed 0.45.
- Charpy V-notch specimens for both longitudinal and transverse orientations were obtained and tested. The sampled were tested according ASTM A673M, frequency H, and had to meet 27 joules average at +4C.
- The drawing specified minimum thickness of material.

The contractor had problems with getting nominal thickness material to meet the minimum thickness required by the drawing. The material obtained met the thickness requirements, however significant amounts of repair were done on pitting to meet AWS code requirements even though the material met the ASTM A6 criteria.

Recommendations Regarding Changes in Special Provisions

The Special Provisions, AWS D1.1 Code, or Caltrans Standard Specifications were found to be deficient in the following areas:

- The radiographic acceptance criteria specified in the Special Provisions and AWS D1.1 Code does not address or provide limitations for discontinuities that are located at intersecting welds. The code only provides limits for discontinuities of this type in the Figure 6.6 – Weld Quality Requirements for Elongated Discontinuities as Determined by Radiography of Tubular Joints and Paragraph 6.12.3.1 of AWS D1.1-98.

- The minimum number of image quality indicators (IQI's) required for a panoramic radiograph of a girth weld should be specified. The suggested minimum number is eight with one IQI at each quarter point and one in between each quarter point.

- Other deficiencies were discussed and incorporated into the special provisions.