Table 1—Paints Used in Welding Tests

Paint No.	Specification[a]	Pigment Volume	Vehicle % by Wt.	Pigment, % by Wt.	97% Red Lead	Zinc Chromate	Zinc Oxide	Magnesium Silicate	Iron Oxide	Graphite Mica	Asbestine	Other
L1	TT-P-86	[illegible]	[illegible]	[illegible]	[illegible]	..	..	[illegible]	..	..	..	[illegible] Aluminum stearate
L2	52-MC-22	[illegible]	[illegible]	[illegible]	[illegible]	..	..	[illegible]	..	..	..	[illegible]
L3	M-4712-A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	[illegible]	..	[illegible]	[illegible]
L4	LIA-83	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	[illegible]	..	[illegible]	[illegible]
L5	LIA-84	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	..	..	[illegible]	[illegible]	[illegible]
L6	LIA-111	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	[illegible]	[illegible]	..	[illegible]
L7	LIA-110	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	[illegible]	[illegible]	..	..	[illegible] Aluminum stearate
L8	LIA-101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	..	[illegible]	[illegible]	..	[illegible] Aluminum stearate
L9	LIA-101A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	[illegible]	[illegible]	..	..	[illegible] Aluminum stearate
L10	LIA-100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	[illegible]	[illegible]	[illegible]	..	[illegible] Aluminum stearate
L11	LIA-100A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	..	[illegible]	..	..	[illegible] Aluminum stearate
L12	LIA-105	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	..	[illegible]	..	..	..	[illegible] Titanium oxide
Z1	52-P-16	[illegible]	[illegible]	[illegible]	..	[illegible]	..	[illegible]	..	..	..	[illegible]
Z2	52-MC-20	[illegible]	[illegible]	[illegible]	..	[illegible]	[illegible]	[illegible]	..	..	..	[illegible]
Z3	52-P-26	[illegible]	[illegible]	[illegible]	..	[illegible]	[illegible]	[illegible]	[illegible]	..	..	....

[a] Red lead base paints
- TT-P-86: Federal Specification
- 52-MC-22: Maritime Commission Specification
- M-4712-A: Same as 52-MC-22, different vehicle
- LIA-XX: Lead Industries Association

Zinc chromate base paints
- 52-P-16: Navy Department Specification
- 52-MC-20: Maritime Commission Specification
- 52-P-26: Navy Department Specification

Vehicle constituents (other than thinners and driers).
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

Test Procedures

Evaluation of Effect of Paints on Ease of Welding

In all of the welding tests, whether designed primarily for an evaluation of the ease of welding or for strength tests, a systematic rating of various welding factors was made. These included arc stability, filler-metal transfer, action of the molten-metal pool and the slag, penetration at the root, spatter, tendency for undercutting and external appearance of the finished weld. A sufficient number of replicate tests (from 4 to 18, depending on the test) was made so that a reliable average rating could be obtained. Some of the tests were repeated by different operators, to bring in varying degrees of welding skill.

Inspection for Weld-Metal Soundness

Almost all of the weld specimens were radiographed, and the type and number of internal defects, such as porosity, slag entrapment and incomplete root penetration noted. In a few instances where it was desired to definitely determine the location of defects, stereoscopic radiographs were made or the test piece was broken to expose the defect. The internal soundness was rated according to an arbitrary scale to differentiate between various welds, and was also rated in comparison with Navy Department X-Ray Standards. No radiographs, except the Navy X-Ray Standards, are reproduced in this paper, because so much detail is lost in reproduction, and because too many radiographs would be required to illustrate the individual degrees of internal soundness encountered.

Strength Tests

Weld specimens for tension, bend, and notched-bar tests were first rated for ease of welding, then radiographed and then machined and tested. Duplicate tests were made by different welders.

Weld-Bead Tests

To obtain a preliminary appraisal of the influence of the various test paints on welding characteristics and weld quality, bead deposits were welded in the flat position with 5/32-in. Class E6010, E6011, E6012 and E6030 electrodes on 1/2-in. steel plates coated with various paints.

The welds were deposited with an automatic welding head using travel speeds of 6 to 8 in./min. and low, normal and high currents for the various electrode types.

Paints L1, L2, L3, Z1 and Z2 (Table 1), applied to a dry film thickness of about 1.5 mils, were used in the bead-deposit tests. Tests were also made with Paints L4, L5, L6 and L7 applied to dry film thicknesses of 3 to 7 mils, and with Paints L1 and L2 about 10 mils thick.

