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Summary

Starting in 1925 and ending in 1927 an extensive field investigation was conducted of the performance of some 5275 culverts installed in highways of the state.

The following types and classes were inspected: 4279 Corrugated metal culverts, 785 Reinforced concrete (Monolithic) culverts up to 10 ft. span, 197 Concrete pipe culverts, 14 Vitrified pipe culverts 5275 Total.

Of these structures 4797 were on the State Highway System and 481 on county roads.

Groups of culverts were selected for inspection in all parts of the state in order that the widest ranges in soils and climatic conditions might be included.

The survey was conducted at the request of State Highway Engineer R.M. Morton by Mr. C.L. McKesson, Materials and Research Engineer.

The purpose of the investigation was to determine, if possible, the relative values of concrete and different kinds of metal in the hope of developing some constructive information regarding proper installation and protective measures for increasing the service value of the types in use.

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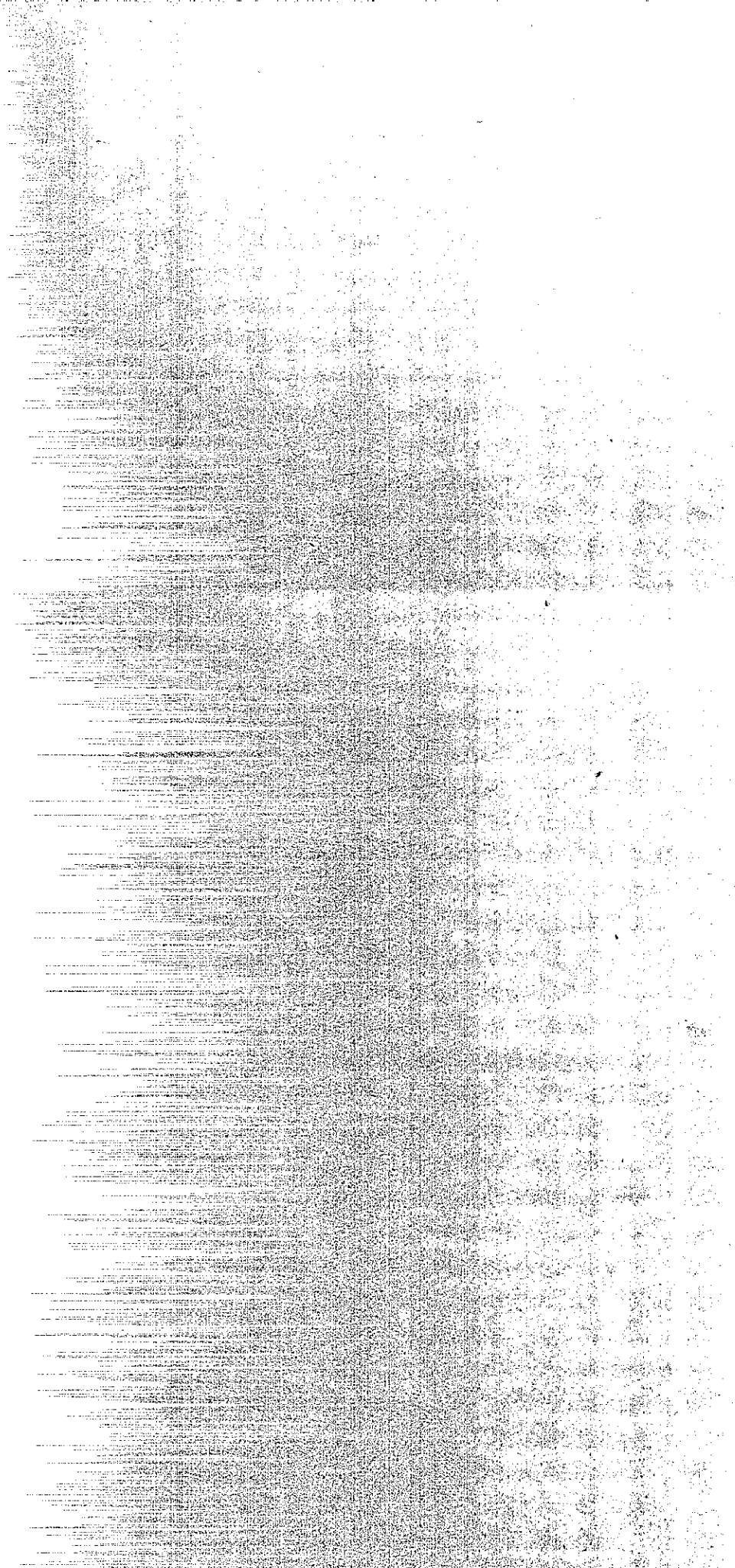

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MATERIALS AND RESEARCH DEPARTMENT
CALIFORNIA DIVISION OF HIGHWAYS

FINAL (20 YEAR) REPORT ON THE CORRUGATED METAL CULVERT FIELD TEST STARTED IN 1929 - 1930

Report by Thos. E. Stanton
Materials and Research Engineer
January, 1951

SUMMARY

Starting in 1925 and ending in 1927 an extensive field investigation was conducted of the performance of some 5275 culverts installed in highways of the state.

The following types and classes were inspected:

4279	Corrugated metal culverts
785	Reinforced concrete (Monolithic) culverts up to 10 ft. span
197	Concrete pipe culverts
14	Vitrified pipe culverts
5275	Total

Of these structures 4797 were on the State Highway System and 481 on County roads.

Groups of culverts were selected for inspection in all parts of the state in order that the widest ranges in soils and climatic conditions might be included.

The survey was conducted at the request of State Highway Engineer R. M. Morton by Mr. C. L. McKesson, Materials and Research Engineer.

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The purpose of the investigation was to determine, if possible, the relative values of concrete and different kinds of metal in the hope of developing some constructive information regarding proper installation and protective measures for increasing the service value of the types in use.

As a result of the study, Mr. McKesson in 1928 reached the following conclusions (which are herein quoted as of historical interest and of value in supplementing the data developed from the subsequent study herein reported):

(Quoting from Mr. McKesson's Report of 1928)

"(1) The entire absence of structural failures among 4250 corrugated metal culverts inspected in California shows that these culverts have sufficient strength to meet highway loading requirements, and that present practices as to gauge, riveting, etc. are adequate (as of 1928).

(2) The average indicated life of corrugated metal culverts in California, in fresh water and with intermittent flow, based on observation of 2500 such structures, is about eighty years.

(3) Deterioration in corrugated metal culverts is due almost exclusively to corrosion, is preventable in many cases, and may be greatly reduced in others.

(4) Spelter alone does not provide sufficient protection against corrosion, except under most favorable conditions of exposure, and bituminous and other protective coatings are usually desirable even where spelter is used.

(5) The probable effect of such variables of exposure as rainfall, filling abrasion and the presence of salts, alkalis or minerals can be foretold in a general way and the knowledge can be utilized in the economic selection of culvert types.

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(6) The life of metal culverts can be most economically prolonged by carefully eliminating detrimental conditions of exposure.

(7) The average age of the culverts inspected was about ten years and more than half of those under normal conditions of exposure were still in a spelter stage. The life of spelter under normal conditions in California appears to average about 8.5 years. The average length of exposure of the base metal in culverts which had lost their spelter was about 3.5 years. This period is too short to justify definite findings as to relative performance of base metals. Trends were noted which indicated some slight superiority of one metal under one set of conditions and of another under different conditions but, in spite of attempts which were made to evaluate or eliminate variables of exposure, inconsistencies from the apparent trends were noted which proved conclusively that unknown variables still remain which, if understood, might explain or nullify the slight apparent differences in performance. Much additional data and the lapse of more time will be required before variations in culvert performance, if any, due to differences in base metal can be definitely known or evaluated. To this end the data gathered in this study will be made available to National Research Organizations for study along with data from their own tests. A reinspection of the culverts included in this study after an additional period of ten years would probably bring conclusive findings.

(8) Assuming highway funds to have an earning power of 5% per annum, a 100 year life constitutes "permanent" service in that no additional capital expenditure would be justified to secure longer service. Upon this basis the average indicated life of eighty years for corrugated metal culverts in California under the normal conditions described in Paragraph 2 would justify a cost of about 98% of the cost of permanent structures. Familiarity with causes for deterioration and elimination of these causes will reduce this 2% preferential showing in favor of permanent structures.

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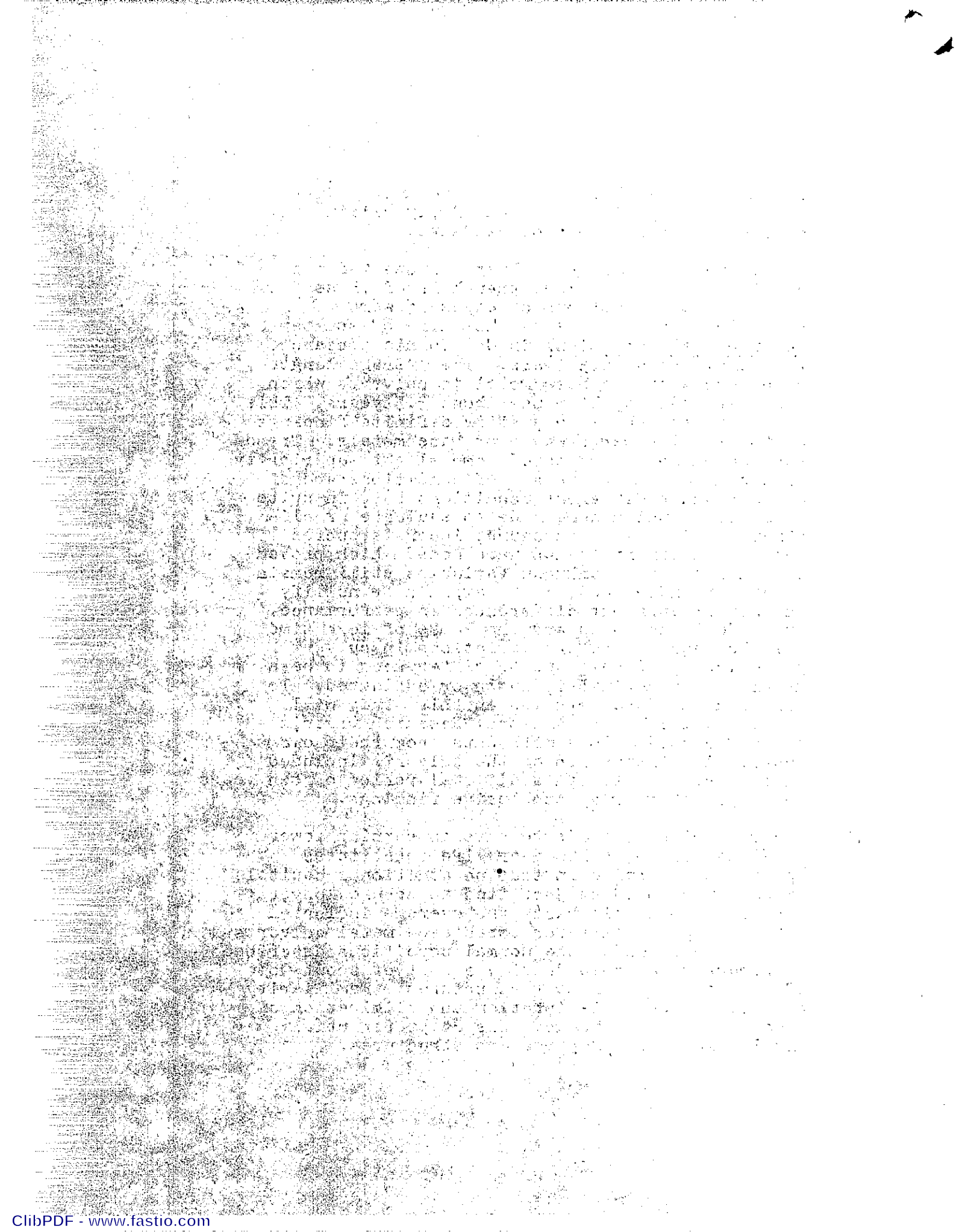

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(9) Concrete pipe culverts have not been extensively used on California State Highways, but a study of a limited number shows an indicated average life of 96 years. Well made reinforced concrete pipe meeting present specification requirements will probably be "permanent" structures under conditions prevailing in this state.

(10) Under favorable conditions of exposure the value of corrugated metal culverts, measured in paragraph 8, may be only 25 to 75% of the value of permanent structures. Economic considerations should control under these circumstances, as in all others, and the selection of some type not affected by these destructive conditions may thus be found desirable.

(11) Monolithic reinforced concrete culverts have been found to depreciate very slowly under conditions prevailing in California and the average performance of these culverts justifies classifying this type as permanent. They are not greatly affected by the unfavorable conditions which accelerate corrosion in corrugated metal and are, therefore, suitable for use where the unfavorable conditions cannot be eliminated and where there is economic justification for their use."

In addition to the above, McKesson's report set forth certain other conclusions which the State Highway Engineer, feeling that the service experience up to that time had been of such short duration as to not justify a decision which it was felt might be difficult to sustain without a longer service record for all types studied, decided that the report should be given limited circulation as a confidential document in so far as publication and general distribution was concerned. For that reason the complete conclusions of the McKesson report have never been published, although reasons for any reticence which may have been justified some twenty odd years ago probably no longer exist.

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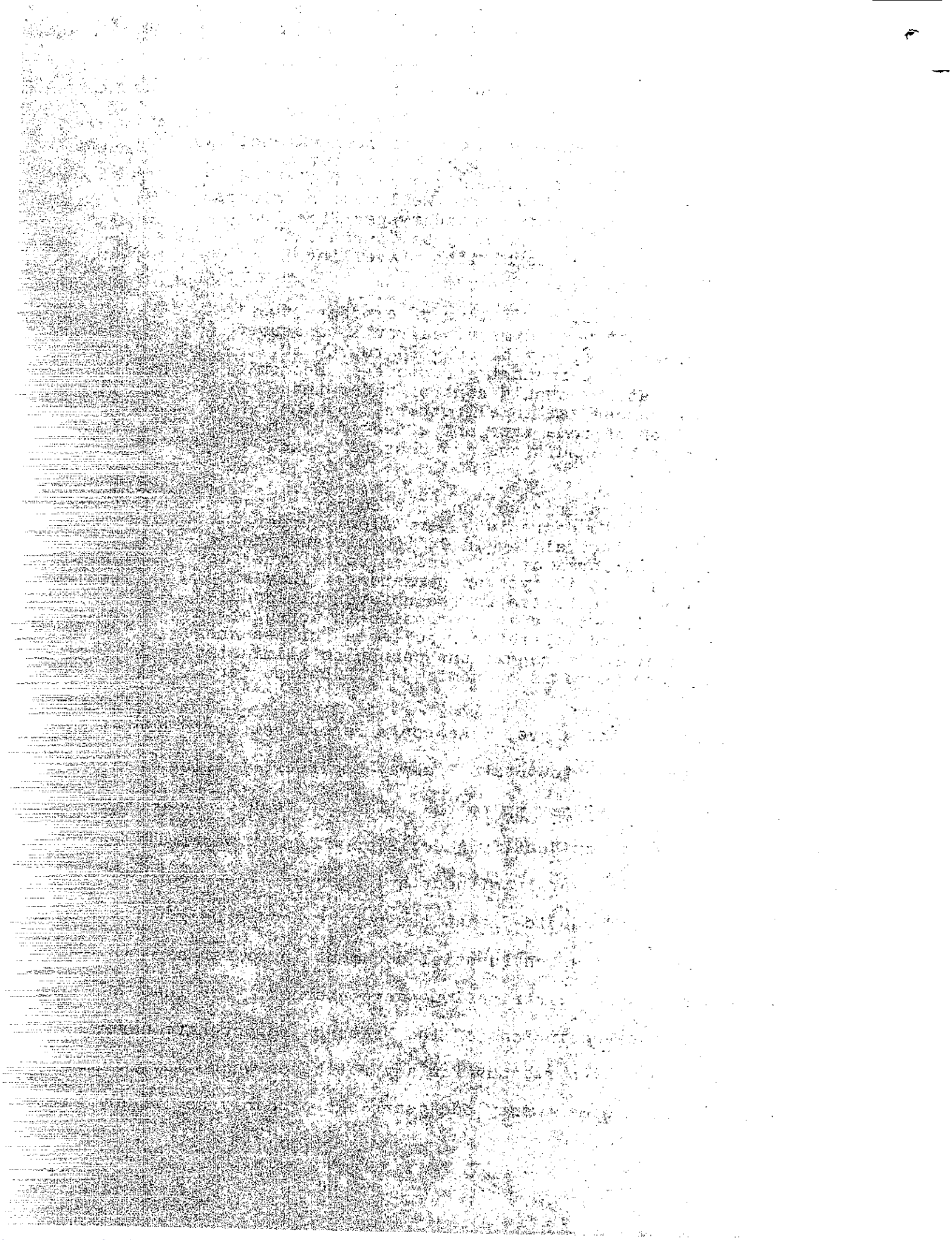

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The 1925-27 study did not indicate sufficient, if any, advantage of pure iron over copper steel to justify the preference in favor of pure iron which had, up to that time, frequently influenced the California Division of Highway purchases.

In recognition of the relatively limited evidence on which to base a definite conclusion McKesson's report contained the following statement:

RELATIVE SERVICE VALUE OF PURE IRON
AND COPPERED STEEL IN CULVERTS

"When this study was begun it was believed and expected that observation of four thousand or more metal culverts which had been in use on State highways up to 12 or 13 years, supplemented by inspection of some few older culverts not on the State system, might furnish data which would justify conclusions as to relative service value of pure iron and coppered steel, the two metals most generally used in these structures.

"It was found, as has been generally stated, that there are many other considerations which vitally affect culvert performance and that comparisons of relative corrosive resistance of base metal could only be arrived at after all known variables had been eliminated by grouping.

"When the field data had been gathered and the effect of known variables eliminated by studying separately the small groups under supposedly identical conditions of service and exposure, it was found that differences and inconsistencies existed even between the performance of culverts of the same analysis. This indicated that there are still other conditions which affect corrosion but which have not yet been defined or classified.

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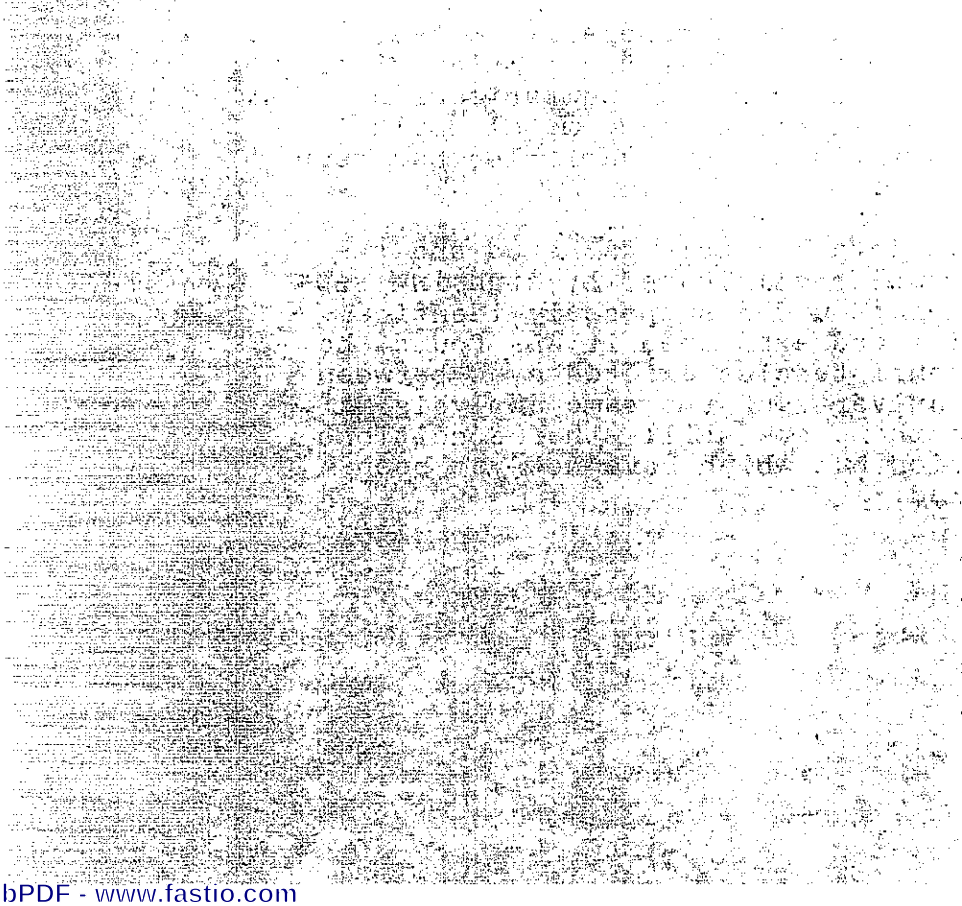

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"At the time of inspection the coppered steel culverts had been in service from four to ten years, the predominant quantities being from seven to nine years of age. The pure iron culverts had been in service from four to seventeen years and the age of the predominant quantities ranged from ten to thirteen years.

"It was found that the average life of spelter under average normal conditions in California is about 8.6 years, and that the total average life of all of the culverts inspected, under normal conditions, is about 10 years. It is obvious that corrosive resistance of base metal cannot be measured on culverts which still have a zinc coating. It was found that the average period of exposure of base metal, on the group of culverts which had passed spelter stage, was three and one-half years and the shortness of this period added to the difficulty in the evaluation of slight differences in base metal performance.