The quality of the weld beads was evaluated principally by radiographs. Radiographs of weld beads on unpainted plates and Navy Department X-Ray Standards (Fig. 4), were used as a basis for comparing the welds on painted steel. (The Navy X-Ray Standards are intended primarily for classification of the soundness of multiple-pass welds, and were so used in later tests; they were used in the bead-deposit tests, however, because no other standard was available.) The external appearance of the welds and the welding characteristics of the electrodes were also considered in the over-all evaluation.

The internal soundness of welds made with E6010, E6012 and E6030 electrodes on plates coated with 1.5 mils of paint was satisfactory, and was comparable to the

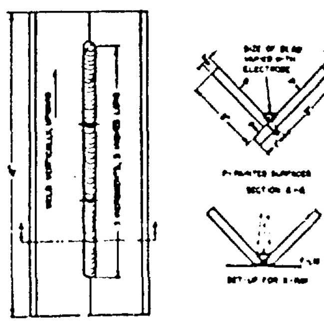
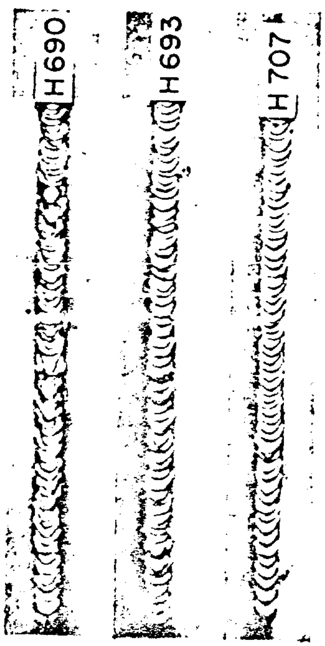


Fig. 1—Vertical Fillet-Weld Test

soundness of welds made on the unpainted steel and to Group 1 of the Navy X-Ray Standards. The E6011 welds on unpainted plates, and on plates coated with 1.5 mil paint films, were of Group 2 soundness or better. The external appearance of all welds was satisfactory and comparable to welds made on unpainted plates. The arc characteristics of the electrodes were satisfactory for all welds at normal and high currents; at low currents, the initial starting was difficult for most electrodes, regardless of the type of paint.

The bead-deposit tests also showed that, regardless of the type of paint, the thicker films did not cause an excessive amount of porosity in the weld metal, but had a detrimental influence on the arc characteristics and weld-bead appearance. The chief effect of thick paint films (5 mils or more) was to insulate the steel from the electrode, causing difficult starting and erratic arc action,



RED LEAD — 67% RED LEAD 33% IRON OXIDE — IRON OXIDE

Fig. 2—Vertical Fillet Welds Made with 5/32-In.-Diam. E6010 Electrodes on Steel Coated with 3-Mil Barrier of Pigments as Indicated

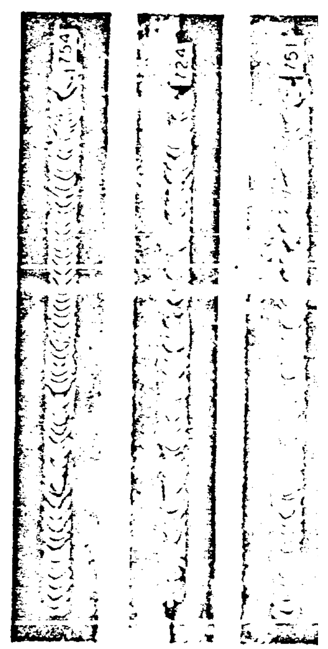
especially at low welding currents. The bead rougher, narrower and more convex than when un or thinly painted plates were used.

Fillet-Weld Tests

Vertical and horizontal fillet welds were made to mine the effect of various paints on the ease of dep and quality of weld metal. These tests provided a critical means for evaluating variations in el operating characteristics, the manipulation tech required to make the weld, and weld-metal soun The specimen used for the vertical fillet-weld t shown in Fig. 1.

Initial Comparison Tests

Vertical-up fillet welds were made with 5/32- and E6010 and E6011 electrodes in joints coated with



UNPAINTED — L8 — Z1

Fig. 3—Vertical Fillet Welds Made with 5/32-In.-Diam. E6 Electrodes on Unpainted Steel and on Plates Coated with 3.5 of L8 and Z1 Paints. The Weld Soundness, External W Appearance and Weld Metal Deposition Were Conside "Satisfactory."

1.5 mils of L1, L2, L3, L6, L7, Z1, Z2 and Z3 paints. Eighteen specimens, made under various conditions of plate preparation (e.g., as-received, pickled or grit blasted), electrode diameter and welding current were used for each test paint.