"Under some conditions of exposure one or the other of the metals appeared to indicate some superiority, but no general trend under all conditions has been established at this time. It seems unreasonable to attempt, with this brief period of exposure and lack of repeated observations on the same culverts at different periods of time, to definitely evaluate the possible trends which were noted under some conditions. It seems however, that the relative effect of the important variable conditions of exposure and of service which are so outstanding, and so easy to identify should be compiled and evaluated as far as possible with the data at hand. Such information should be of use to those interested in culvert manufacture or performance.

"Since the inception of this study several national research agencies have undertaken studies with the same objective in view; that is, of determining the influence of base metal composition on corrosion and of determining factors related thereto. Outstanding among these institutions are the National Highway Research Board and the American Society for Testing Materials. The U. S. Bureau of Standards also has under way a very elaborate study of the metal corrosion problem. Instead of attempting to compile and release conclusions based on the limited

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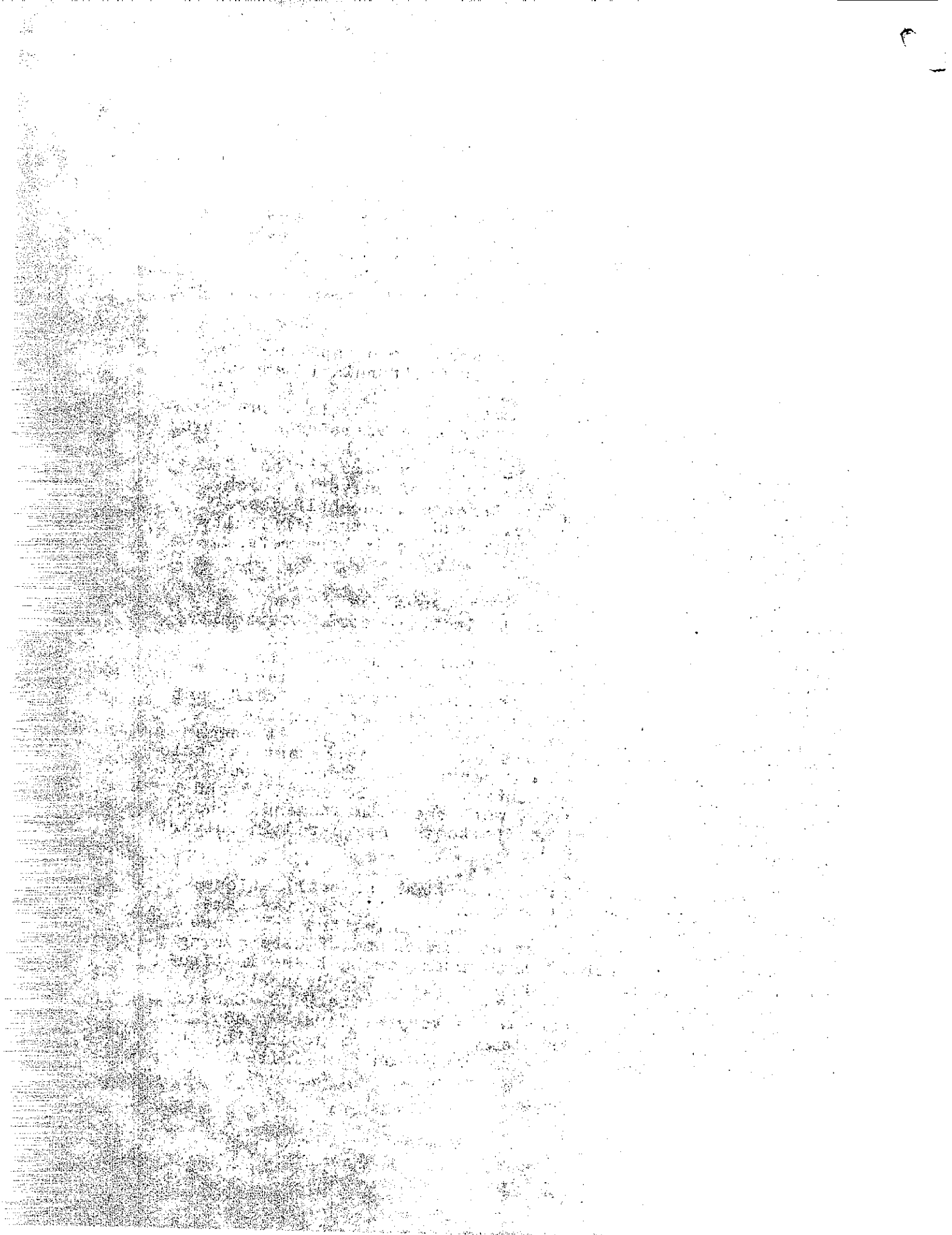

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period of exposure as pointed out, it is thought better to place the data brought out in this study at the disposal of the above named research agencies for the use of their committees detailed to the solution of this important but intricate engineering problem. It is hoped that a continuation of the study may bring forth definite answers to the perplexing problem of corrosion."

1929-30 SERIES

Following the completion of the McKesson Report in 1928 Mr. McKesson resigned from state service, Mr. Purcell succeeded Mr. Morton as State Highway Engineer in the fall of 1928, and the writer was appointed Materials and Research Engineer that same year.

Shortly after Mr. Purcell became State Highway Engineer a fresh controversy developed over the relative merits of copper molybdenum iron vs. pure iron and/or copper steel.

The California representatives of the manufacturers of copper molybdenum iron contended that it should be given preferential treatment, at least equal to any given pure iron.

Mr. Purcell demanded service records to substantiate the claims of the proponents of the use of molybdenum. This they were unable to furnish, at least to the extent of California experience with pure iron and copper steel, as recited in the McKesson report.

After considerable discussion, accompanied by voluminous correspondence during the latter part of 1928 and much of 1929, the State Highway Engineer agreed to undertake a series of long time field tests designed to determine, if possible, the relative merits of pure iron vs. copper steel, and further decided that

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culverts of Bessemer and open hearth steel should be included.

The above is the background of the current series of tests herein reported, which have been under way for 20 years.

In order to secure accelerated test results, all of the culverts in this series were installed in locations under bad to moderately severe exposure conditions for which the 1926-27 studies had indicated a relatively short life.

It was decided that the test should be conducted on uncoated (black) as well as galvanized sheets.

Considerable difficulty and delay was encountered from the start owing to the refusal of one of the manufactures to furnish black sheets on the contention that in the process of galvanizing added protection was afforded not only by the zinc coating but likewise in the transition zone at the junction of the coating and the base metal, which it was claimed was greater in the case of their product than the other types.

It was further contended that in the process of preparing the metal for galvanizing some of the surface glaze and impurities, such as scale, etc., on the unprocessed base metal was removed, thereby rendering it more resistant to corrosion.

Owing to the impossibility of securing black uncoated iron sections from all participants it was decided to confine the purchase to galvanized culverts and remove the spelter coating

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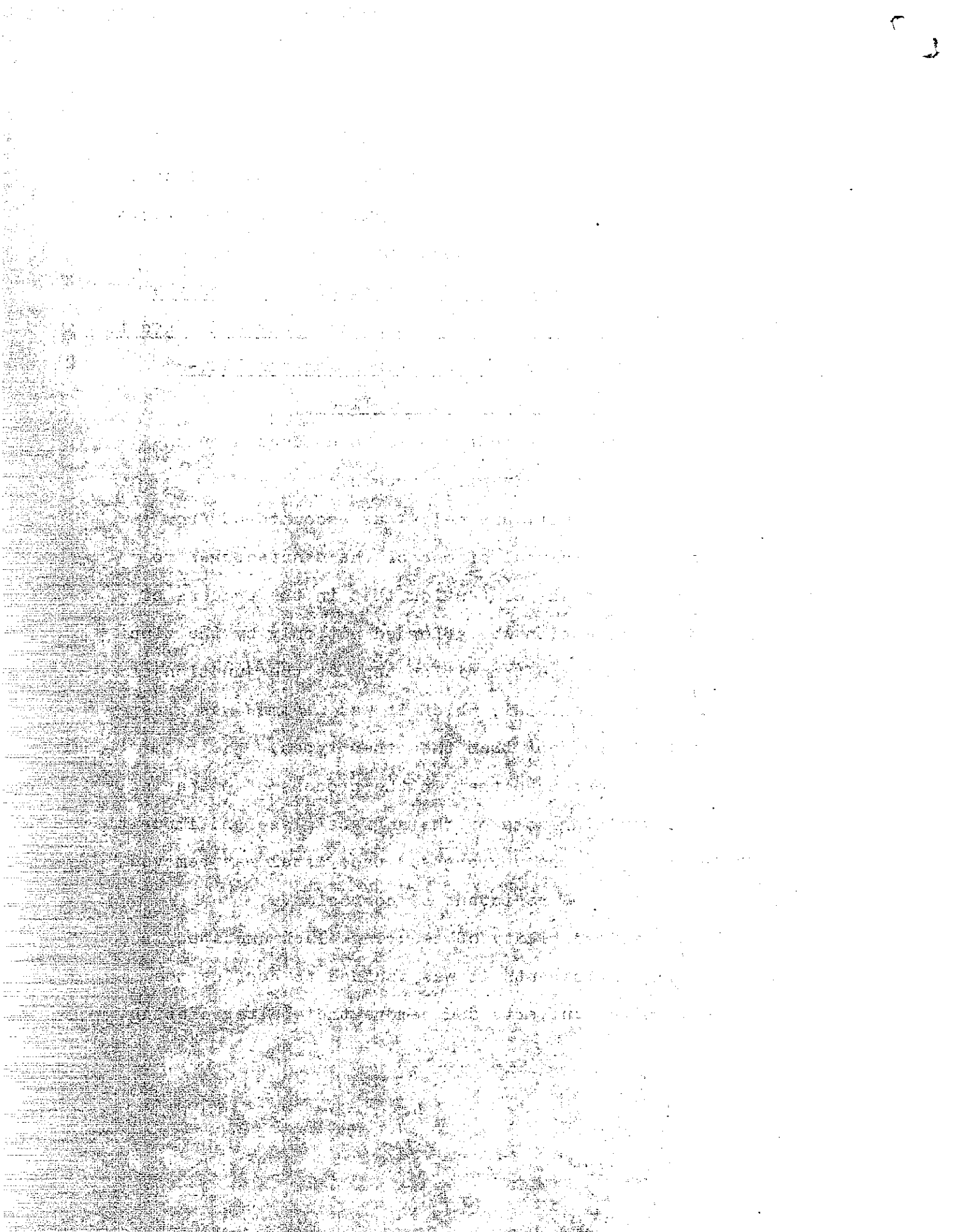

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from one half the length of each culvert section by acid treatment at a commercial plant in the San Francisco Bay region as will be noted from the detailed report on procedure.

Prior to the start of the 1929-30 test series that part of the California Division of Highways Standard Specifications relating to the quality of metals used in culvert manufacture provided that the material should conform to one or either of two alternatives (a) Pure Iron and/or (b) Copper Steel.

It had been the practice to give preference to pure iron whenever more than normally severe weathering conditions were anticipated.

However, after thorough consideration of the data developed from the 1925-27 survey supplemented by a study of data developed by other State and National agencies, the California Standard Specifications for 1930 provided that the base metal should conform to chemical requirements for five listed types which were identical with specification M-36 of the A.A.S.H.O. but without specific reference to A.A.S.H.O.

Subsequent C.D.H. Standards conformed with and made specific reference to A.A.S.H.O. M-36 included an added (6th) metal (wrought iron) with the proviso that any of the six kinds could be used "unless otherwise" designated in the special provisions.

The six kinds include Copper Molybdenum Iron, which was the occasion for the 1929-30 tests.

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Therefore, in so far as the present situation is concerned there is no current controversy over types.

However, continuing studies are being carried on nationally relative to the comparative merits of different composition culvert metals and it appears desirable therefore that all of the data developed by this department be reported for such use as future developments require.

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CONCLUSIONS BASED ON THE 20 YEAR PERFORMANCE OF THE CULVERTS IN THE 1929-30 TEST SERIES

1. There was no outstanding resistance to corrosion of any one metal over the others in the project.

2. The thirteen sets on which tests have been completed showed a length of life for the base metal from 0.3 to 13.3 years, with an average of 5.5 years.
The nine sets still available for observation have an estimated life span for the base metal from 23 to 60 years with an average of 35 years. These results were obtained by extrapolation of the base metal deterioration curves shown in Figures 6, 7, 8, and 9 of the report of Supervising Materials and Research Engineer J. L. Hemmert (attached). It is significant to note that all these sets are in the northern part of the state. (See Table No. 3 of Hemmert's report.)

3. All metals, regardless of composition, reached the end point at approximately the same time at each site where the thirteen sets on which tests are completed are located, with the exception of Set No. 23 located on VIII-Imp-12-B at Sta. 22+97 and Set No. 4 located on II-Sis-3-B at Sta. 621+51. On Set No. 23 the Armco galvanized section holed through approximately two years before the other metals failed, and on Set No. 4

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the Armco black section was found to be holed through when the twenty year inspection was made while the Western and Toncan metals still have 30 points to go (See Table No. 3).

The galvanized sections, however, in all locations had a longer life than the ungalvanized.

4. Of the nine sets still in service, there is no appreciable, if any, difference between the various metals with the exception of Set No. 4 as mentioned above. In all cases, the galvanized sections are in better condition than the ungalvanized.

Enclosed and made a part of this report is the detailed report by Supervising Materials and Research Engineer J. L. Hemmert, who was in direct charge of the inspections and ratings.

T. E. Stanton
Materials and Research Engineer

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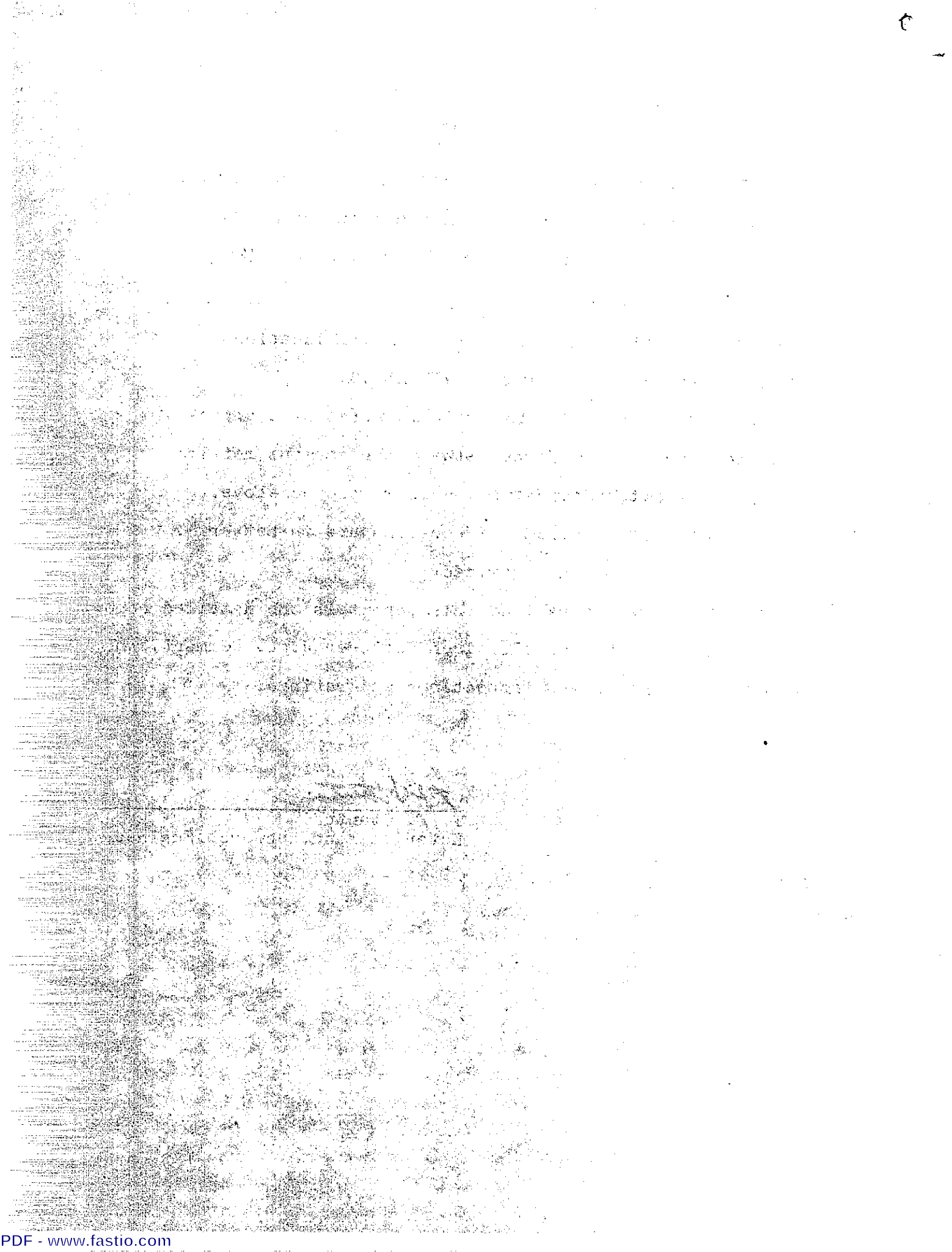

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Research .00067
Project No. 22

CULVERT INVESTIGATION
TWENTY YEAR AND FINAL REPORT ON
TEST CULVERT PIPE INSTALLATIONS
IN
DISTRICTS I, II, X, AND XI

Report by John L. Hemmert
Supervising Materials and Research Engineer

SYNPOSIS

During the year 1929 arrangements were made for the Materials and Research Department of the California Division of Highways to conduct field tests on corrugated metal pipe culverts to determine the relative resistance to corrosion of the different kinds of metals then being used by the various culvert pipe manufacturers.

These test pipes were installed at locations throughout the State which would submit them to severe corrosive conditions. The following types of culverts were secured for test purposes:

"Armco Pure Iron," "Western Bessemer and Open Hearth Steel," and "Toncan Copper Molybdenum Iron."

Twenty-six culverts, twenty-four inches in diameter, by twenty feet in length made up of No. 14 USS Gauge metal of each of the above types were fabricated at Oakland, California. Each set consisted of five 2 ft. galvanized sections and five 2 ft. sections with the spelter removed.

A complete record of the fabrication, sampling, identifying, and weights of spelter removed was compiled by a representative of the Laboratory.

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The purpose of removing the spelter was to gain advance information on the corrosive resistance of the base metals as the test progressed.

Samples were taken of all base metals which were submitted to the Laboratory for chemical analysis.

PROCEDURE

Each test pipe was installed with the galvanized section at the inlet end and the black sections at the outlet end. Each section was numbered in succession and tagged with metal tags, stamped with two letters identifying the type and the series of the section. The first letter indicated the type of metal and the second the series. For example, a tag showing TD identified a Toncan Culvert with the sections numbering from 31 to 40 inclusive. The arrangement of the Bessemer and Open Hearth sections were as follows: For sets A to M, inclusive, the first two and last two sections of each culvert pipe were Bessemer steel, and six central sections were Open Hearth steel. For sets N to Z, inclusive, the reverse order was followed; i.e., two Open Hearth, six Bessemer and two Open Hearth Sections.

The seventy-eight test pipes were shipped to Sacramento in the latter part of January, 1930. See Figures Nos. 1, 2, 3, and 4.

During January, 1930, Districts I, II, IV, VIII, and X were contacted and arrangements made with the District Engineers of each to assist the Laboratory in choosing the proper locations for test pipe installations. Many locations were examined and

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studied with respect to soil and water conditions, accessibility to highway, and information on culverts previously installed in the immediate locality. The locations selected for the installations are listed further on in this report, and are shown on the attached District Maps.

One culvert of each type constituted a set and were installed either side by side or in line, according to the physical condition at the site of installation.

Soil samples were taken from the material covering the pipe at each installation and, where possible, samples were taken of the water flowing through the pipes. The excavated soil was mixed and uniformly distributed over the pipes so that the samples taken would be representative of the whole.

Periodical inspections were to be made and a tentative arrangement agreed upon to do this semi-annually. The first inspection was made 7½ months after installation and sets Nos. 15 and 16 in Amador County were found to be holed through due to the corrosive action by seepage waters from old copper mine tailings. These culverts were then turned on the quarter and reinstalled (See Figure No. 5). Monthly inspections were than made on these two sets.

At each inspection, each pipe was exposed at the center and a rating made of both galvanized and black sections. Both interior and exterior surfaces of each pipe were rated for condition of the spelter and base metals in accordance with method of rating culverts

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used in the 1925 culvert investigation.

As none of these test pipes were under a roadway and as we were not interested in the structural features, the material rating was made and comparative data accumulated on the metals only. The material condition was expressed in per cent, with a maximum of 90% and the corrosion classification expressed in the letters A, B, C, D, E, F, G, and H.

The method of rating is briefly explained as follows:

90% galvanizing entirely intact.

90% to 70% no appreciable loss of metal and no pitting. Some abrasion. Slight rust spot or warty growth. Gradual loss of spelter.

70% to 50% loss of spelter and slight loss of metal in invert. Scattered pitting. Decided abrasion in invert.

50% to 30% heavy loss of metal in invert. Decided pitting. Heavy scaly rust. Severe abrasion effects.

30% to 10% metal corroded or abraded nearly through in invert or elsewhere. General deep rust over pipe. Very heavy scaly rust or pitting.