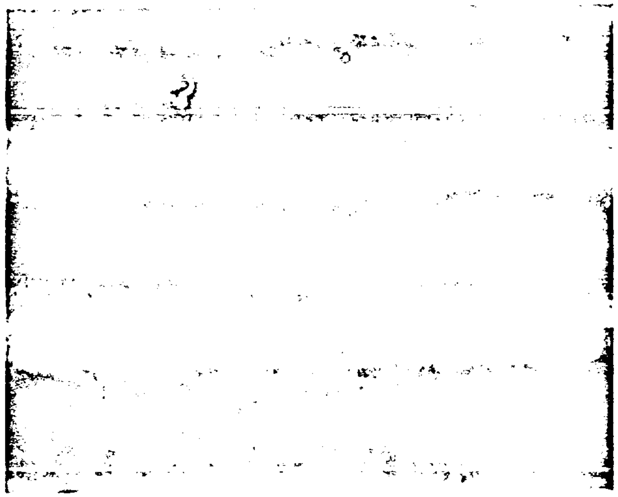
Light coatings of the Z1, Z2 and Z3 zinc chromate base paints had little effect on arc characteristics, weld appearance and weld soundness, and the welds were generally comparable to those on unpainted steel. The influence of the L1, L2 and L3 red lead base paints, with a very high red lead content, was more pronounced. The welding was hindered by some arc instability, and it was rather difficult to control the molten metal and slag. The fillets were considerably rougher and more convex than fillets in unpainted joints, and were moderately porous (no better than Group 3 quality, Fig. 4). The L6 and L7 red lead base paints, which had lower red lead contents than L1, L2 and L3, and which contained other pigments as well, rated about midway between the zinc chromate base and the high red lead base paints in their effect on welding. The soundness of the welds made on plates coated with the L6 and L7 paints was satisfactory.

The fillet welds made with $^5/_{32}$-in. electrodes were better than those made with $^1/_4$-in. electrodes. However, the differences in the influence of the various paints were noticeable in the welds made with both electrode sizes.

Some horizontal fillet welds were made with $^5/_{32}$-in. E6020 electrodes in joints painted with each of the above paints. All of these welds were good, and no difference was observed in the influence of the various paints on weld soundness, appearance or operating characteristics.

The fillet-weld tests (and the bead-deposit tests previously described) indicated that there was no difference in the quality of welds on pickled or grit-blasted plates. Plates in the as-received condition, with mill scale intact, had a noticeable but not important influence on the welding operation; the chief difficulty was in starting and maintaining the arc at low welding currents. This was true even for unpainted specimens. When normal or high currents were used, there was no difficulty in welding the as-received plates. On the basis of these observations, all subsequent tests were made on grit-blasted plates, because it was desired to avoid any extraneous and variable effects of the as-received plates which might mask the effects of the test paints, and because it was easier to grit blast the plates than to pickle them.

Furthermore, most subsequent tests were made with E6010 electrodes only, because the E6020 electrodes seemed to be less affected by the test paints (probably owing to the favorable downhand position used), and because the welds made with the E6011 and E6012 electrodes did not bring out any differences in the various paints which were not shown by the E6010 welds. In addition, the E6010 class was considered as being the most representative electrode for structural and ship welding.



(Group 1)

(Group 2)

(Group 3)

Group 1—Class P-1 piping. Class A-1 and A-2 pressure vessels, shafts, rotors and gears. Group 2—Class P-2 piping. Class A-3 pressure vessels, pumps and machinery subject to fatigue service or impact. Group 3—All machinery except as noted in Groups 1 and 2 above, hull castings, structural hull welds.

Fig. 4—Navy Department Bureau of Ships X Ray Standards for Production and Repair Welds, NAVSHIPS No. 250-692-2, August 1945

Effect of Paint Vehicles

To determine the possible influence of the paint binders or vehicles on welding, vertical fillet welds were made with $^5/_{32}$-in.-diam. E6010 electrodes in joints coated with about 2 mils of the unpigmented vehicles used in the various paints. The results indicated that the vehicles had no effect on the soundness of the weld metal, the weld appearance or the operating characteristics of the electrodes, even when present in quantities greater than those in paint coats of 1–3 mils.

Effect of Paint Pigments

To obtain fundamental information on the effects of various paint pigments on metal-arc welding, vertical fillet welds were made with $^5/_{32}$-in. E6010 electrodes on specimens coated with slurries of various pigments. Twenty-nine single-pigment and mixed pigment slurries, in a vehicle of ten parts mineral spirits to one part alkyd resin (glyceryl phthalate) solution, were tested. The average thickness of the dried slurry coatings was about 3 mils.

In the single-pigment tests, slurries containing lead compounds had detrimental effects in varying degrees. For example, lead sulphates (blue basic lead sulphate, white basic lead, sulphate) produced arc instability and poor-appearing and porous welds. Hot cracks were also observed in the roots of some of the welds (this was attributed to the sulphur in the pigment). White lead (basic lead, carbonate) litharge and red lead gave slightly better results, while lead chromate and lead silicate had the least effect of the lead compounds used.

Slurries of other single pigments affected welding or weld quality only slightly. Iron oxides had almost no effect, and zinc chromate, graphitic mica, zinc oxide, titanium dioxide and magnesium silicate only a slight effect, on the external appearance and soundness of the fillet welds. The welding characteristics of the E6010 electrodes, on plates coated with these slurries, were considered normal. Typical fillet welds on slurry-coated specimens are shown in Fig. 2.

The mixed-pigment slurries contained red lead as the base pigment, with various amounts of other pigments. The results of these tests indicated that all vertical fillet welds on plates coated with slurries containing 75% or more red lead had a poor porosity rating and poor external appearance. The arc characteristics were quite erratic and, in general, were the same as for specimens coated with a plain red lead slurry. The exception was a 75% red lead 25% iron oxide mixture, which did not cause excessive porosity in the weld and did not seriously affect the welding characteristics of the electrode. A decrease in the lead content of the slurries improved the quality of the welds, the degree of improvement was also influenced by the other pigments present. Hydrated iron oxide, iron oxide, zinc chromate and aluminum stearate seemed to have a beneficial effect; carborundum and pigments containing sulphates and carbonates had a detrimental effect.

Tests of Red Lead Mixed Pigment Paints

On the basis of the initial tests of paints and slurries, fourteen red lead mixed pigment paints, in most of which the red lead content of the pigment was less than 75%, and in which various proportions of other pigments were present, were used for further study.

Test plates were coated with 3 mils of all fourteen paints, and vertical fillet welds were made with $^5/_{32}$- and $^1/_4$-in.-diam. E6010 electrodes at normal and high welding currents (four test specimens for each paint). The evaluation of the influence of the paints on the welds was based, as before, on the ease of deposition of the weld metal, external weld appearance and weld soundness.

All fillet welds made with the $^5/_{32}$-in.-diam. electrodes and normal welding current were considered acceptable and, in general, were as satisfactory as welds made on unpainted plates and those coated with the Z1 and Z3 zinc chromate base paints. When high welding currents were used, several of the welds contained slightly more porosity, and the weld metal in some cases was more difficult to deposit. Only one paint in the group showed a definitely deleterious effect on operating characteristics during fillet welding; it contained 98% red lead in the pigment.

When $^1/_4$-in. electrodes and normal welding currents were used, some of the welds were not so good as those made with $^5/_{32}$-in. electrodes on joints coated with the same paints. This is partly attributable to the inherently poorer operating characteristics of the larger electrode in vertical welding. It was evident, however, that some of the lead base paints contributed to the poorer weld quality, because the welds on bare plates and on plates coated with the zinc chromate base paints were still satisfactory.

Figure 3 shows vertical fillet welds deposited with $^5/_{32}$-in. E6010 electrodes at normal current on unpainted steel, and on joints coated with 3 mils of red lead mixed-pigment paint L8, and zinc chromate base paint Z1. These welds were sound and of good external appearance, and were made with no particular difficulty with arc instability or weld-metal manipulation. The fillet weld on Paint L8, shown in Fig. 3, is typical of fillet welds made over some of the other red lead base paints (e.g., L9, L10, L11 and L12).

When $^1/_4$-in. electrodes were used with a high welding current, almost all of the fillet welds were rated as unacceptable. Since the welds on the unpainted plates,

Table 3—Strength of Weld Metal Deposited in Painted Groove Joints with E6010 Electrodes

Paint No.[a]	Yield Strength, Psi.	Tensile Strength, Psi.	Elong. in 2 In., %	Soundness Rating[b]
	Average Strength Properties			
	Flat Position Welds with $^5/_{32}$-In. Electrodes			
Bare	51,000	63,300	26	1
Specimens painted prior to first pass only:				
L1	50,000	64,000	19	[illegible]
L6	50,300	63,300	[illegible]	1
L7	53,000	[illegible]	[illegible]	1
Z1	52,300	66,000	[illegible]	1
Z3	53,300	65,300	24	1
Specimens painted prior to each pass:				
L1	52,300	[illegible]	19	[c]
L6	50,500	64,500	[illegible]	1
L7	56,000	71,500	17	1
Z1	54,300	[illegible]	[illegible]	1
Z3	54,300	66,000	..	1
	Vertical Position Welds with $^5/_{32}$-In. Electrodes			
Bare	54,000	61,800	24	1
Specimens painted prior to first pass only:				
L1	[illegible]	63,000	27	[illegible]
L6	[illegible]	[illegible]	[illegible]	1
L7	[illegible]	[illegible]	27	1
Z1	[illegible]	62,000	21	1
Z3	53,000	61,000	[illegible]	1
Specimens painted prior to each pass:				
L1	57,300	64,300	19	[illegible]
L6	[illegible]	63,500	15	[illegible]
L7	[illegible]	[illegible]	[illegible]	1
Z1	53,500	[illegible]	21	1
Z3	53,000	61,800	[illegible]	[illegible]

[a] Paint thickness approximately 3 mils.
[b] See X-ray Standard, Fig. 4.
[c] Porosity exceeding that of Group 3 standard.