0% holes in metal due to corrosion or abrasion.

METAL CORROSION CLASSIFICATION

Spelter Classifications

(90% to 70%)

A. Oxidation of spelter noted by progressive light colored discoloration (usually in scouring condition).

B. Oxidation of spelter noted by deposits of black oxides usually in filling condition.

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RUST CLASSIFICATION

After Loss of Spelter

(70% to 0%)

C. Dark, tight, hard, smooth, uniform, slow acting.

D. Dark heavy scale, tubercle or barnacle, usually in patches near flow line. First indication of pitting. Barnacles formed from iron and compounds of minerals in flow.

E. Pitting (E_1 Hard, small, deep, tight -------- follows D)

(E_2 Soft, red, shallow, large, loose ----- follows G)

F. Red, loose, smooth, soft, uniform, rapid action.

G. Red, heavy scale, tubercle or barnacle usually in clusters near flow line forerunner of E_2.

H. Barnacle growth in invert of metal pipe carrying mine or marsh water, not properly a rust, but an organic growth, although carrying some iron compounds. Probably organic.

Location of Test Pipe Installations

and

Conditions at Sites Selected

Set No. 1

Installed on II-Sis-3-C, at Station 404+55. This set was laid in line on the west side of the highway and carries the seepage from a shale hillside overlaid with reddish soil. The soil to cover the pipes was taken from this hillside. An indication of the corrosion to be expected was presented by the appearance of a side drain showing severe rust action. This set is now on an abandoned portion of the highway and the lower one-quarter portion is in a filling condition.

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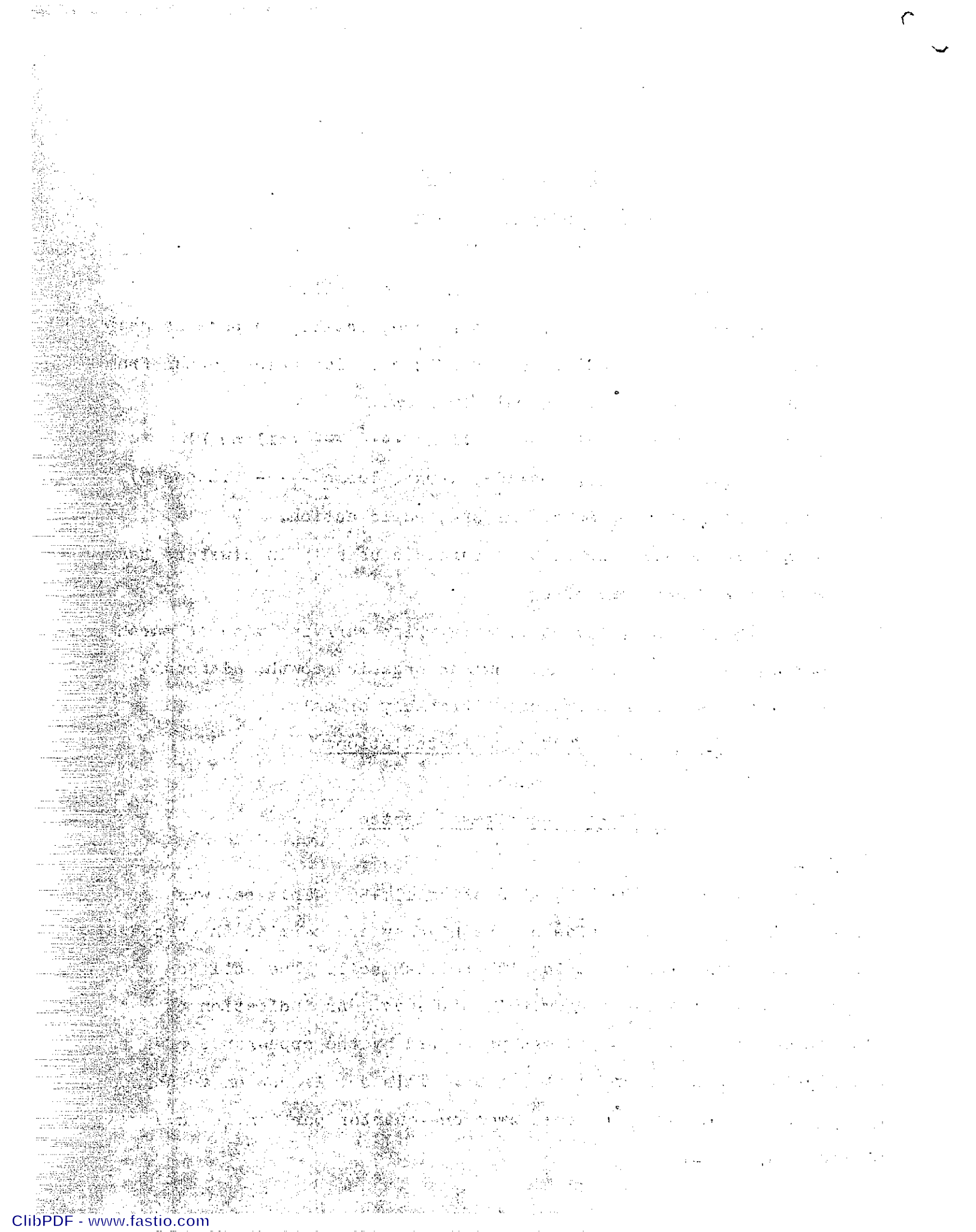

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Set No. 2

Located on II-Sis-3-C, at Station 164+86. This set was placed in line on the west side of the highway below a barn and stock corrals. The drainage from this area seemed to have effected a metal pipe across the highway at this location, which showed a metal loss of 50% or more at the time the site was selected. No data could be obtained as to date of installation of this pipe. The barn and corrals were moved in the year 1931, and little moisture reaches this set thereafter.

Set No. 3

Located on II-Sis-3-B at Station 202+79. This set was placed side by side twelve inches apart, on wooden stringers set to grade in the ditch on the west side of the highway. The soil is of a black adobe nature containing small gravel. The run-off is more or less constant for nine months of the year.

Set No. 4

Located on II-Sis-3-B at Station 621+51. This set was placed in line on the east side of the highway and receives the water from a portion of the north slope of Mt. Shasta. The flow is continuous throughout the year. The pipe was placed outside the ditch line and the water diverted so that it flows through the pipe and ditch simultaneously. The soil is a sandy clayey loam and contains some gravel.

Set No. 5

Located on II-Sha-3-B at Station 424+50. This set was placed

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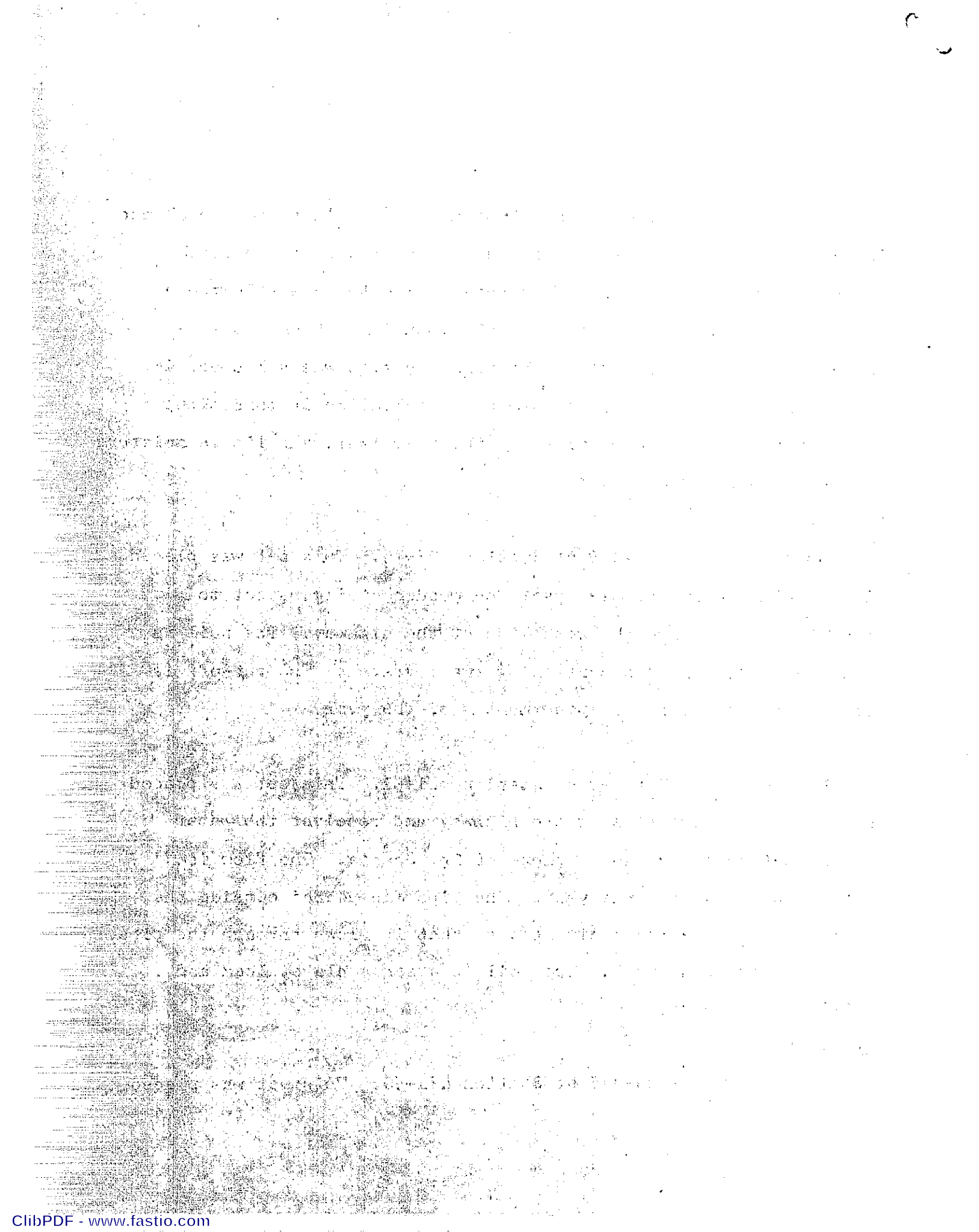

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in line in the ditch on the southerly side of the highway below a sloping springy meadow. It carries considerable run-off during the winter and spring months and remains dry during the summer and fall period. The soil is a red clayey loam containing considerable gravel. This location was selected for a test site as all metal culverts previously placed across the highway adjacent to this slope had been replaced with concrete owing to the rapid deterioration of the metal.

Set No. 6

Installed on II-Sha-3-B at Station 58+50. This set was installed side by side on the north side of the highway at the base of a steep slope. Just below it is a copper steel culvert which showed severe deterioration when the site was selected. The soil is of a brown gravelly nature and being on a steep slope, the pipes would be subjected to some abrasion.

Rating of this set terminated in 1937 due to the fact that the new alignment of the highway eliminated this section of roadway, and it was allowed to revert to the county. The installation being near a junction with the new highway, a roadside community sprang up. Private enterprise leveled off the hillside above these pipes and buried them under a ten foot fill.

Set No. 7

Located on I-Hum-1-I at Station 383+47. This set was placed in line on the west side of the highway. It carries a continuous run-off from a brown and black adobe soil, heavily wooded with

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timber, a large percentage of which is second growth redwood. Immediately above the installation and crossing the highway is a twenty-four inch (24") Armco Culvert installed in January, 1922. Also, in the same water course, 100 feet above, is a Toncan culvert (date of installation unknown) both of which showed severe rust action when this site was selected. The test pipe having been placed in front of a wayside eating house, it was necessary to construct a manhole to allow for inspection. Since the inspection in 1940, the grade at this point has been raised 12 to 18 inches and a gravel base laid over the manhole and test pipes, and an extension of 80 ft. of 24" pipe has been placed at the lower end. Ten inches of water is now flowing through this set and it was deemed uneconomical to uncover for inspection.

Set No. 8

Located on I-Hum-1-H at Station 229+65. This set of pipe was placed side by side on the west side of the highway. The location is on the mud flats of Humboldt Bay between Eureka and Arcata. They were so placed that the pipe would be subjected to alternating wetting and drying by salt water during the fluctuation of the tides.

Set No. 9

Located on I-Hum-1-G at Station 342+98. This set was laid in line on private property west of the highway. A written permit was obtained from the owner which is on file in the District office.

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The soil is brown clay and the immediate terrain is steep, rolling pasture land. The culvert crossing the highway immediately above this installation had holed through in the invert at the time this site was selected.

The highway adjacent to the location of these pipes has been abandoned and is now about a mile from any point accessible by car.

Set No. 10

Located on I-Hum-1-D at Station 307+85. This set was laid in line on the south side of the highway through a section of the redwoods. It is just below a twin eighteen inch (18") culvert, which had shown a loss of 45% in eight years of service. The soil is sandy, reddish brown in color, and contains considerable vegetable matter. The drainage area consists mainly of the run-off from the ditches along the roadside.

Set No. 11

Located on I-Men-1-K at Station 115+21. This set was laid in line on private property in Lilly's Redwood Flat south of the highway. A permit from the owner is on file in the District office. A twelve inch (12") Armco culvert installed in 1926 across the highway above the test installation showed a loss of 30% during four years service. The soil is a reddish yellow clayey sand containing considerable vegetable matter. Immediately above the highway is a small grove of tan oak.

Set No. 12

Installed on I-Men-48-A at Station 55+00. This set was placed side by side on the south side of the highway in the side

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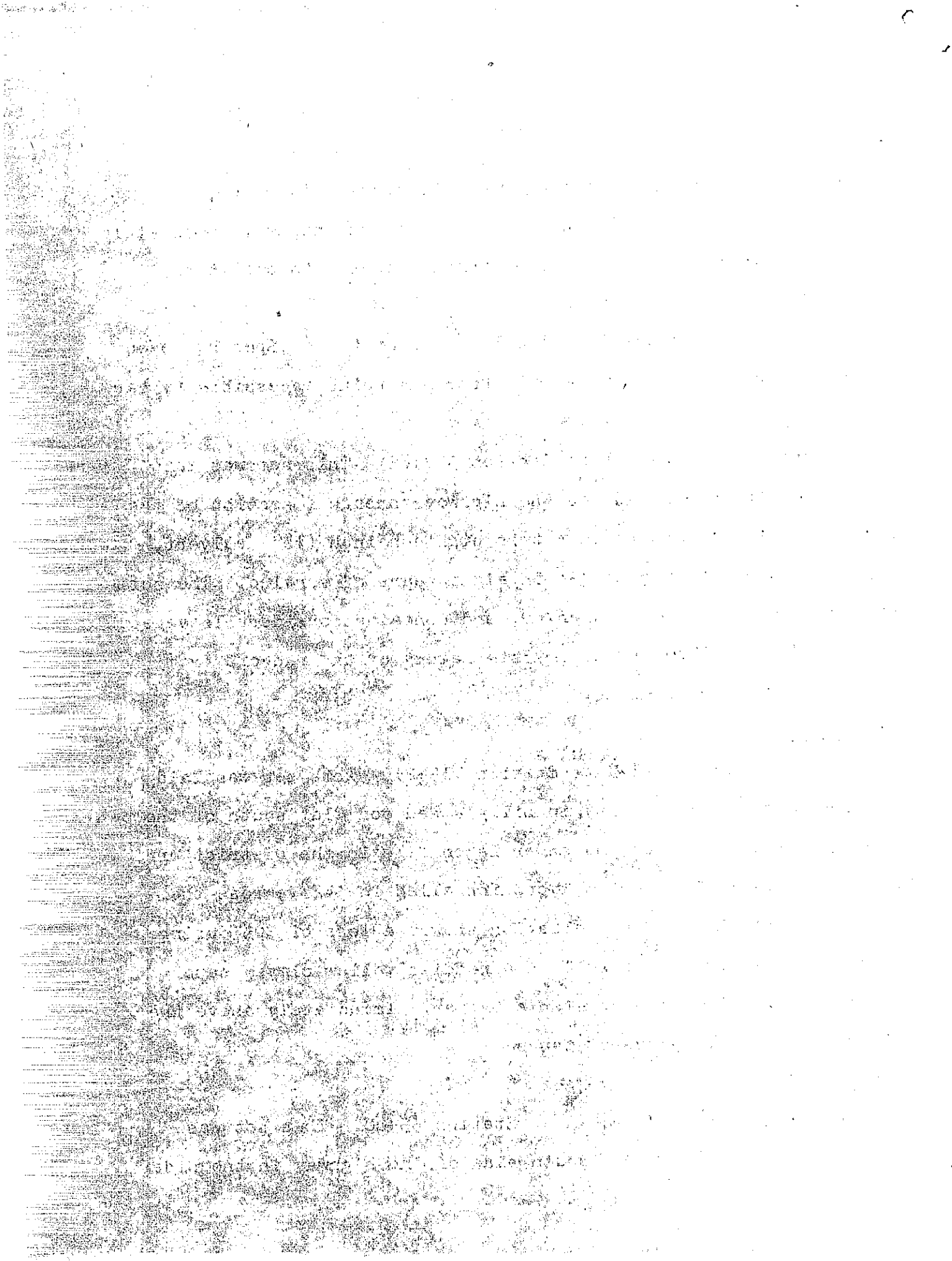

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ditch. All sections were laid on stringers to grade. Below and across the highway is a thirty inch (30") Armco culvert which showed a loss of 50% at the time of test pipe installation. No information as to the date of its installation could be found but two tenths of a mile below a thirty-six inch (36") Armco dipped culvert carrying the same water showed a loss of 25% in two years. Part of this deterioration was due to abrasion. The drainage area consists of a brown gravelly soil forming a fairly steep hillside, heavily wooded with tan and scrub oak.

Set No. 13

Installed on X-Sol-City of Benicia at South Hampton Bay. This set was placed side by side on the east beach of South Hampton Bay. It was set on leveled stringers at an elevation which subjected the pipe to alternately wetting and drying by salt water during the rise and fall of the tides. The soil covering the pipe is clay and shale.

Set No. 14

Located on X-Sol-7-D at Station 229+27. This set was laid in line on the south side of the highway in the ditch and covered with a light brown clayey loam taken from the bed of a draw one mile easterly. Immediately above and across the highway is a twin twenty-four inch (24") copper steel culvert installed in 1924, which showed a loss of 25% in six years of service. The last inspection of this set was made in 1945. A four lane highway has subsequently been constructed over this site and the set is now inaccessible.

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Set No. 15

Installed on X-Ama-34-B at Station 189+53. This set was laid in line in the ditch on the south side of the highway. Below is an eighteen inch (18") culvert installed in 1921 or 22 which showed a loss of 60% in eight or nine years of service. This water course carries the drainage from a hilly wooded section also the seepage from the tailings of an old copper mine. The soil is a brown gravelly clay mixed with some decomposed material. The first inspection was made seven and one-half (7½) months after the installation. At that time the action was so severe that the pipes were holed through and had to be turned on the quarter. Inspection was made monthly thereafter.

Set No. 16

Installed on X-Ama-34-B at Station 187+00. This set was placed side by side on private property south of the highway in the same water course as Set No. 15, two hundred and fifty feet downstream. A permit was obtained from the property owner which is on file in the District office.

Set No. 17

Installed on X-Tuo-13-B at Station 576+93. This set consists of two pipes, of each make, laid in line, in the ditch, on the west side of the highway. A twenty-four inch (24") copper steel culvert installed in 1915 just below and across the highway had the invert holed through at the time this installation was made. The concrete headwalls also showed excessive disintegration of the concrete

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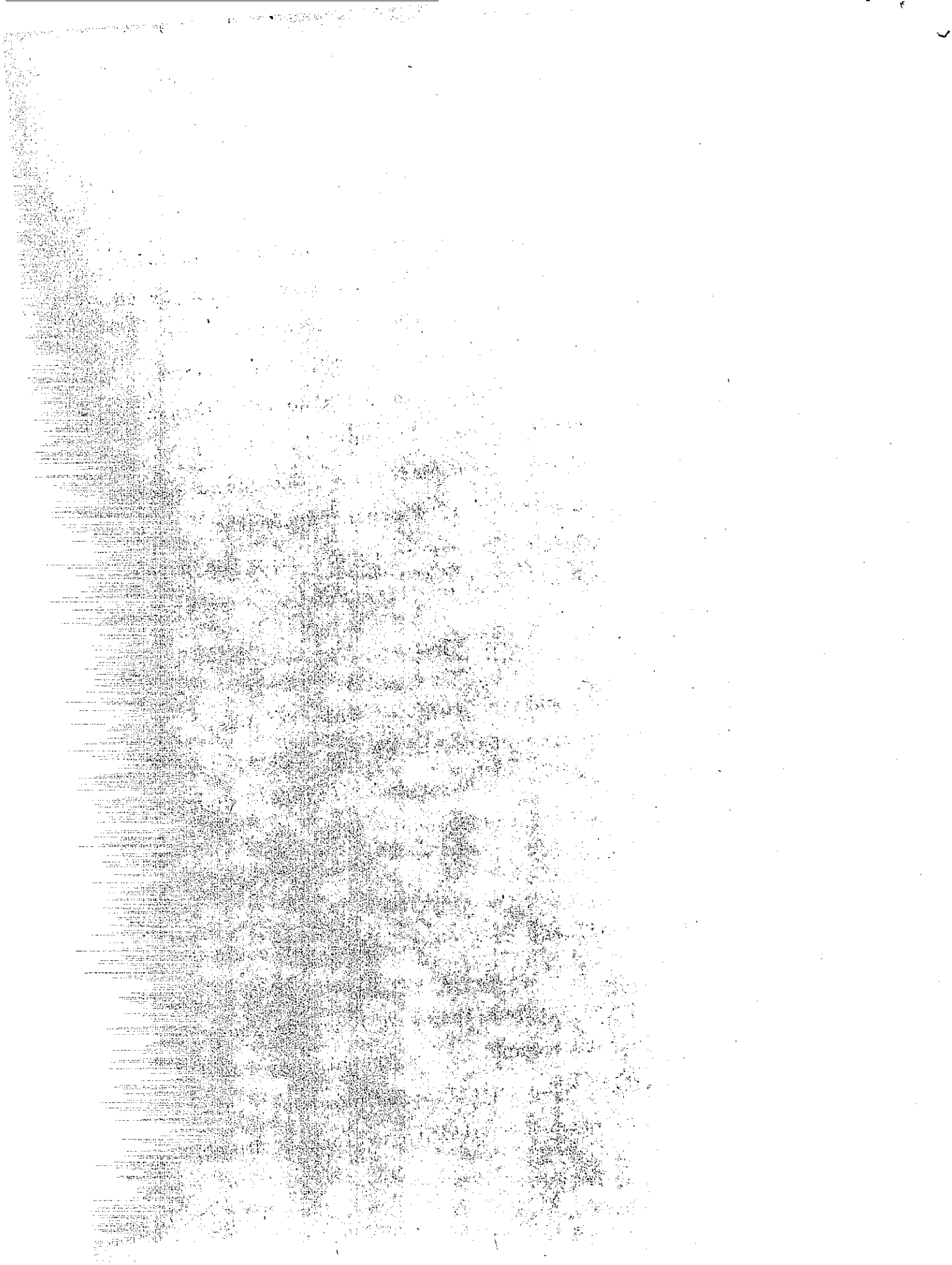

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itself, apparently due to the drainage from old mine dumps. The terrain is hilly with steep wooded slopes and the brown clayey soil being of a gravelly nature, some abrasion was to be expected.