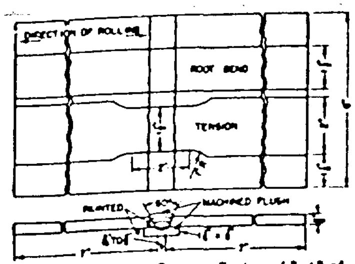


Fig. 5—Welded Plate for Transverse Tension and Root-Bend Tests

and on plates coated with the "Z" paints, were also poorer (chiefly increased porosity), the welding conditions were considered as unfavorable. Consequently, this series of tests was not considered in the over-all evaluation of paint effects.

These tests confirmed previous tentative observations that a clear-cut relationship between paint composition and its influence on welding could not be made. In general, pigments with red lead contents of 50 to 70% appeared to be satisfactory, and in the case of the multiple-pigment red lead base primers containing various amounts of zinc chromate, hydrated iron oxide or iron oxide, the performance of the paints during welding seemed to improve.

Correlation of the data from the vertical fillet weld tests of the red lead mixed-pigment paints indicated that half of them had satisfactory characteristics under a variety of welding conditions. Welds on plates coated with 3 mils of these paints were comparable in soundness, appearance and ease of deposition to welds on unpainted joints, and on joints coated with the zinc chromate base paints. Five of the red lead mixed-pigment paints (L8 to L12, inclusive, Table 1) were chosen for further study.

All-Weld-Metal Tension Tests

Concurrently with the initial fillet-weld tests, strength tests were made of weld metal exposed to several paints. The paints used were L1, L6, L7, Z1 and Z2. Groove welds for all weld metal tension tests were made on painted plates with E6010 electrodes, using the procedure set forth in A.W.S.-A.S.T.M. Specification A233-45T and Navy Department Bureau of Ships Specification 46E3 (12-1-41). One series of groove welds was made on plates with the groove faces, upper and lower surfaces and the backing strip painted with a 3-mil coat of the test paints. After the paint had dried, the grooves were welded completely (one set in the flat position with $^{3}/_{16}$-in. electrodes; another set in the vertical position with $^{5}/_{32}$-in. electrodes). Another series of groove welds was made on plates painted the same as above, but with additional paint applied after each pass (8-10 passes for flat welds, 6 passes for vertical welds). All welding was done with a preheat and interpass temperature of about 212° F. The specimens painted after each weld pass were held at 212° F. for an additional 10 min. between passes, to allow the paint to partially dry.

The quality of the weld metal was evaluated by radiographs and static tension tests, the results of which are shown in Table 2. The soundness was rated on the basis of the Navy Department X-Ray Standards (Fig. 4). Except for a single weld made on steel coated after each pass with the L1 high red lead base paint, the internal soundness of all welds was satisfactory, and was as good or better than that typified by Group 3, Fig. 4.

The results of the all-weld-metal strength tests show that none of the test paints, when applied to groove joints prior to the first pass only, had an effect on the strength of the weld metal. The soundness of these welds was classed as Group 2 or better. The weld-metal ductility met the specification requirement of 22% elongation in 2 in., except for one specimen coated with L1 paint. During welding of this specimen, the arc performance was erratic, and there was more porosity than in the other specimens.

The application of paint to a joint after each weld pass is obviously a laboratory expedient intended to create an extreme condition of exposure of weld metal to paint. The test results in Table 2 indicate that weld metal painted after each pass had the same strength, but somewhat lower ductility, and fractures of poorer appearance than weld metal in joints painted prior to the first pass only.

Transverse Tension Tests

Groove-Welded Butt Joints

Several groups of welded butt joints for transverse tension tests were made in the flat and vertical positions with $^{5}/_{32}$-in. E6010 electrodes, and in the flat position with $^{5}/_{32}$-in. E6020 electrodes. The weld specimen for these tests is shown in Fig. 5. The grooves and backing strips were coated with about 3 mils of red lead base paints L1, L6, L7, L8, L9, L10, L11 and L12, and zinc chromate base paints Z1 and Z2. For all welds, a preheat and interpass temperature of 200° F. was used, to obtain results more comparable to those of the all-weld-metal tension tests previously discussed. During welding, an evaluation was made of the influence of the paints on ease of deposition, arc stability, degree of fusion and penetration and tendency to undercut. These data were correlated with similar observations made during the vertical and horizontal fillet-weld tests, to obtain a more complete evaluation of paint effects.

Table 3—Transverse Tension Tests of Weld Joints Made with $^{5}/_{32}$-In. E6010 Electrodes on Painted Plates

Paint No.[a]	Yield Strength, Psi.	Tensile Strength, Psi.	Elong. in 2 In., %	Location of Fracture[c]	Soundness Rating[d]
	—Average Strength Properties[b]—				
		Flat Position Welds			
Bare	50,800	65,800	27	W, W, W, P	1
L1	50,000	62,000	13	W, W	2
L6	49,800	66,500	20	P, P	1
L6[e]	54,800	67,000	[f]	W, P	1
L7	49,500	66,000	27	W, P	1
Z1	48,500	66,800	31	W, P	1
Z2	50,800	67,000	30	W, P	1
		Vertical Position Welds			
Bare	45,700	61,600	31	P, P	1
L1	45,800	62,400	23	W, W	2
L6	46,100	60,800	27	W, P	1, 2
L9	45,200	61,700	20	W, P	2, 1
L10	44,000	61,200	25	W, P	2, 1
L11	43,500	58,800	22	P, P	2, 2
L12	45,700	61,700	18	W, W	2
Z1	44,200	62,800	27	W, P	2, 1
Z2	44,700	62,800	30	W, P	2, 1

[a] Paint thickness approximately 3 mils.
[b] Average, two tests.
[c] W, Weld metal; P, Plate.
[d] See X-ray standard, Fig. 4.
[e] Weld painted after every pass.
[f] Not measured.

Table 4—Transverse Tension Tests of Weld Joints Made with $^{5}/_{32}$-In. E6020 Electrodes in the Flat Position on Painted Plates

Paint No.[a]	Yield Strength, Psi.	Tensile Strength, Psi.	Elong. in 2 In., %	Location of Fracture[c]	Soundness Rating[d]
	—Average Strength Properties[b]—				
Bare	43,300	60,100	27	W, W	1
L1	43,000	60,600	16	W, W	2, 1
L6	42,200	61,200	26	W, W	1, 1
L8	42,200	61,800	30	W, W	2, 1
L10	41,800	60,700	30	W, W	2, 1
L11	43,100	60,200	26	W, W	1, 1
L12	43,100	61,000	28	W, P	2, 2
Z1	41,800	61,800	27	W, P	1, 1
Z2	42,700	60,800	31	W, P	1, 1

[a] Paint thickness approximately 3 mils.
[b] Average, two tests.
[c] W, Weld metal; P, Plate.
[d] See X-ray standard, Fig. 4.

The welded plates were radiographed, and specimens cut from them were tested in tension. The results are given in Table 3 for welds made with E6010 electrodes and in Table 4 for welds made with E6020 electrode. The tensile strength of the joints was not influenced by any of the paints in the thickness used. The "composite" elongation across the weld joint (measured on a gage length which included both weld metal and base metal) was generally satisfactory, except for somewhat low elongations in some of the specimens coated with L1 and L12 paints (99.7 and 75% red lead, respectively).

Figure 6 shows the root side of typical fractures in specimens welded vertically with E6010 electrodes. The specimens with the soundest weld metal (Group 1 quality) had the highest elongations and, when failure occurred in the weld metal, the cleanest fractures. Specimens with visible defects at the root, after the backing strip had been machined away, failed more often in the weld metal, but in several instances the fracture was in the base metal even though root defects were present.

The influence of the 3-mil paint films on ease of welding was most evident in the vertical welds, and was confined largely to the root passes, when the paint film was intact. No difficulty was encountered in the deposition of the upper weld passes, because most of the paint had been burned away during the welding of the root. The flat-position specimens were welded with very little difficulty.

A single weld specimen was tested in which a 3-mil coat of L6 paint was applied prior to each of the 4 weld passes required to fill the groove. This specimen was welded in the flat position with E6010 electrodes (see Footnote e, Table 3). During the deposition of the root pass, there was some trouble, but the paint on subsequent passes had surprisingly little influence on the welding. This is attributed to the increased width of the groove, for the upper passes, which facilitated manipulation of the electrode and the molten metal pool. The strength of this weld was equal to that of specimens painted only prior to welding; unfortunately, the elongation across the joint was not measured. The radiograph of the joint disclosed only a few scattered holes, mostly at the root, and the joint was classed as being of Group 1 quality.