*Set No. 18

Installed on VIII-Imp-26-C at Station 64+40. This set was placed side by side on the west side of the highway in a shallow borrow pit without any particular regard to drainage. The site is in a sandy desert with practically no rainfall. The pipes were covered with sand from the surrounding area. This sand is alkaline and contains considerable iron oxide or magnetite.

*Set No. 19

Installed on VIII-Imp-26-A at Station 96+00. This set was laid in line on the north side of the highway along side an irrigation ditch. The soil is fine sandy silt and during irrigating periods becomes moist.

*Set No. 20

Installed on VIII-Imp-26-G at Station 395+61. This set was laid in line on the east side of the highway immediately adjacent to a main irrigation canal carrying a constant flow of water. The soil is sandy adobe and is in a constant state of dampness. A few feet north of this set is a twenty-four inch (24") Armco culvert laid in 1929 which showed a 30% deterioration in metal in approximately one year.

*Set No. 21

Installed on VIII-Imp-27-C at Station 150+40. This set was

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laid in line in the ditch on the north side of the highway. The pipes were covered with adobe soil taken from the top six inches of the adjacent railroad right of way. The soil has a high percentage of chlorides. A small eight inch (8") metal side drain west of the installation showed severe rust action when this site was selected.

*Set No. 22

Installed on VIII-Imp-12-C at Station 199+14. This set was laid in line on the north side of the highway in the side ditch at the outlet of an eighteen inch (18") culvert. This culvert had holed through from the exterior at the time this site was selected. It had originally been used for irrigation purposes, but had been abandoned. The soil is silty adobe and is heavy in chlorides.

*Set No. 23

Installed on VIII-Imp-12-B at Station 22+97. This set was laid in line on the north side of the highway above an eighteen inch (18")Armco culvert which showed a 60% deterioration. Sand from the immediate vicinity constituted the cover.

* Note:

Set Nos. 18 to 23 inclusive, were installed in District VIII, but are now in District XI due to a change in District Lines.

TEST RESULTS AND COMMENTS

The chemical analysis of the base metals and weight of spelter coatings for the various types of C. M. P. used in

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this investigation are shown in Table No. 1.

The Armco and Toncan base metals comply with specifications for these metals being used at the present time. All galvanized sections had over 2 ounces of spelter per square foot which is presently being specified as a minimum.

The chemical analysis of the soil which was used to cover the pipes and the analysis of the water passing through some of them is shown in Table No. 2. Note the high chlorine and sulphate contents of the water passing through sets 8, 13 and 16, and the alkali present in the soil in Imperial County sets 18 to 23 inclusive.

The ratings of the nine sets of pipes under observation twenty years after installation is shown in Table No. 3. Also shown in this table is the spelter life, base metal life, dates sets were installed, dates of last inspections and the over-all average rating of the black and galvanized sections at this period.

Figure No. 13 shows the averages of all sets plotted over a twenty year period.

In order to facilitate the description of test results on the entire series the installations are grouped by counties as follows:

Siskiyou County Series

Sets 1 to 4 inclusive compose this series. They are located as follows:

Set No. 1 - II-Sis-3-C, Sta. 404+55

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Set No. 2 - II-Sis-3-C, Sta. 164+86

Set No. 3 - II-Sis-3-B, Sta. 202+79

Set No. 4 - II-Sis-3-B, Sta. 621+51

These sets are still intact after 20 years, except the Armco black section in Set No. 4. This was holed through at the 1949 inspection, whereas, the Western and Toncan still had 30 points to go. All show a slow gradual deterioration over this period. See Figure No. 6. By extrapolation of the curves shown here it is estimated that the base metal life of these sets will be as follows:

Sets Nos. 1 and 4, 33 years, Set No. 2 - 60 years and Set No. 3 - 50 years. The spelter life on these sets ranged from 4.4 to 15 years. (See Table No. 3)

Shasta County Series

Sets 5 and 6 compose this series.

Set No. 5 installed on II-Sha-3-B at Sta. 424+50 is still intact after 20 years and shows a slow gradual deterioration similar to those in Siskiyou County. Set No. 6 installed on II-Sha-3-B at Sta. 58+50 followed the same trend for 7.3 years. After this period it became unaccessible due to having been buried under a ten foot fill by private enterprise. See Figure 7 for deterioration curves of these sets.

By extrapolation of the curves shown for Set No. 5, it is estimated the base metal life will be 40 years. The spelter life of this series is as follows: Set No. 5 - 5.8 years and Set No. 6 - 7.3 years.

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Humboldt County Series

Sets 7 to 10 inclusive comprise this series. They are located as follows:

Set No. 7 - I-Hum-1-I, Sta.383+47

Set No. 8 - I-Hum-1-H, Sta. 229+65

Set No. 9 - I-Hum-1-G, Sta. 342+98

Set No. 10 - I-Hum-1-D, Sta. 307+85

All show a uniform gradual deterioration, although a somewhat more rapid action than those in Siskiyou and Shasta Counties, except Set No. 8 installed in Humboldt Bay. This set shows a very rapid deterioration for approximately the first two years, then slowed up for five years, and again deteriorated rapidly for approximately three years. See Figure No. 8. The spelter life of this set was 0.7 years and the base metal life 10.5 years. By extrapolation the base metal life of the other three sets in this series is estimated to be approximately 25 years. The spelter life of these three sets ranged from 2.5 to 3.5 years. (See Table No. 3)

Mendocino County Series

Sets Nos. 11 and 12 comprise this series.

Set No. 11 installed on I-Men-1-K at Sta. 115+21, which is in Lilly's Redwood Flat follows a deterioration pattern very close to the inland installations in Humboldt County. The estimated base metal life of this set is 25 years.

Set No. 12 installed on I-Men-48-A at Sta. 55+00, carries the drainage from a heavily wooded tan and scrub oak area showed compara-

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tively rapid deterioration, through both the spelter and base metal stages. (See Figure No. 9) The life of this set was 13.3 years, which is approximately one half that of Set No. 11 above, installed in a redwood drainage area.

Solano County Series

Sets Nos. 13 and 14 comprise this series.

Set No. 13 installed on X-Sol-City of Benicia at South Hampton Bay deteriorated rapidly, very similar to Set No. 8 installed in Humboldt Bay. The spelter life was only 0.8 years and the base metal life 7.3 years. It is considered significant to note that the exposed ends of the black sections holed through approximately 2 years before the covered sections. (See Fig. No. 10) This is undoubtedly due to being exposed to salt water spray.

Set No. 14 installed on X-Sol-7-D at Sta. 229+27 showed a comparatively rapid deterioration for the first few years and then slowed up considerably up to 1945, when the last inspection was made. This set is now inaccessible due to a four lane highway having been constructed over the site.

Amador and Tuolumne County Series

Sets Nos. 15, 16, and 17 comprise this series. See Figure No. 11 for rates of corrosion.

Sets 15 and 16 installed on X-Ama-34-B Sta. 189+53 and 187+00 respectively are in the same water course. This drainage area carries the seepage from the tailings of an old copper mine dump

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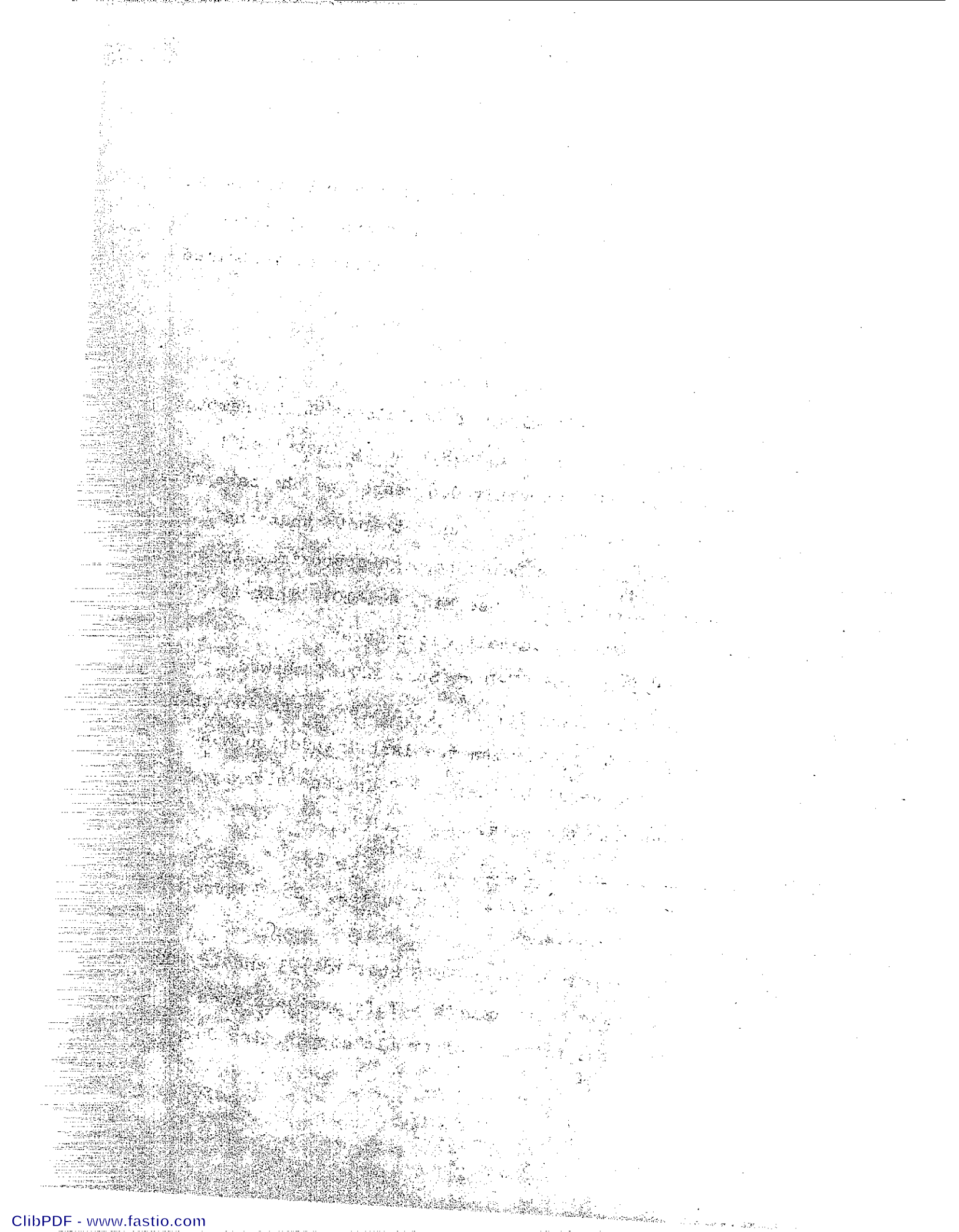

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which is very destructive to metal pipe. Figure No. 5 shows the conditions of the pipes when the first inspection was made 7½ months after installation. Following the discovery of this condition, the pipes were turned on the quarter and inspected monthly. Under the existing conditions, it was found that both galvanized and black sections had a life span of only 4½ months.

Set No. 17 installed on X-Tuo-13-B at Sta. 576+93 had a life span of 5 years. The deterioration of this set was very rapid for the first 2 years, then slowed up for 1½ years and then accelerated again for the last 2½ years. It is probably that the drainage from old mine dumps from remote localities figured in the deterioration of this set also.

Imperial County Series

Sets 18 to 23 inclusive comprise this series. Sets were installed throughout Imperial County at the following locations:

Set 18 -*VIII-Imp-26-C, Sta. 64+40

Set 19 - VIII-Imp-26-A, Sta. 96+00

Set 20 - VIII-Imp-26-G, Sta. 395+61

Set 21 - VIII-Imp-27-C, Sta. 150+40

Set 22 - VIII-Imp-12-C, Sta. 199+14

Set 23 - VIII-Imp-12-D, Sta. 22+97

*These locations are now in District XI due to a change in District lines.

Figure No. 12 shows the progress curves for the deterioration of these sets. The rate of deterioration varies considerable for

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all sets except Set No. 23 which is comparatively uniform. The spelter life of these sets varied from 0.7 to 4 years, with an average of 1.3 years and the base metal lifespan varied from 3 to 8.7 years with an average of 4.95 years. (See Table No. 3)

The life span of these sets appear to be directly related to the alkali concentration present in the soil at the time of installation. (See Table No. 2)

Attention is called to Set No. 23 in which the Armco galvanized sections holed through approximately 2 years before the Western and Toncan failed.

SUMMARY AND CONCLUSIONS

With ratings completed on fifteen of the twenty-four test sets originally installed, thirteen having holed through in both the galvanized and ungalvanized sections and two are covered by fills making them inaccessible, the results at the twenty year period may be summaried as followed:

1. There was no outstanding resistance to corrosion of any one metal over the others in the project.

2. The thirteen sets on which tests have been completed showed a length of life for the base metal from 0.3 to 13.3 years with an average of 5.5 years.

The nine sets still available for observation have an extimated life span for the base metal from 23 to 60 years with an average of 35 years. These results were obtained by extrapolation of the

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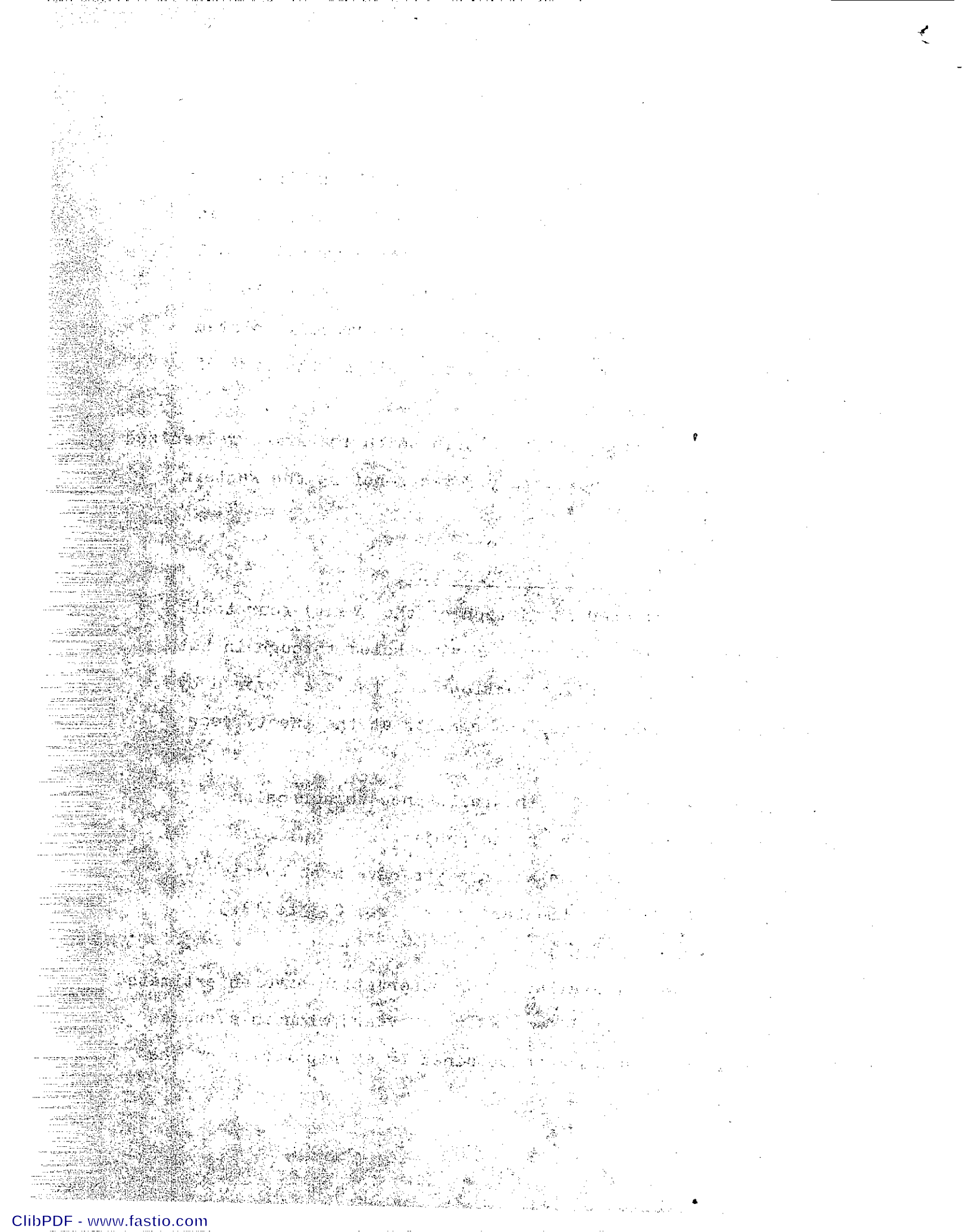

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base metal deterioration curves shown in Figures 6, 7, 8, and 9. It is significant to note that all these sets are in the northern part of the State. (See Table No. 3)

3. All metals, regardless of composition, reached the end point at approximately the same time at each site where the thirteen sets on which tests are completed are located, with the exception of Set No. 23 located on VIII-Imp-12-B at Sta. 22+97 and Set No. 4 located on II-Sis-3-B at Sta. 621+51. On Set No. 23 the Armco galvanized section holed through approximately 2 years before the other metals failed, and on Set No. 4 the Armco black section was found to be holed through when the twenty year inspection was made while the Western and Toncan metals still have 30 points to go. (See Table No. 3)

The galvanized sections, however, in all locations, had a longer life than the ungalvanized.

4. Of the nine sets still in service, there is no appreciable, if any, difference between the various metals with the exception of Set No. 4 as mentioned above. In all cases, the galvanized sections are in better condition than the ungalvanized.

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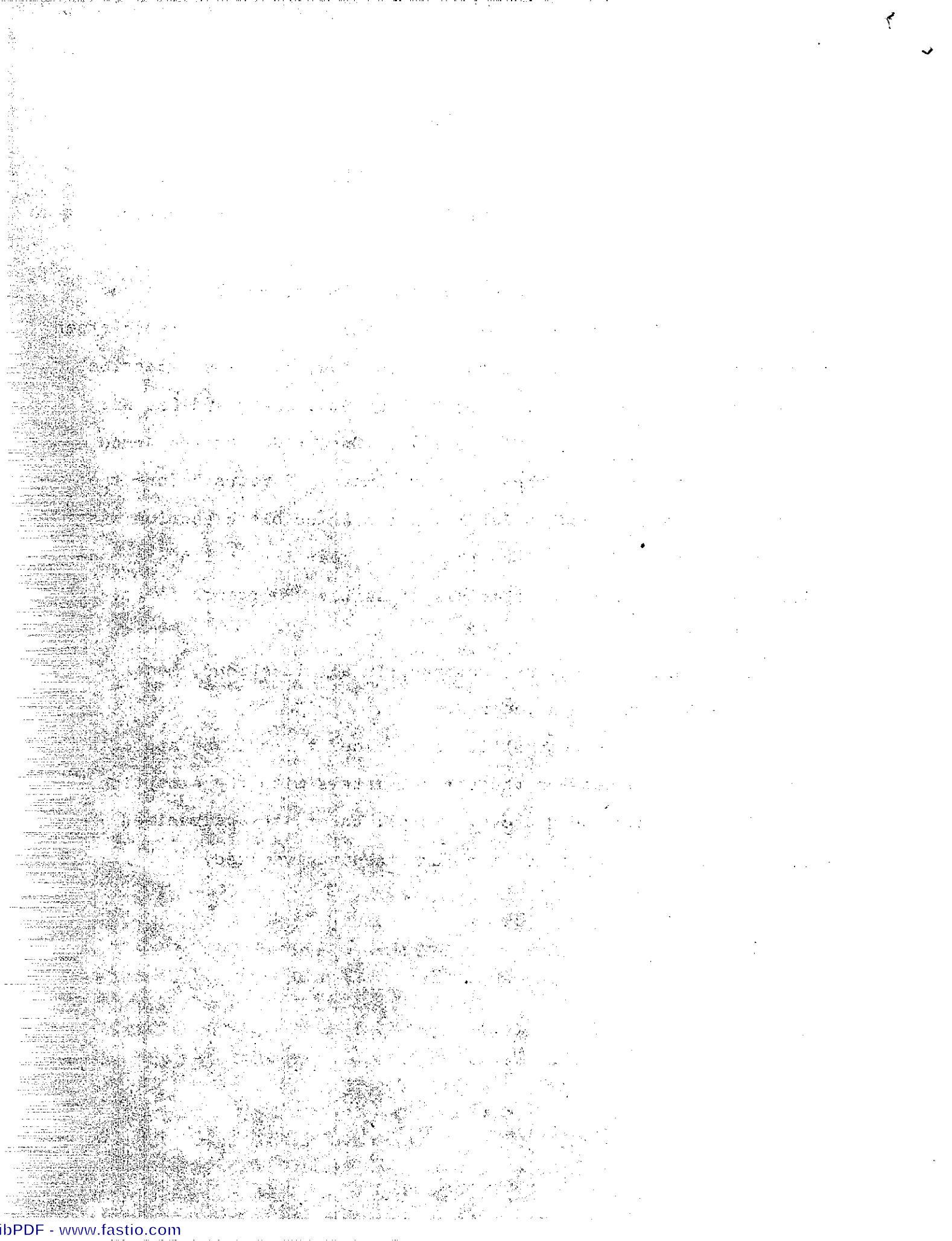

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TABLE NO. I

LABORATORY ANALYSES
OF
BASE METAL AND SPELTER

	Ga.	Tests Run	Mo. %	Mn. %	Sul. %	Ph. %	Si. %	Cu. %	Total Determined Elements	Spelter Oz. Per Sq. Ft.
Armco	14	3	-	.027	.023	.003	.003	.026	.082	2.49
Toncan	14	4	.086	.174	.022	.008	.004	.421	.715	2.20
Western (OH)	14	1	-	.220	.039	.010	.002	.027	.298	2.06
Western (Bes.)	14	1	-	.227	.029	.128	.002	Tr.	.386	2.23

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TABLE 2
SOIL AND WATER ANALYSIS

Soil - per cent			Water - parts per million				
Set No.	CO_2	Cl	SO_4	HCO_3	CL	SO_4	Date
			Siskiyou County				
1	.019	.028	T	338	12	242	4-17-30
2	.018	.035	T				
3	.066	.040	T	262	6	T	2- 3-30
				420	22	7	4-17-30
4	.073	.038	T	203	10	15	2- 3-30
				383	8	10	4-17-30
			Shasta County				
5	.018	.018	T	42	4	4	2- 3-30
				57	10	6	4-17-30
6	.013	.030	T				
			Humboldt County				
7	.014	.028	T	32	13	4	2- 3-30
				31	50	T	4-17-30
8	.014	1.375	.914	93	7290	253	2- 3-30
				185	15400	2070	4-17-30
9	.018	.025	T	31	34	52	2- 3-30
				71	70	8	4-17-30
10	.022	.025	T				
			Mendocino County				
11	.023	.045	T				
12	.017	.038	T	102	10	3	4-17-30
			Solano County				
13	.040	.058	.030	60	140	44	4-17-30
				71	4120	495	4-20-31
14	.034	.035	T	112	4	T	4-17-30
			Amador County				
15	.036	.040	T	(49	24	158	11-12-30
16	.020	.035	T	(--	20	938	1- 8- 31
				(--	24	1241	2- 11-31
				(--	22	966	3- 16-31
			Tuolumne County				
17	.014	.050	.004	--	2	283	4- 6- 30
				--	12	458	4- 17-30
			Imperial County				
18	.034	.837	.421				
19	.033	.085	.103				
20	.033	.155	.339				
21	.041	2.137	.600				
22	.026	4.475	.357				
23	.031	.070	.073				

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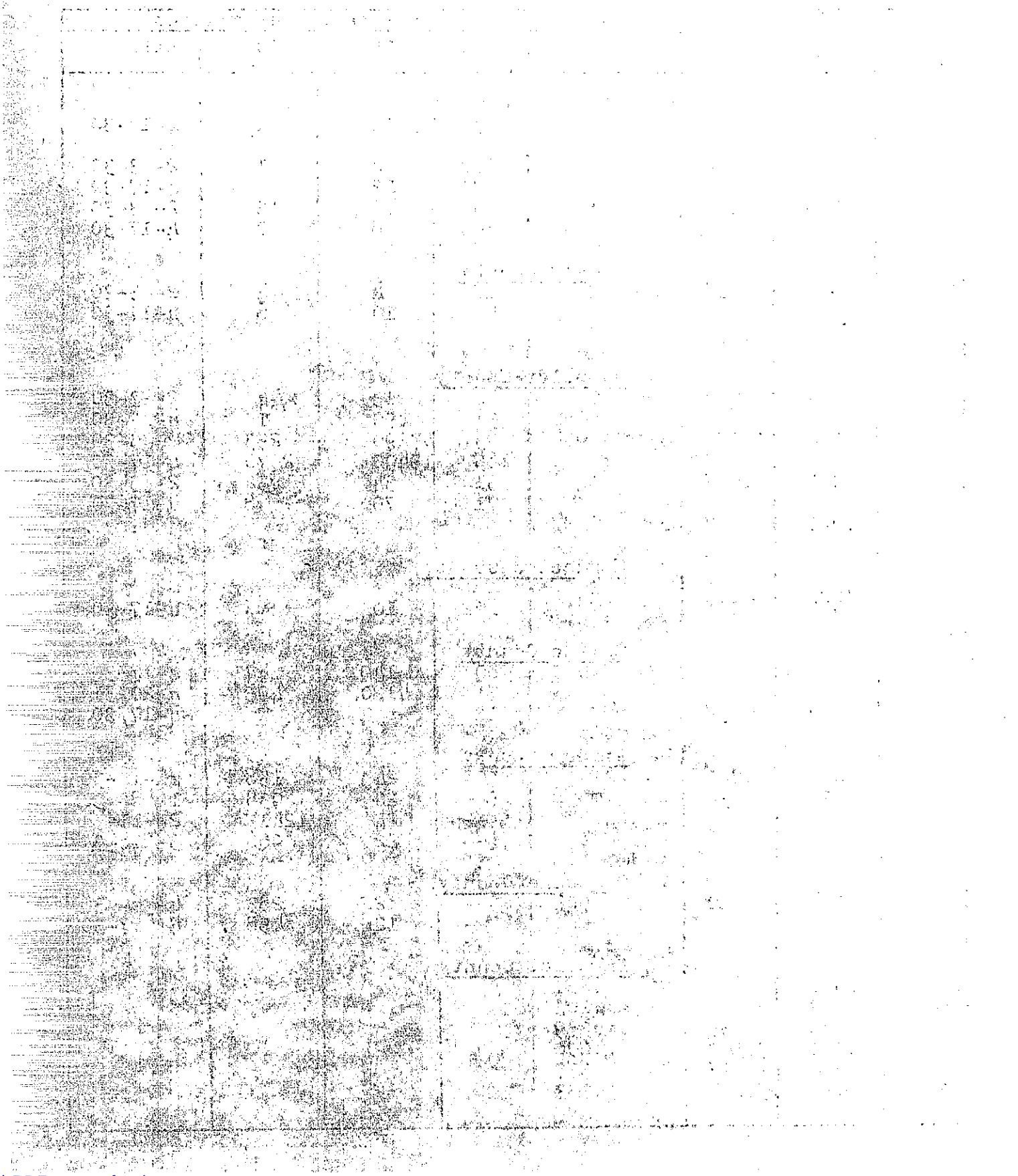

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TABLE NO. 3

MATERIAL RATINGS OF CMP TEST SERIES TWENTY YEARS AFTER INSTALLATION

	ARMCO					WESTERN					TONCAN								
		Galv.		Black			Galv.		Black			Galv.		Black		Insta-	Last	Age	Spelter	Base Metal
No.	Iden	In	Out	In	Out	Iden	In	Out	In	Out	Iden	In	Out	In	Out	lled	Inspec.	Months	Life-Yrs	Life-Yrs
	Siskiyou County																			
1	AO	G40E2	G50E2	G30E2F	G40E2	WH	G40E2	G50E2	G30E2F	G40E2	TE	G40E2	G50E2	G30E2F	G40E2	3-28-30	9-12-49	233	4.4	+33.0
2	AV	G70E2	G70E2	G40E2	G45E2	WU	G70E2	G70E2	G40E2	G45E2	TU	G70E2	G70E2	G40E2	G45E2	3-31-30	9-12-49	233	15.0	+60.0
3	AE	G60E2	G60E2	G35E2	G35E2	WQ	G60E2	G60E2	G35E2	G35E2	TX	G60E2	G60E2	G35E2	G35E2	3-28-30	9-13-49	233	10.0	+50.0
4	AK	G45E2	G50E2	Holed Thru		WD	G45E2	G50E2	G30E2	G30E2	TB	G45E2	G50E2	G30E2	G30E2	3-23-30	9-13-49	233	4.4	+33.0
	Shasta County																			
5	AH	G55E2	G60E2	G40E2	G45E2	WT	G55E2	G60E2	G40E2	G45E2	TH	G55E2	G60E2	G40E2	G45E2	3-25-30	9-13-49	233	5.8	+40.0
*6	AD	Inaccessible 7-22-40				WW	Inaccessible 7-22-40				TF	Inaccessible 7-22-40				3-25-30	6-24-37	---	7.3	----
	Humboldt County																			
°7	AX	G30E2	G40E2	-----	G30E2	WM	G30E2	G40E2	-----	G30E2	TW	G30E2	G40E2	-----	G30E2	4- 4-30	9- 8-49	233	8.5	+26.0
8	AD	Test Completed 9-20-45				WO	Test Completed 9-20-45				TS	Test Completed 9-20-45				4- 3-30	9-20-45	135	0.7	10.5
9	AG	G50E2	G45E2	G15E2	G15E2	WJ	G50E2	G45E2	G15E2	G15E2	TT	G50E2	G45E2	G15E2	G15E2	4- 3-30	9- 7-49	233	3.5	+24.0
10	AR	G25E2F	G15E2F	G10E2F	G5E2F	WI	G25E2F	G15E2F	G10E2F	G5E2F	TP	G25E2F	G15E2F	G10E2F	G5E2F	4- 5-30	9- 7-49	233	3.5	+23.0
	Mendocino County																			
11	AZ	G35E2F	G40E2F	G20E2F	G15E2F	WK	G35E2F	G40E2F	G20E2F	G15E2F	TV	G35E2F	G40E2F	G20E2F	G15E2F	4-12-30	9- 7-49	233	3.1	+25.0
12	AW	Test Completed 9-19-45				WN	Test Completed 9-19-45				TQ	Test Completed 9-19-45				4-10-30	9-19-45	186	1.2	13.3
	Solano County																			
13	AC	Test Completed 7-26-40				WV	Test Completed 7-26-40				TM	Test Completed 7-26-40				3-18-30	7-26-40	136	0.8	7.3
*14	AL	Inaccessible 9- 6-49				WP	Inaccessible 9- 6-49				TG	Inaccessible 9- 6-49				3-14-30	9-19-49	---	1.7	----
	Amador County																			
15	AB	Test Completed 3-16-31				WR	Test Completed 3-16-31				TK	Test Completed 3-16-31				11-6-30	3-16-31	4	0.1	0.3
16	AA	" " 3-16-31				WE	" " 3-16-31				TO	" " 3-16-31				11-6-30	3-16-31	4	0.1	0.3
	Tuolumne County																			
17	AN	Test Completed 3-5-35				WB	Test Completed 3-5-35				TI	Test Completed 3-5-35				3-8-30	3- 5-35	60	0.4	4.8
	AM	" " 3-5-35				WF	" " 3-5-35				TL	" " 3-5-35				3-8-30	3- 5-35	60	0.4	4.8
	Imperial County																			
18	AJ	Test Completed 2-26-35				WS	Test Completed 2-26-35				TJ	Test Completed 2-26-35				2-26-30	2-26-35	60	0.7	3.0
19	AT	" " 5- 4-39				WZ	" " 5- 4-39				TA	" " 5- 4-39				2-27-30	5- 4-39	108	1.0	8.7
20	AS	" " 5-30-37				WA	" " 5-30-37				TY	" " 5-30-37				2-26-30	5-30-37	84	0.7	3.0
21	AP	" " 2-28-35				WY	" " 2-28-35				TD	" " 2-28-35				2-24-30	2-28-35	60	0.5	3.0
22	AI	" " 2-27-35				WC	" " 2-27-35				TN	" " 2-27-35				2-27-30	2-27-35	60	4.0	5.0
**23	AY	" " 9-25-46				WG	" " 9-25-46				TZ	" " 9-25-46				2-22-30	9-25-46	199	1.0	7.0
Avgs.		18.6	19.5	10.0	10.5		18.6	19.5	10.5	11.8		18.6	19.5	10.5	11.8			148	3.0	17.5

LEGEND

* Pipe Covered by Fill due to new construction.
° Water in pipe at time of inspection.
** Rated by District Forces.
\+ Obtained by extrapolation of Fig. No's. 6, 7, 8 & 9

RUST CLASSIFICATION

E - Pitting - E2 - Soft, red, shallow, large, loose - Follows G.
F - Red, loose, smooth, soft, uniform, Rapid acting.
G - Red, heavy - scale, tubercle or barnacle, forerunner of E2.

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TABLE 4

AVERAGES OF ALL SETS AT VARIOUS RATING PERIODS

			1931 %	1933 %	1935 %	1937 %	1940 %	1945 %	1949 %
Armco	Galv.	In	71.5	60.2	51.7	34.6	28.1	24.1	18.6
		Out	68.8	58.0	49.4	34.6	29.3	25.0	19.5
	Blk.	In	54.4	40.3	36.1	22.9	17.3	14.3	10.0
		Out	54.5	40.1	36.9	23.9	19.2	16.6	10.5
Western	Galv.	In	71.5	60.2	51.7	37.1	29.9	25.9	18.6
		Out	68.9	58.3	49.2	35.6	29.7	25.5	19.5
	Blk.	In	54.3	40.3	36.1	22.9	17.3	14.5	10.5
		Out	55.0	40.3	37.2	23.9	19.2	16.6	11.8
Toncan	Galv.	In	71.5	60.2	51.7	37.1	29.9	25.9	18.6
		Out	68.9	58.2	49.2	35.2	29.5	25.5	19.5
	Blk.	In	54.4	40.3	36.1	22.9	17.3	14.3	10.5
		Out	55.0	40.3	37.2	23.9	19.2	16.6	11.8

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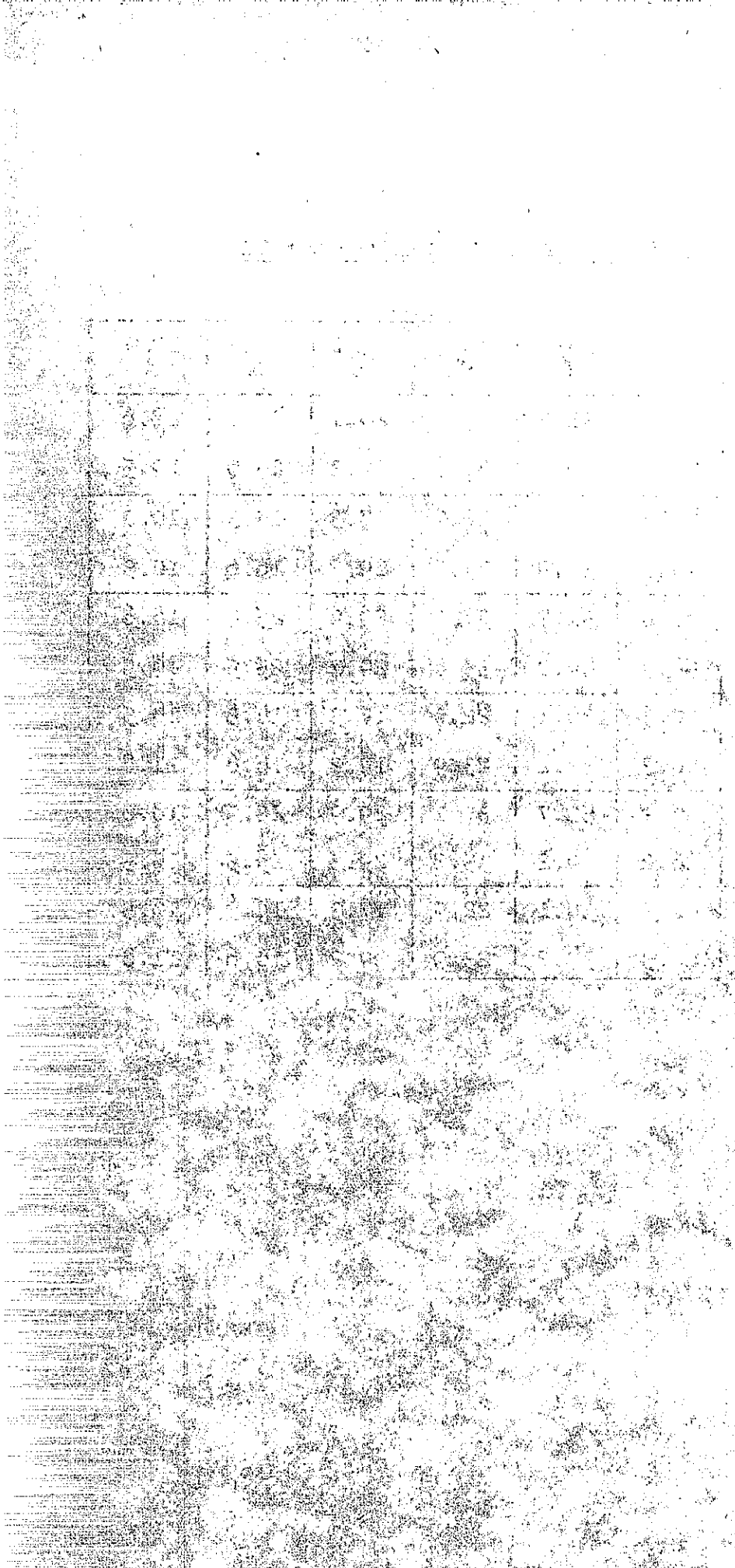

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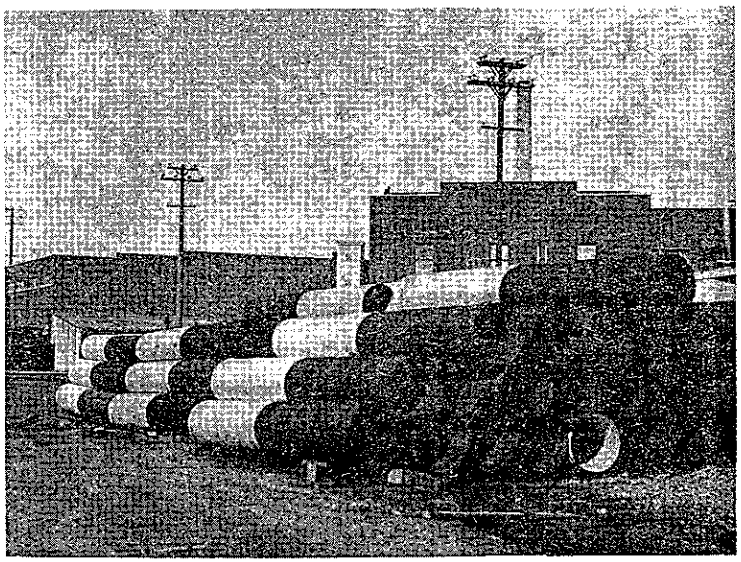
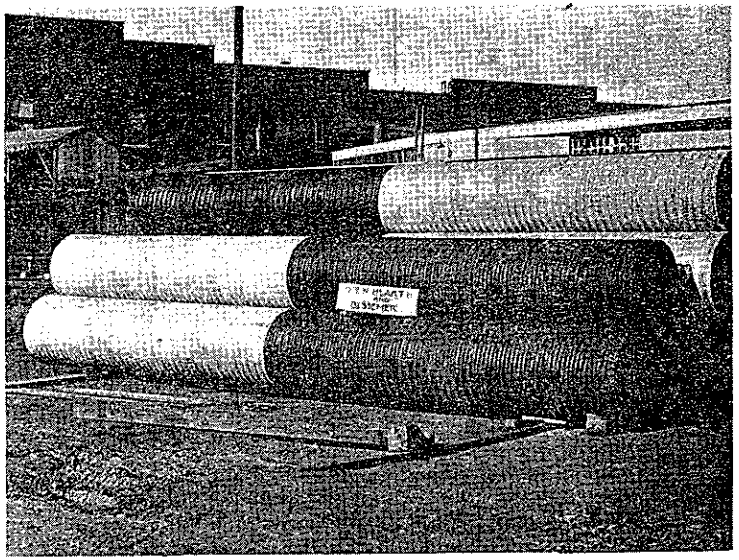