In most of the above tests, the two welded plates required to obtain a pair of tension specimens were welded by different operators. Frequently, the plate welded by one operator was better than the similarly painted duplicate plate welded by the other operator. However, there was no over-all consistency in the relative quality of work of the two welders. That is, one operator produced the better plates on some paints, while the other operator produced the better plate of a pair on other paints. It was quite evident, all through this and other work, that the welding ability of the operators (all fully qualified under various specifications) was influenced in different degrees by a given paint.

Fillet-Welded Double-Tee Joints

To obtain information on the effect of paint on the strength of joints made with single-pass welds (the entire weld thus being subjected to the full influence of the paint) transverse tension tests were made on fillet-welded specimens, the design of which is shown in Fig. 7.

The parts of the assembly were painted with 3 mils of the test paints, tack welded together at the ends, and fillet welds "1" and "2" were made with $^{5}/_{32}$-in. E6010 electrodes, in the flat position. The first fillet was deposited on unaffected paint; the second fillet on paint

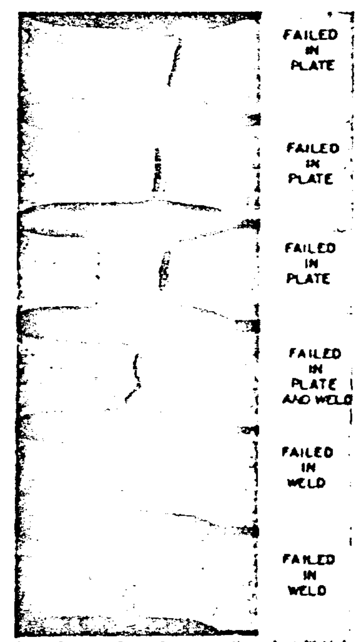


Fig. 6—Transverse Tension Specimens of Groove Joints Welded in the Vertical Position with E6010 Electrodes Illustrating Various Types of Failures

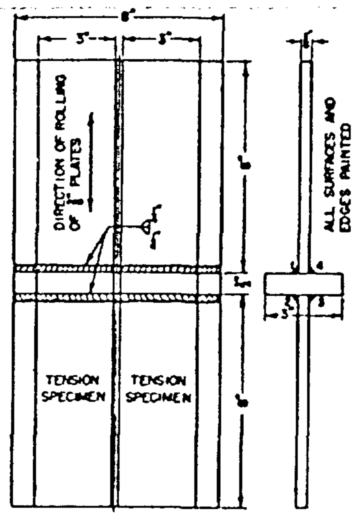


Fig. 7—Fillet-Welded Double-Tee Joint Specimen for Tension Tests

which was overheated and discolored and, in some cases, blistered or charred by the heat flowing through the $^1/_2$-in. cross plate. The remaining two corners were then brushed and repainted, and fillet welds "3" and "4" were deposited in flat position with $^5/_{32}$-in. E6010 electrodes.

The size of the fillets was maintained as closely as possible at $^1/_4$ in. This was done to obtain a joint not quite 100% efficient (according to accepted design specifications), since it was desired to produce failure in the weld, so that the possible effects of the paints could be detected. The welds were made in the flat position in order to obtain best control of fillet size, even though it was recognized that the influence of the paints might be more pronounced if vertical welds were used.

The results of the tests are given in Table 5. Some of the specimens failed in the plate, and some in the welds (either along a leg or through the throat of the fillet). The tensile strength is therefore given in pounds breaking load, rather than as pounds per square inch, because the initial area of the fracture varied with its location. Typical broken specimens are shown in Fig. 8. Most specimens that failed in the weld showed a distinct "necking" in the $^1/_2$-in. plate away from the joints. This indicates that these specimens had almost 100% joint efficiency.

All specimens had practically the same strength. The slightly lower breaking strength of the L1 specimen (94% of the average strength of all specimens) is not considered significant, because even in this specimen, necking of the $^1/_2$-in. parent plate took place. The results of the tee-joint tests support the findings of the previous strength tests, viz., that while difficulty may have been encountered

Table 5—Tension Tests of Fillet-Welded Double-Tee Joints Made with $^5/_{32}$-In. E6010 Electrodes on Painted Plates

Paint No.ᵃ	Averageᵇ Ultimate Load, Lb.	Location of Fracture
Bare	76,800	Plate
L1	70,700	Weld
L8	76,300	Weld
L9	76,800	Weld
L10	76,300	Plate
L11	75,400	Plate
L12	74,300	Weld
Z1	77,000	Plate
Z2	76,100	Plate

ᵃ Paint thickness approximately 3 mils.
ᵇ Average, two tests.

In welding over some paints, the strength of the weld metal and of the average welded joint was not appreciably affected by paint coats 2 to 3 mils thick. This was especially true when welds were made in the flat position.