Figure No. 1



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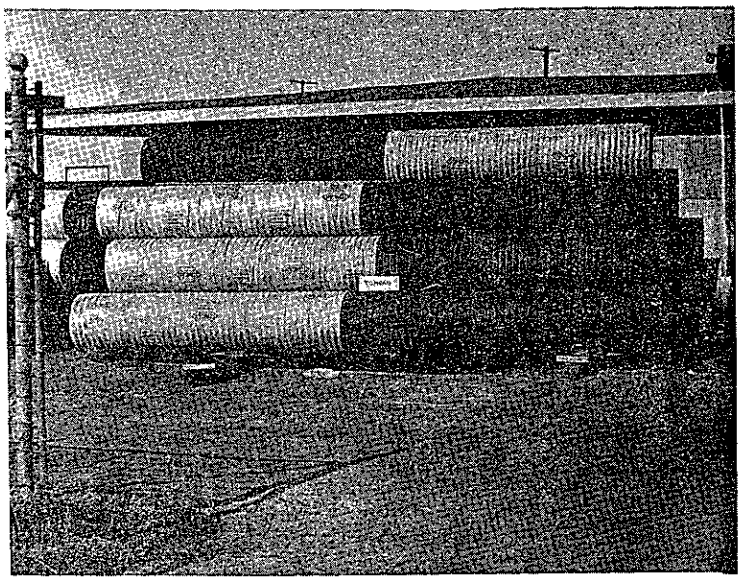

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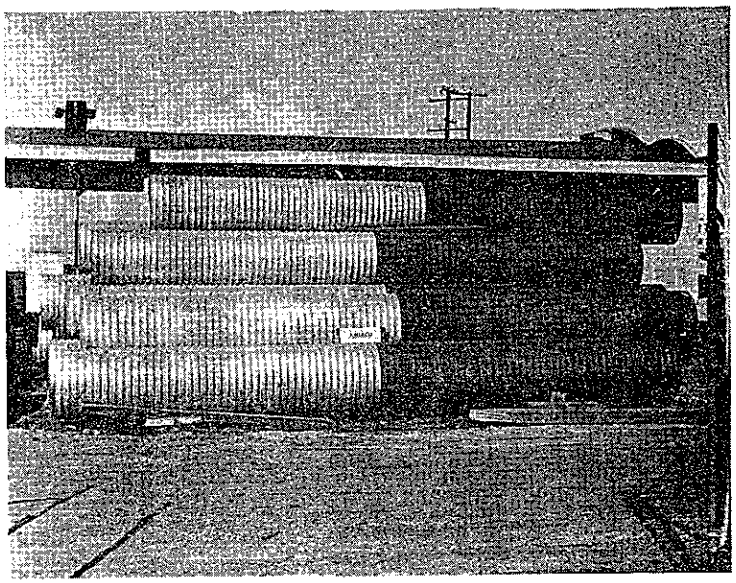
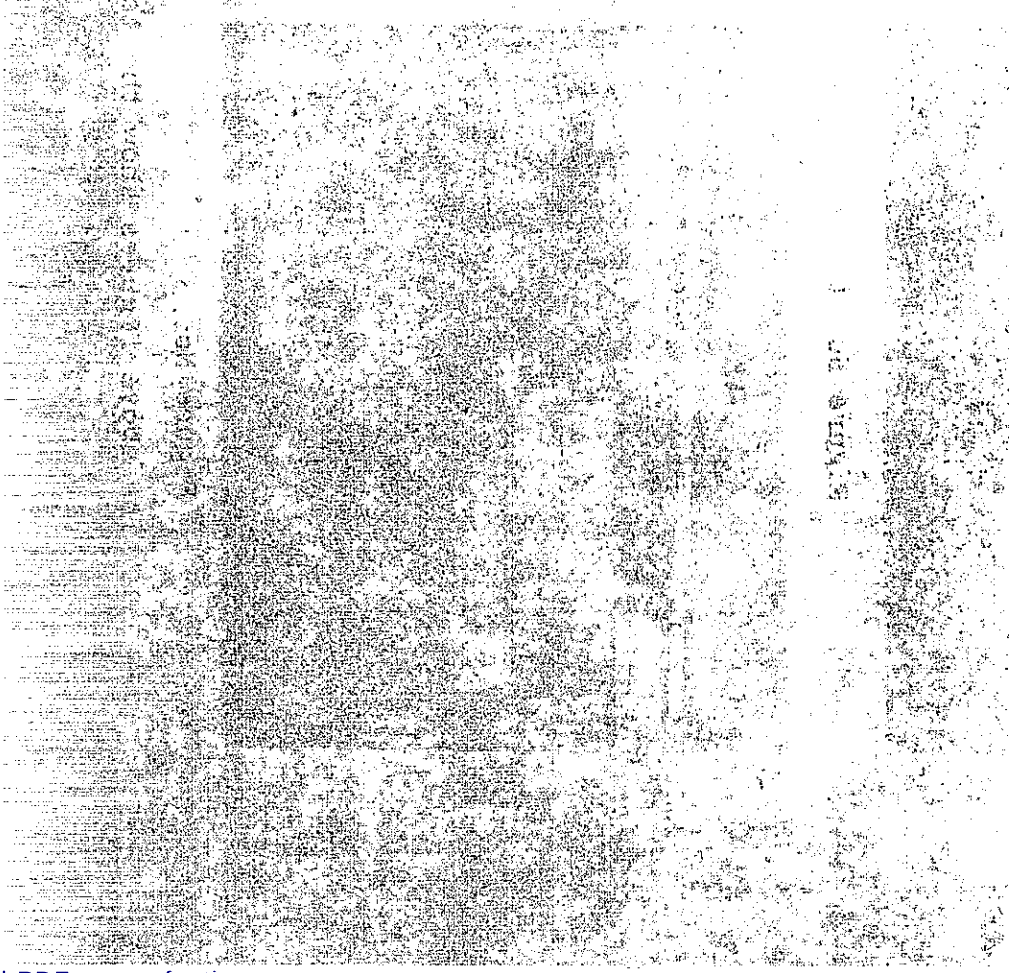


Figure No. 4

The above figures show the test pipe while in storage at Sacramento



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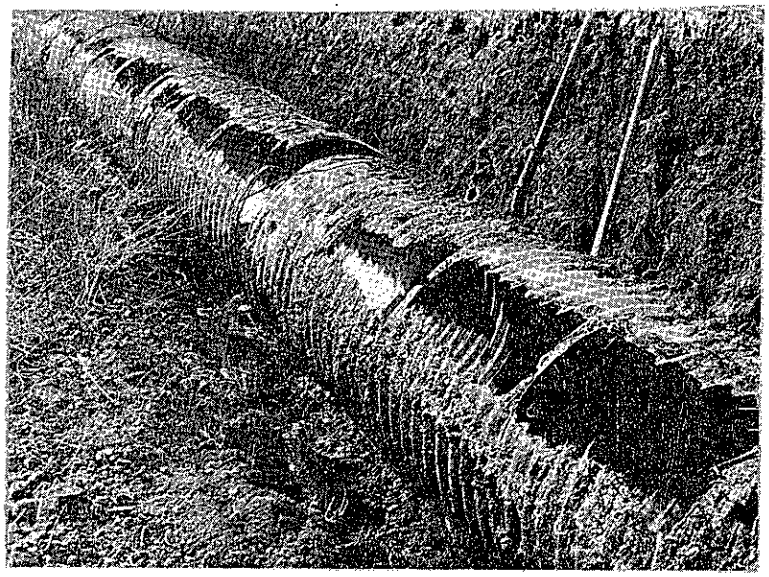

Figure No. 5

The above photograph shows the condition of the metal in sets No. 15 and 16 installed in Amador County seven and one-half ($7\frac{1}{2}$) months after installation.

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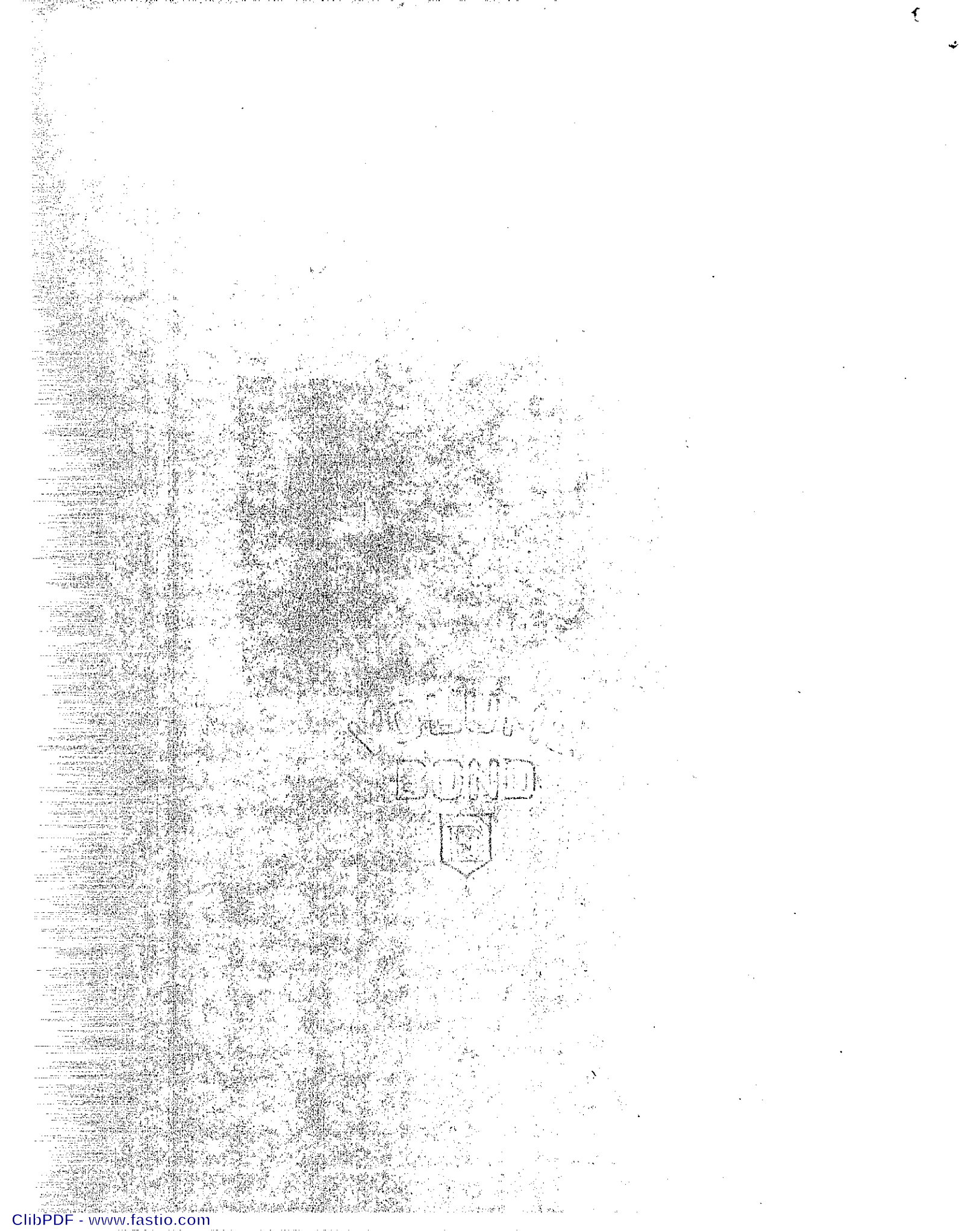

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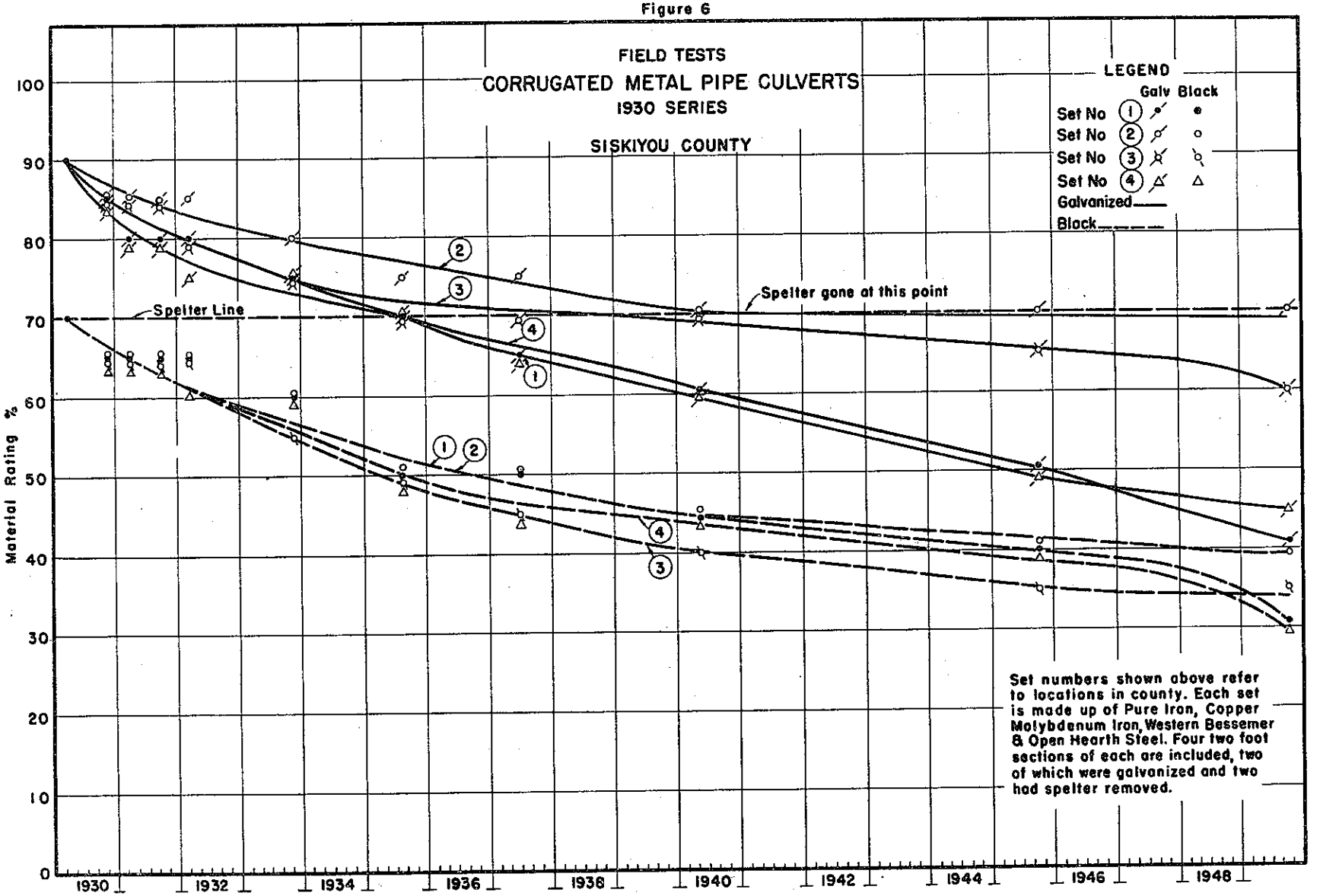
Figure 6



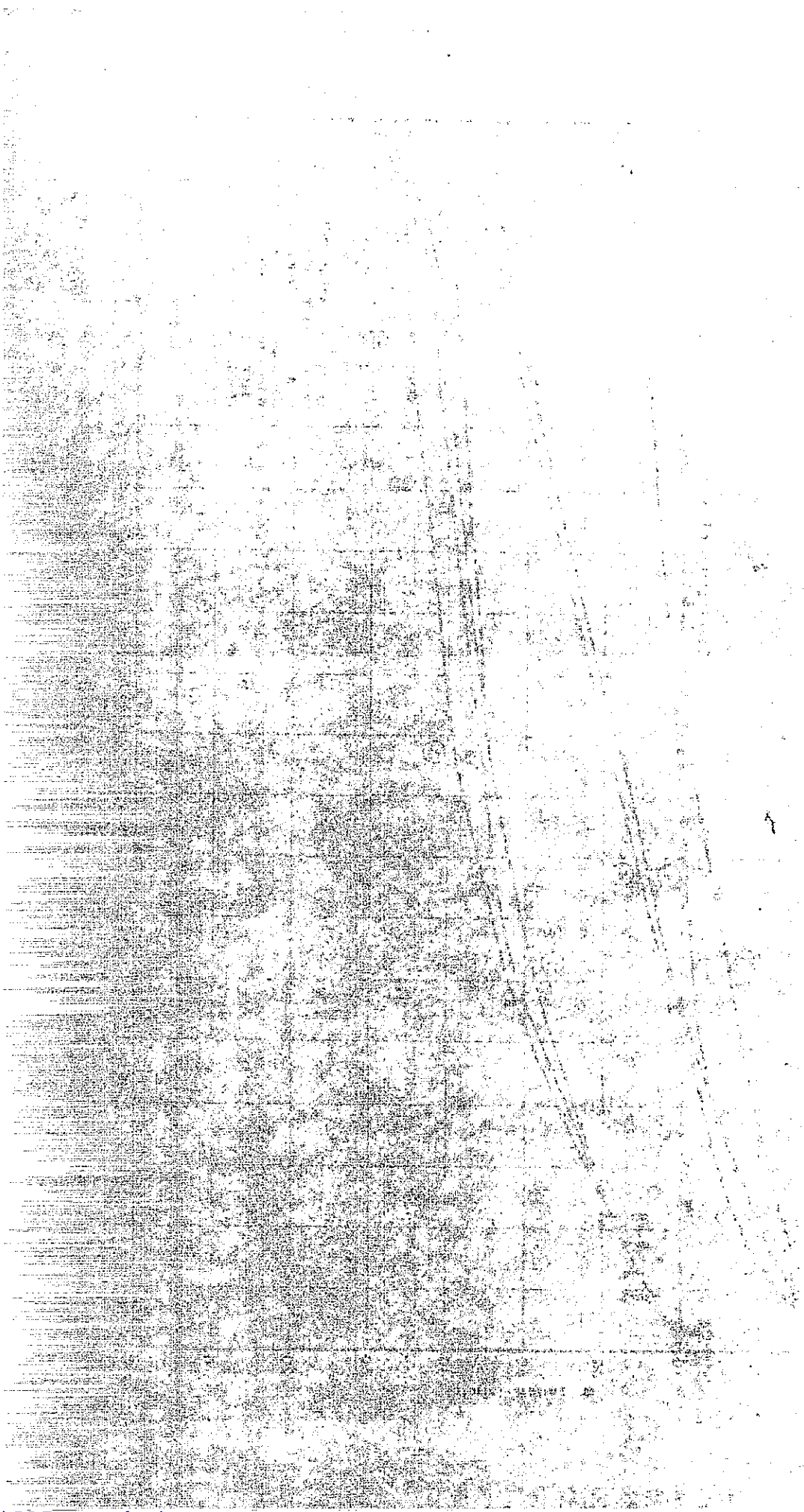


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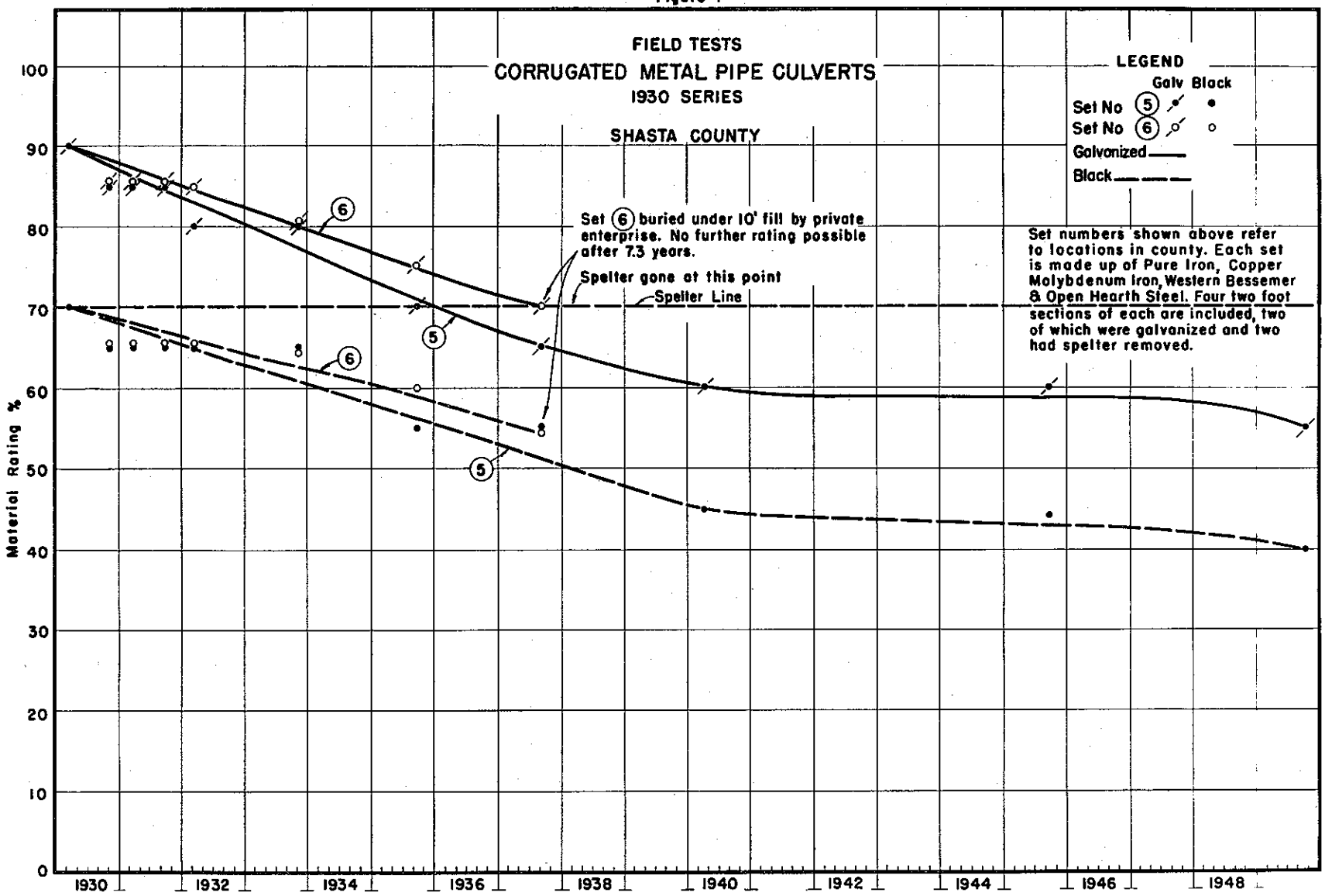
Figure 7



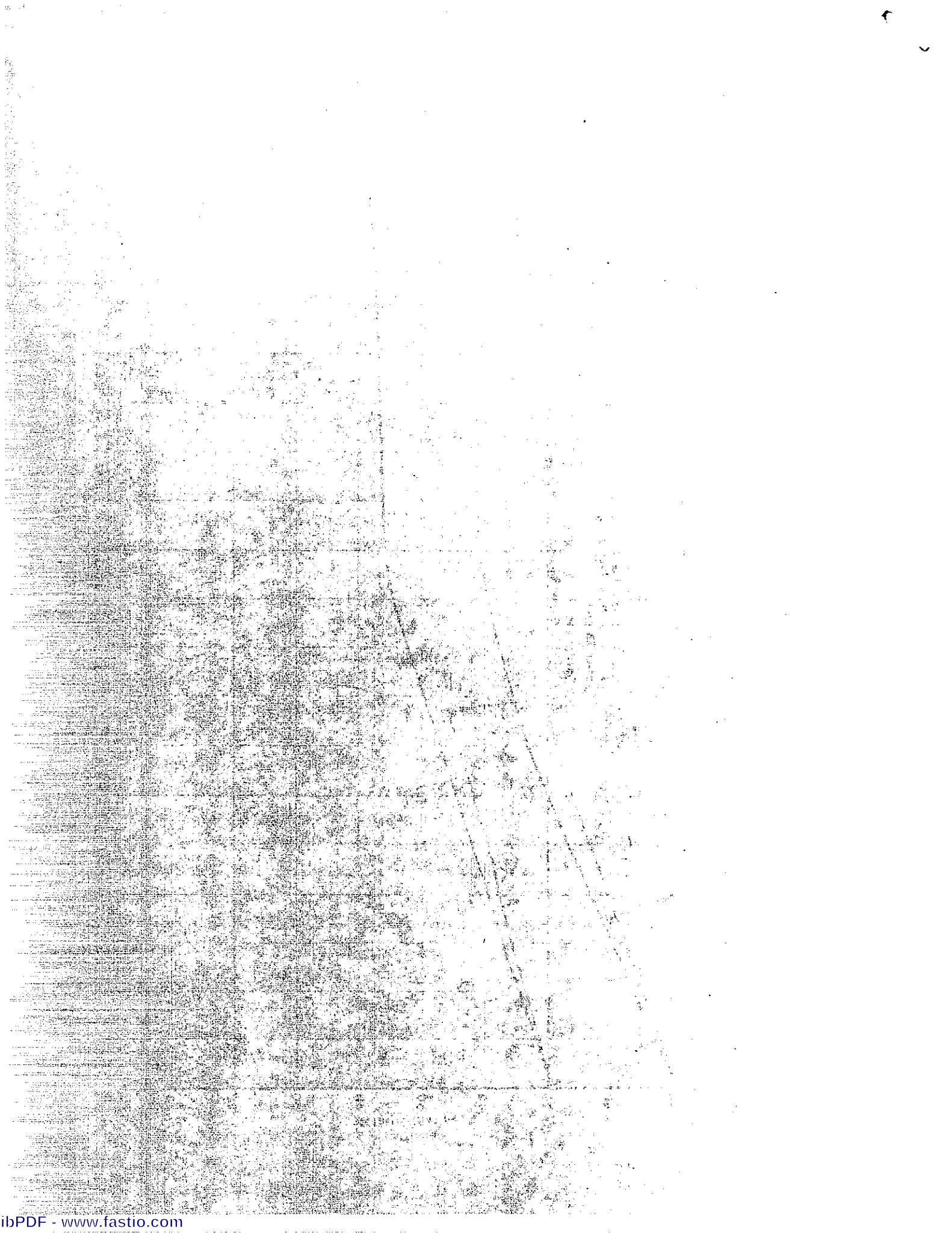


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Figure 8

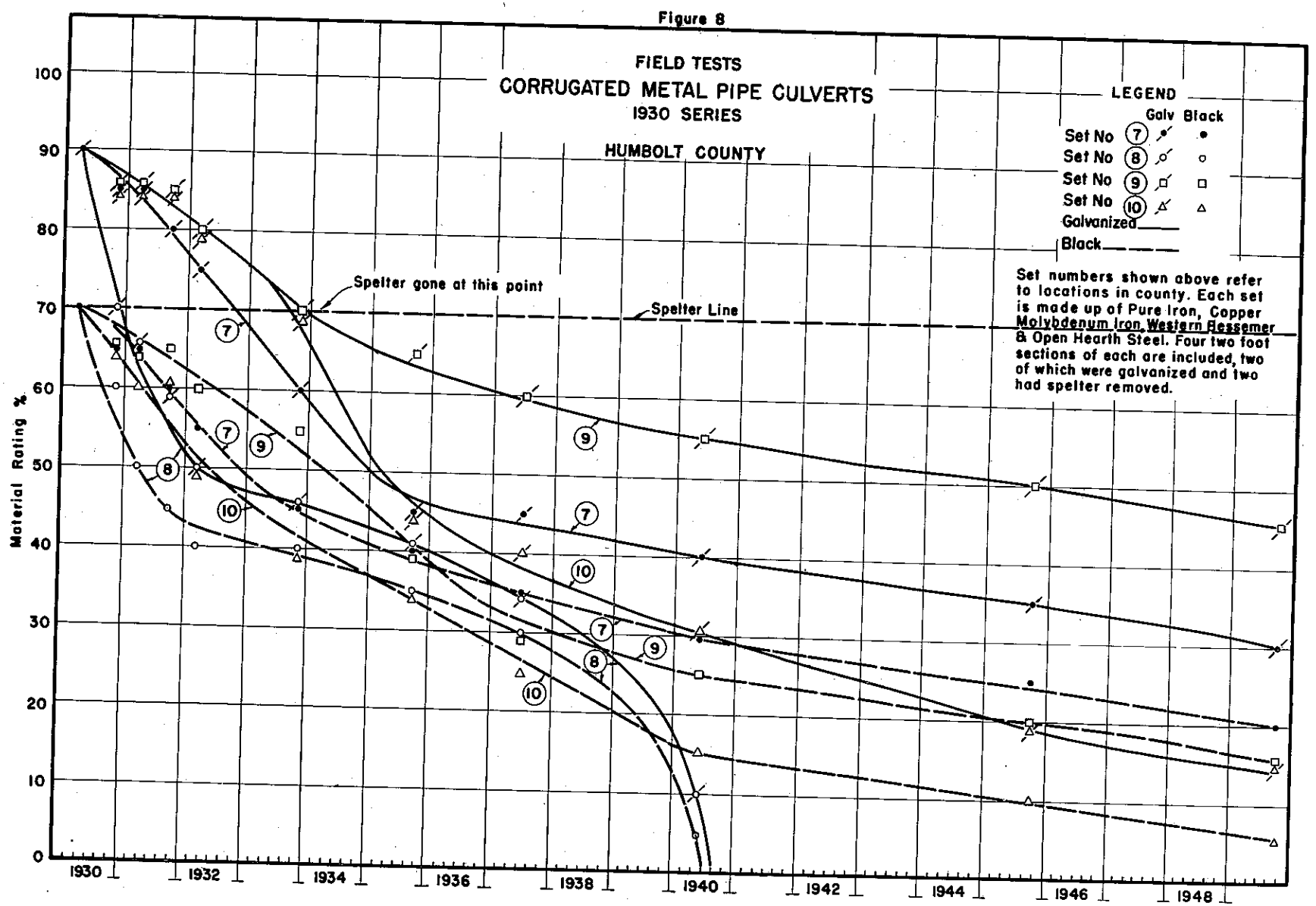

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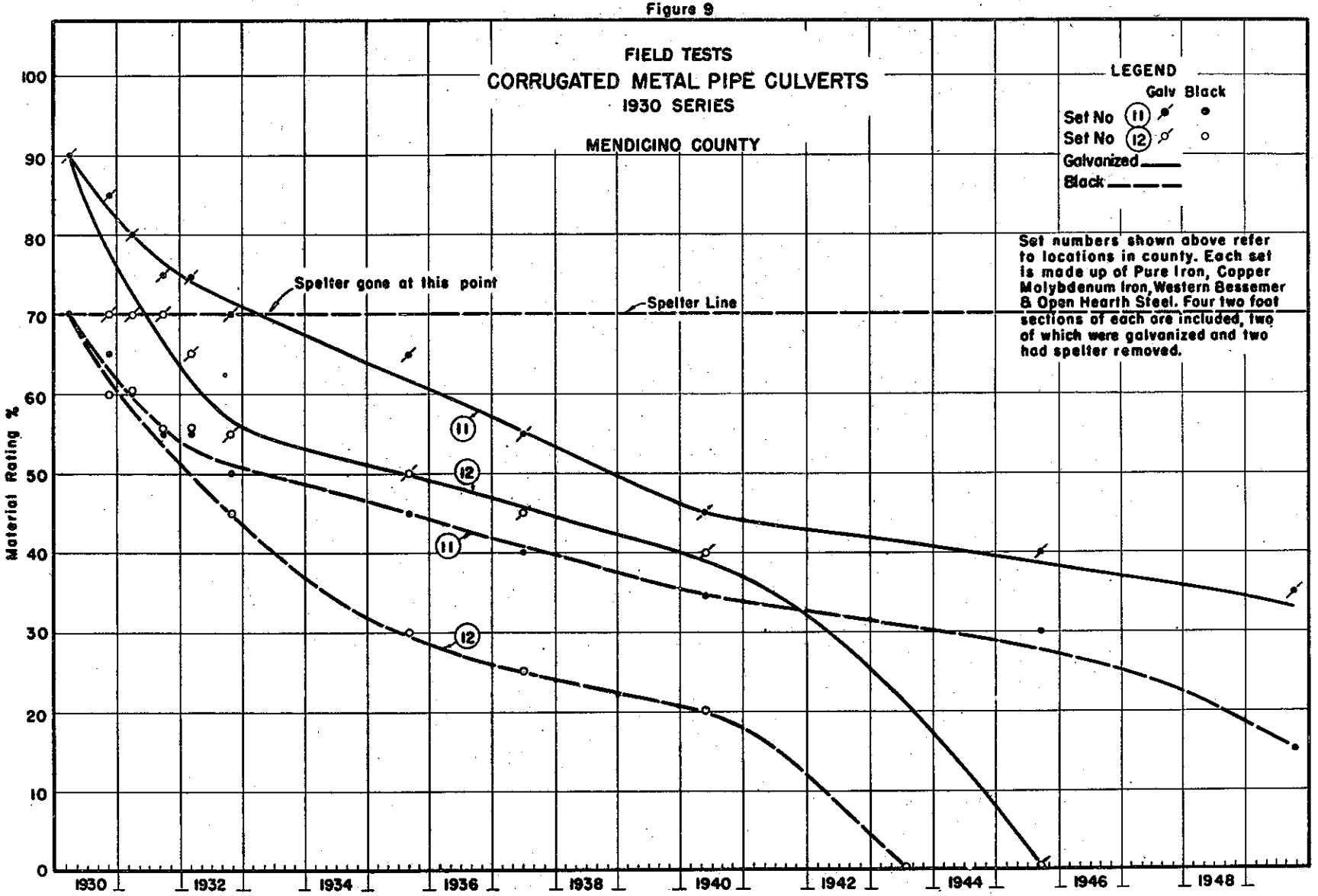
Figure 9



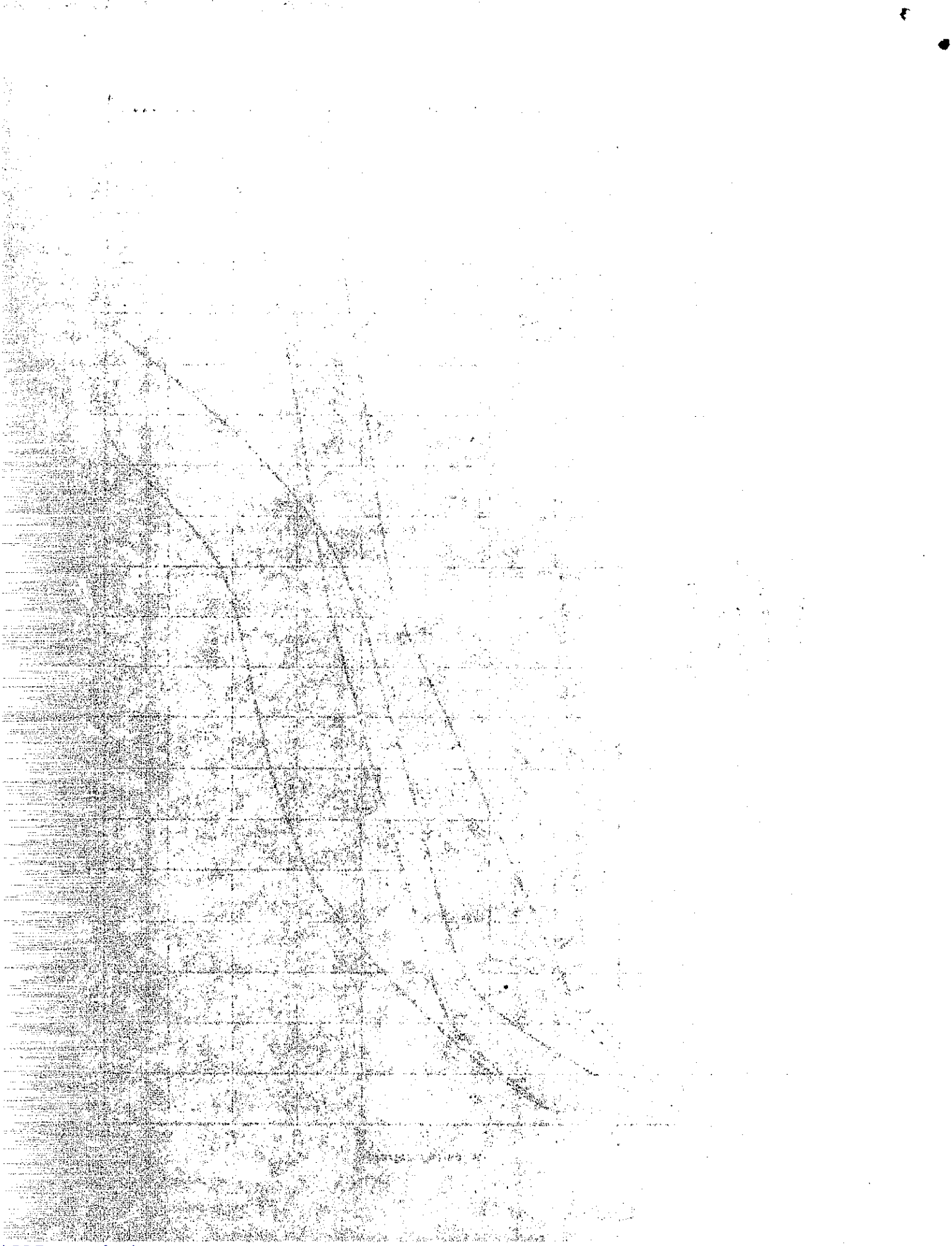


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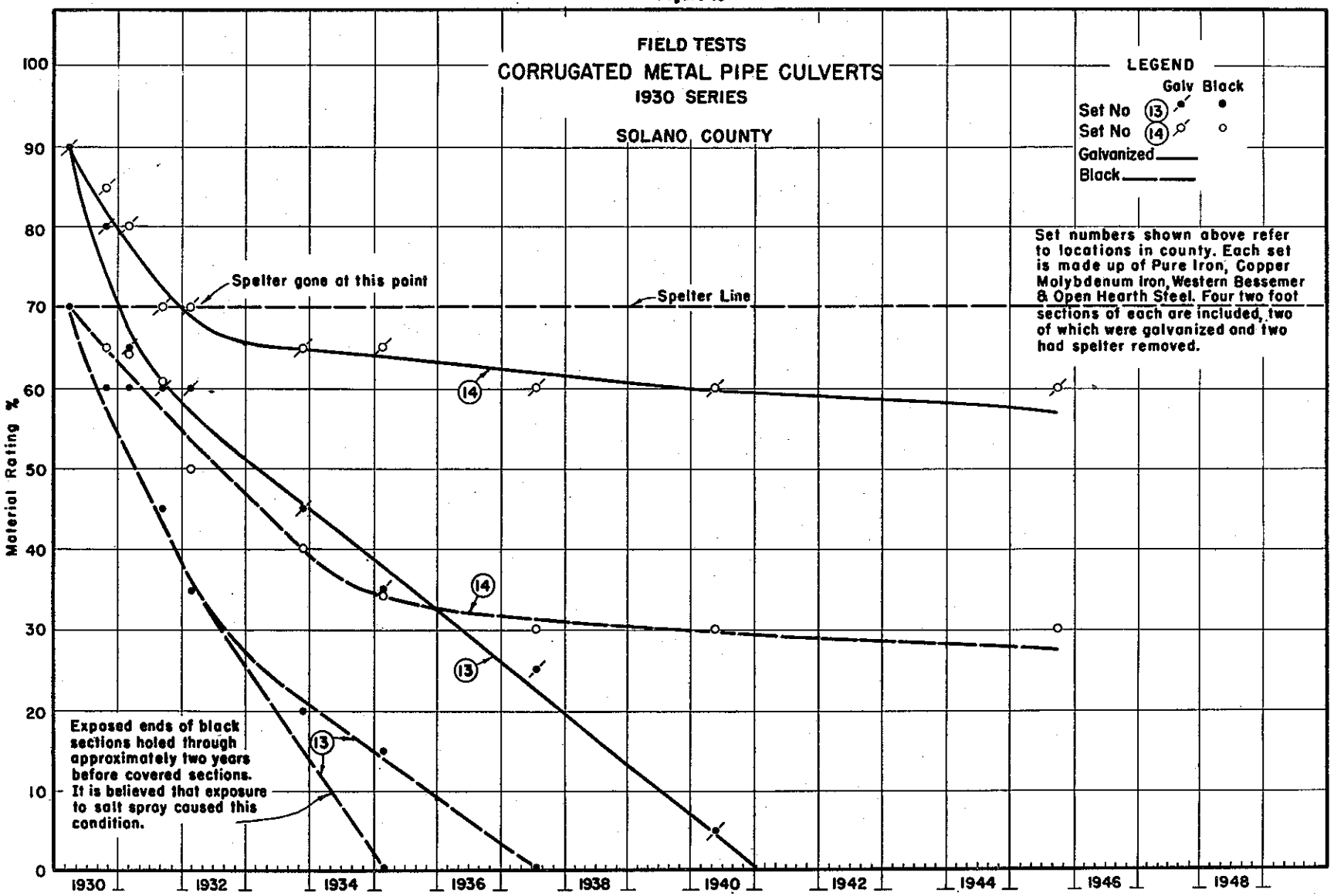
Figure 10



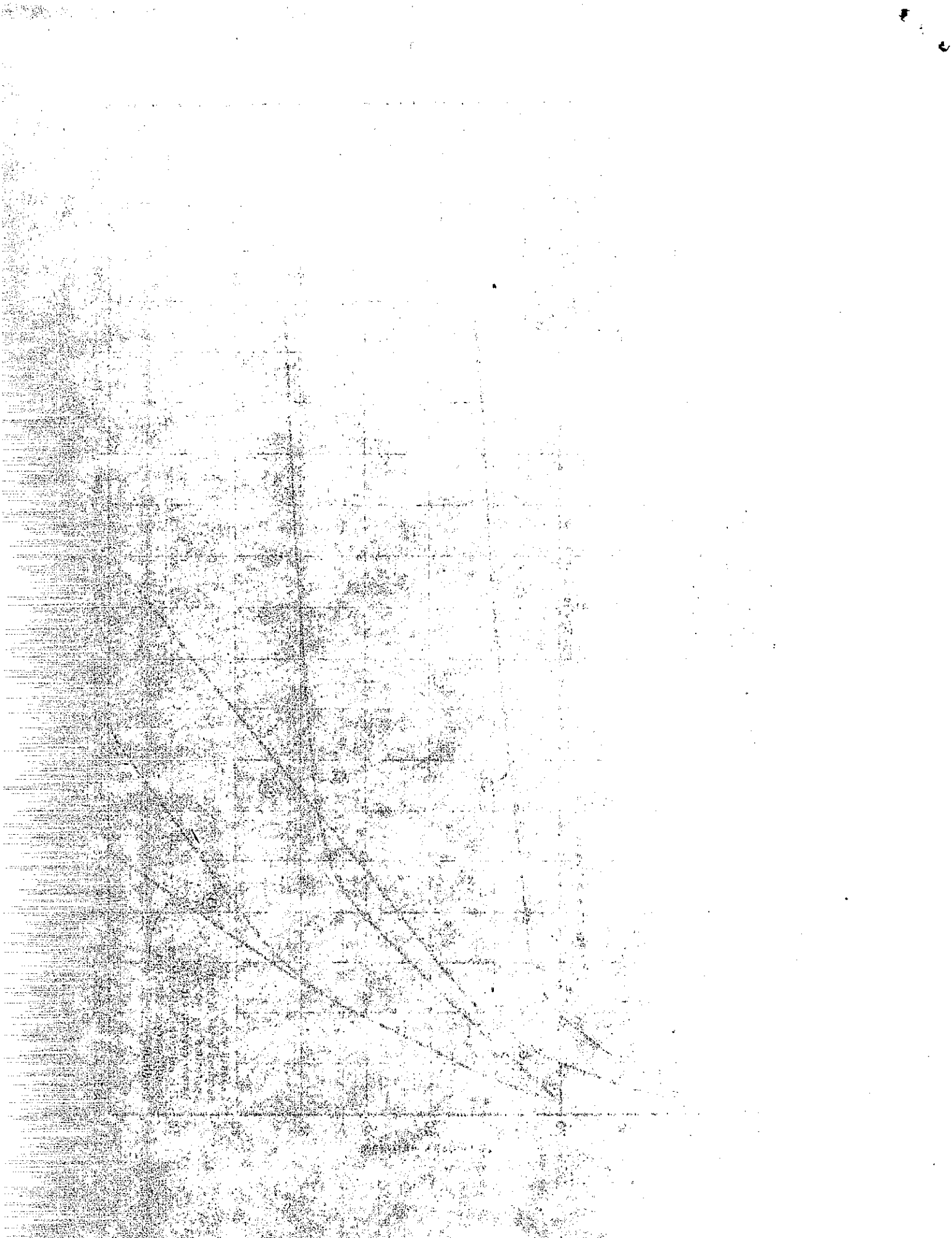


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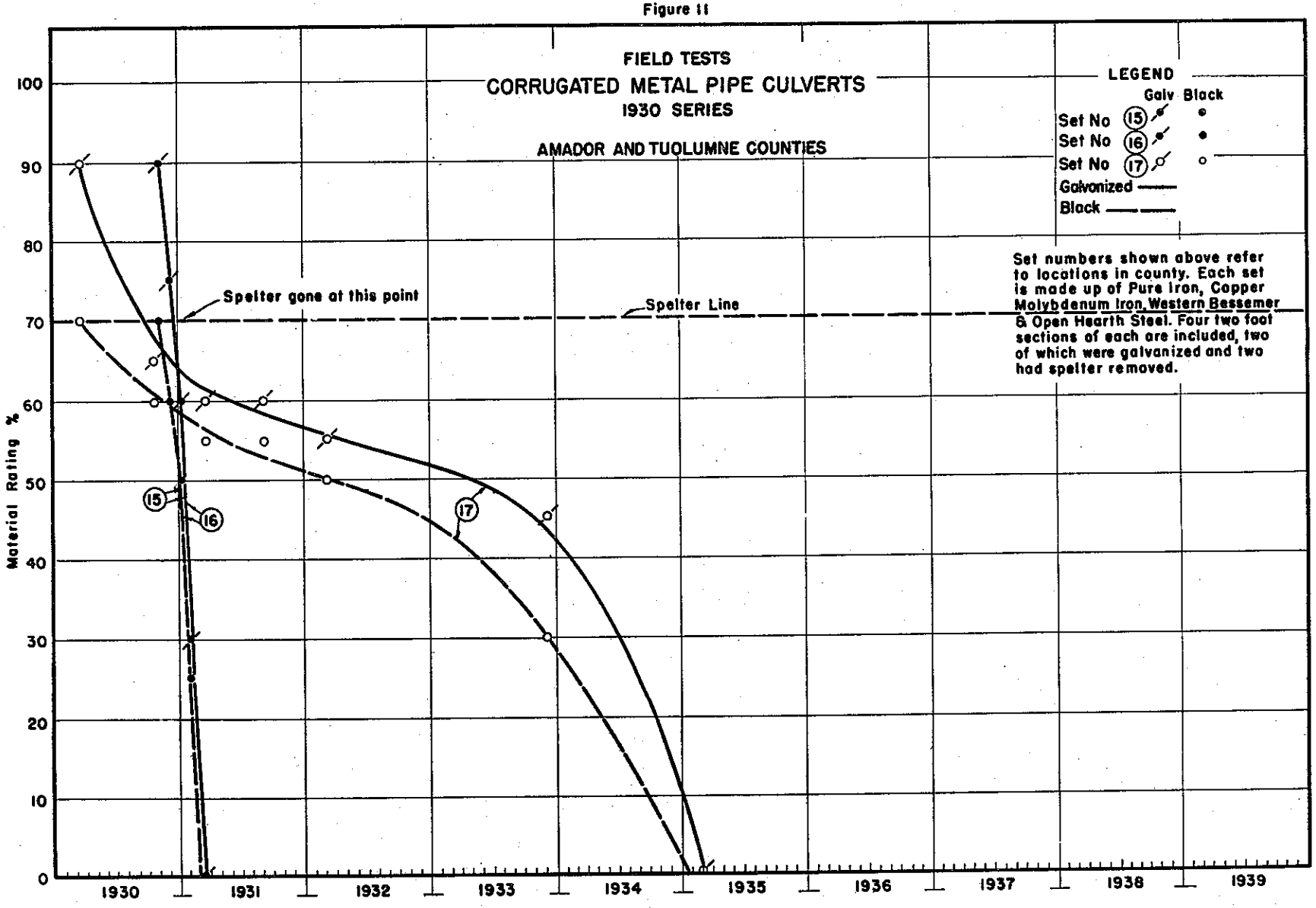
Figure 11



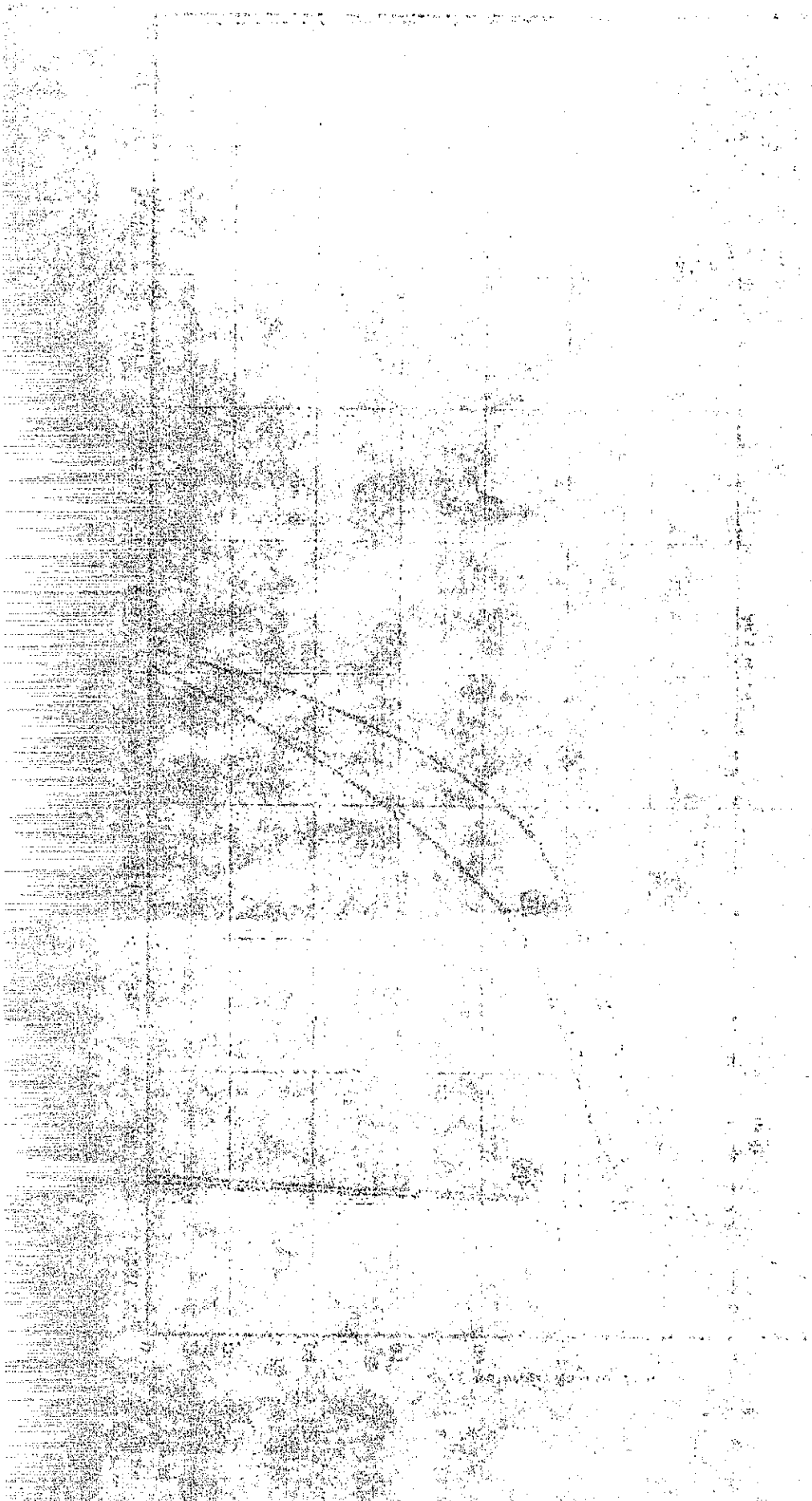


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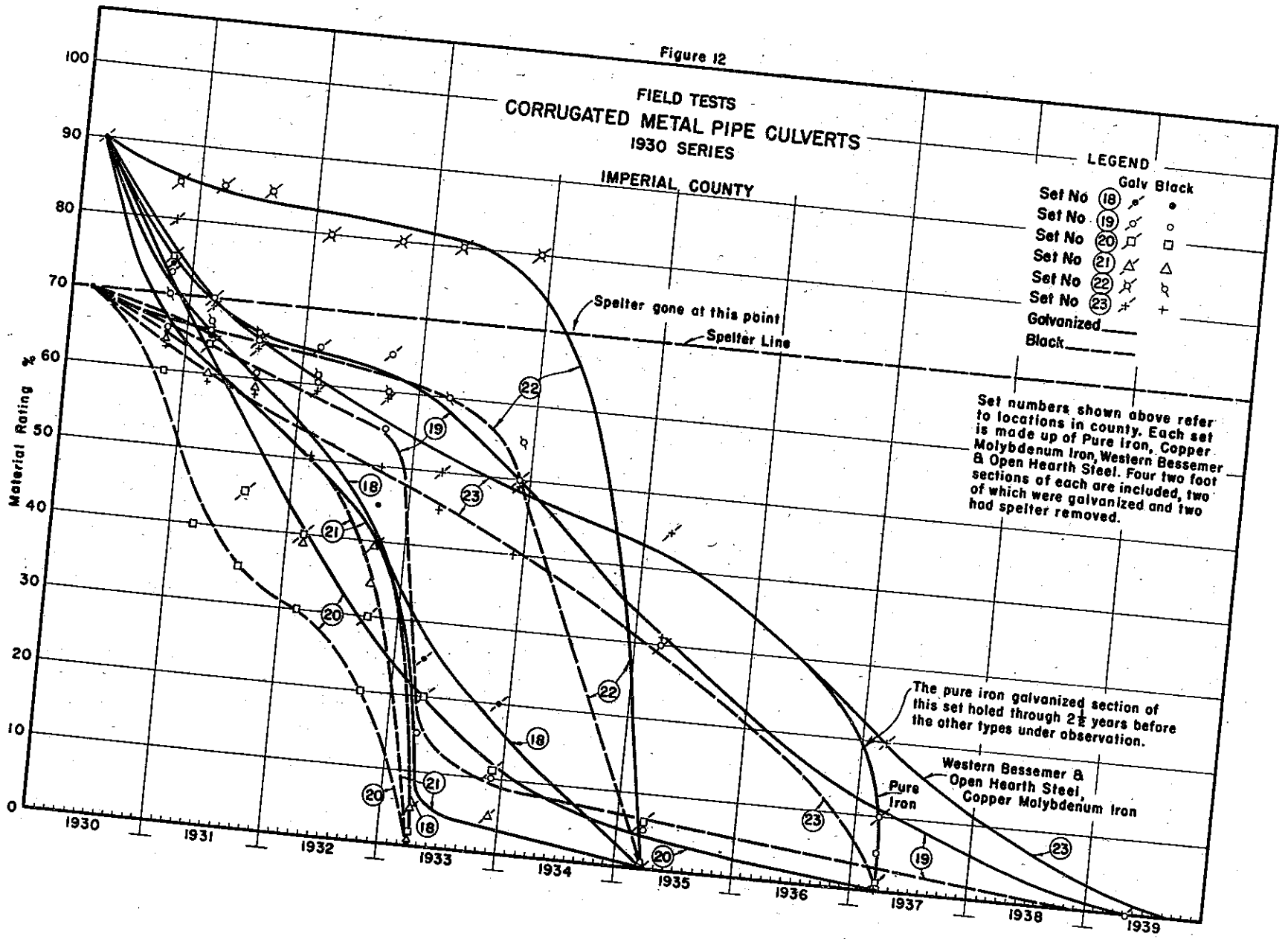
Figure 12



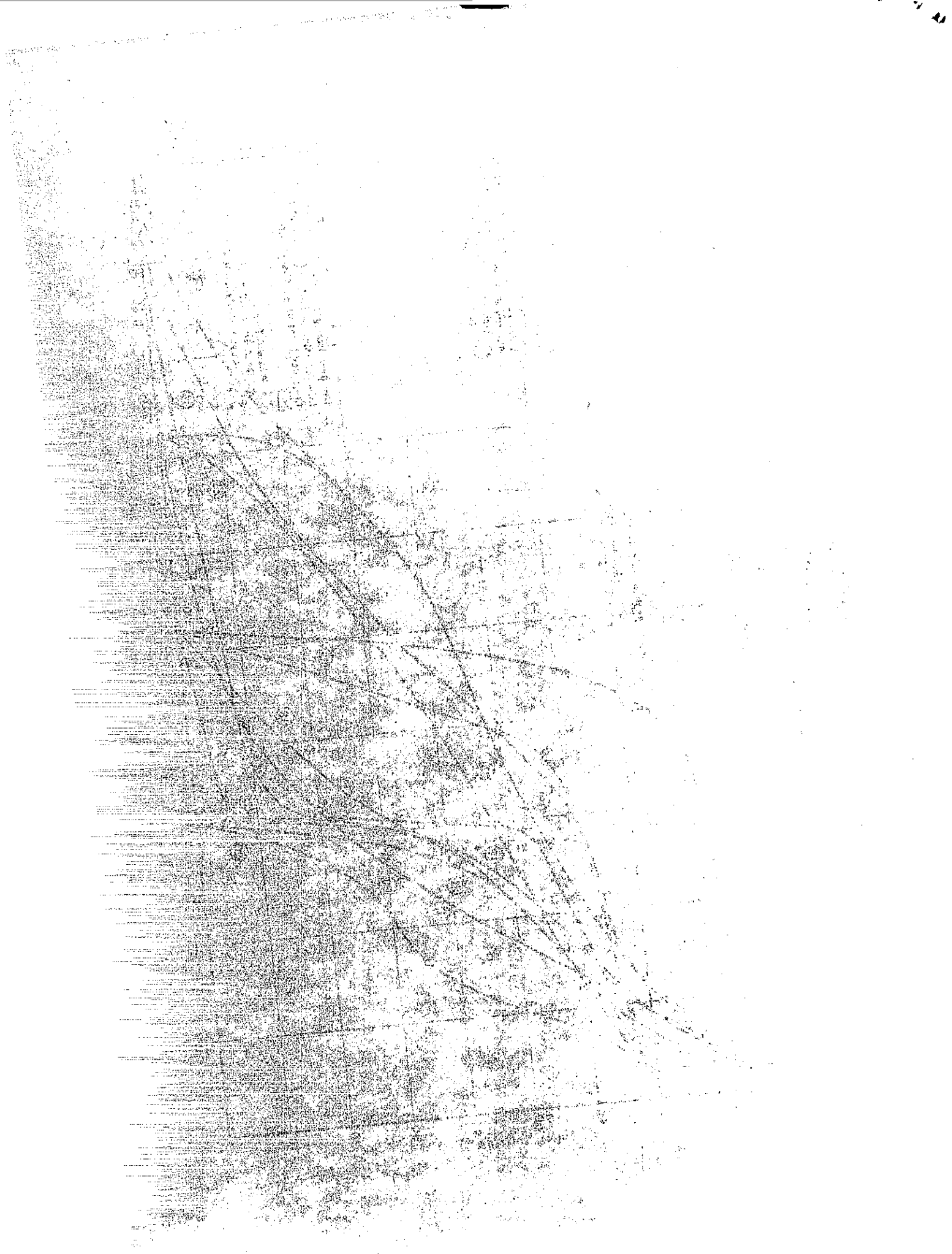


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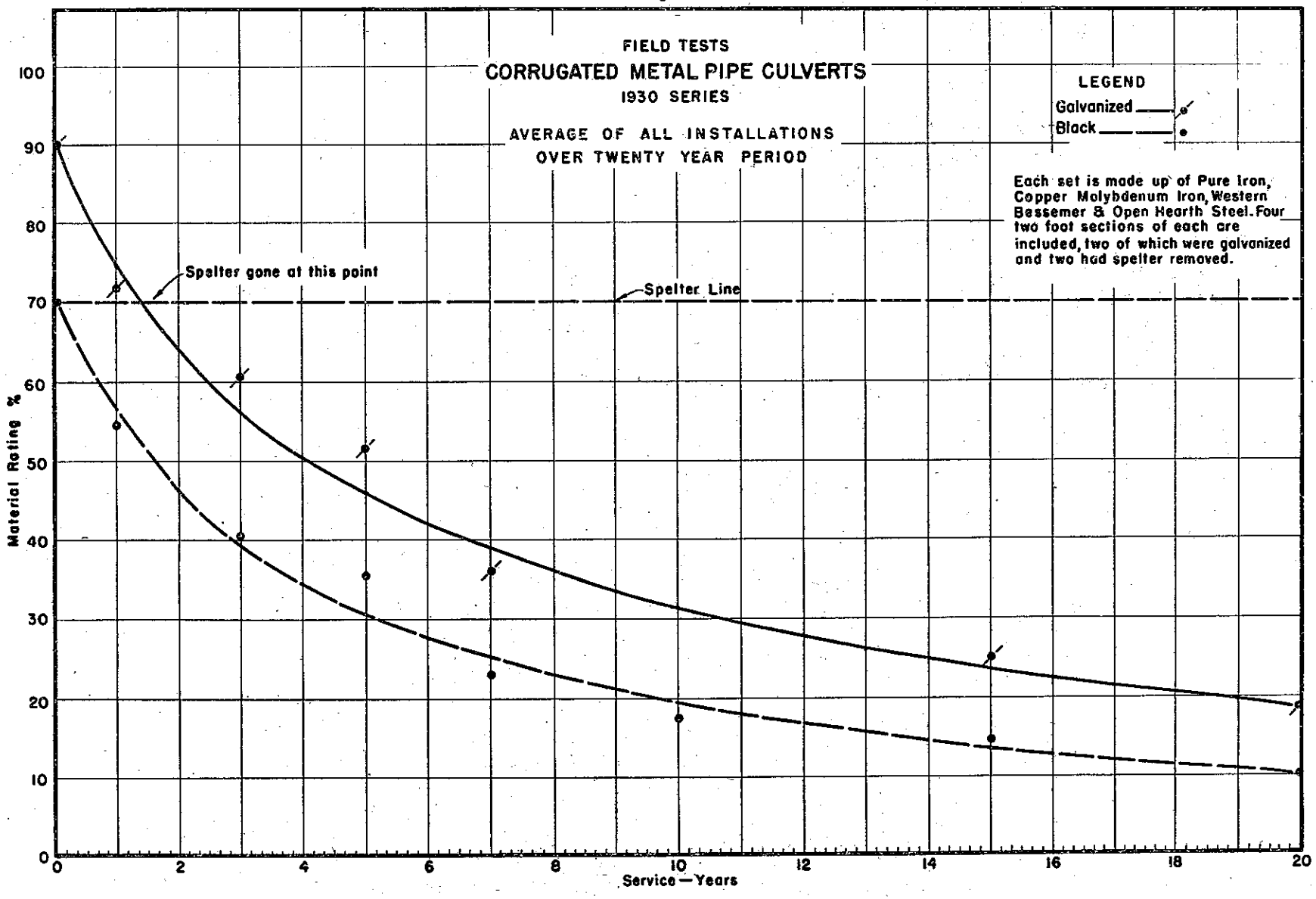
Figure 13



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