Root-Bend Tests

In all of the strength tests previously discussed, the weld metal was either from the heart of the joint, with root metal removed (0.505-in. tension specimen), or was a cross section of the entire weld joint (transverse tension specimens from butt and tee joints). These tests demonstrated the strength properties that may be expected of joints which are subjected to simple static loads, with no localized overstressing.

The radiographs and weld fractures of welds on painted plates indicated that defects, caused by the influence of paints, were most likely to occur at the root of the weld. In this region, manipulation of the electrode is naturally

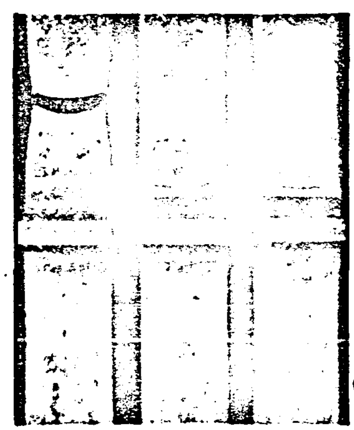
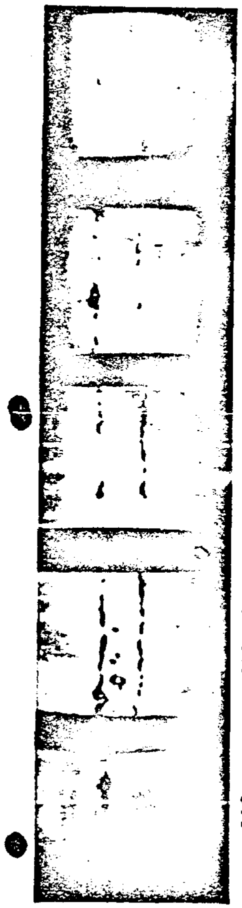


Fig. 8—Typical Tension Fractures of Fillet-Welded Double-Tee Joints

restricted (as in groove joints), or penetration is normally not deep (as at the root of most fillet welds); and the amount of fresh, uncharred paint is usually at a maximum.

To obtain more data on the properties of root weld metal which had been exposed to paint, specimens cut from single-V butt joints were bent in a standard guided-



Class A: Quality of weld and fusion at root are satisfactory. Soundness rating of these welds normally Group 1.

Class B: Quality of weld and fusion at root are satisfactory. Soundness rating of these welds Group 1 or 2.

Class C: Quality of the weld is satisfactory except for shallow but fairly continuous lack of fusion at root. Weld metal ductile, soundness rating Group 1 or 2.

Class D: Border-line weld quality; definite lack of root fusion and some porosity at root face. Soundness rating usually Group 2, occasionally Group 1 or 3.

Class E: Quality of weld unacceptable; excessive root defects. Soundness rating Group 2 or 3.

Fig. 9—Ratings of Root-Bend Tests

Table 6—Root-Bend and Soundness Ratings of Groove Welds in Painted Plates

Paint No.	Bendᵃ and Soundnessᵇ Ratings: Vertical Welds with $^5/_{32}$-In. E6010 Electrodes ᶜ	ᵈ	ᵉ	Flat Welds $^1/_4$-In. E6020 Electrodes ᶠ
Bare	A, A *1*	A, A *1*	A, A *2*	A, A *1*
L1	B, C *2*	B, B *2*	C, D *2*	C, C *2*
L6	D, F *2*	...	...	...
L7	A, C *2*	...	...	...
L8	C, C *2*	A, B *1*	B, D *1*	B, B *1*
L9	B, C *1*	A, D *2*	B, B *2*	D, D *2*
L10	D, E *2*	B, C *2*	C, D *2*	A, B *1*
L11	A, B *2*	C, E *1*	D, *2*	B, D *1*
L12	A, C *2*	B, B *2*	C, C *1*	A, A *1*
Z1	A, A *2*	A, B *2*	B, B *2*	B, B *2*
Z2	A, A *1*	A, B *1*	A, C *1*	A, A *1*

ᵃ Letters indicate bend-test ratings for duplicate specimens; see Fig. 9.
ᵇ Numbers in italics indicate X-ray soundness ratings; see Fig. 4.
ᶜ Paint thickness approximately 1 mil; root of groove $^3/_{32}$-in. wide; no preheat used.
ᵈ Paint thickness approximately 3 mils; root of groove $^3/_{32}$-in. wide; 200° F preheat.
ᵉ Paint thickness approximately 3 mils; root of groove $^1/_8$-in. wide; 200° F preheat.
ᶠ Paint thickness approximately 3 mils; root of groove $^1/_8$-in. wide; 200° F preheat.

bend jig* with the root of the weld on the tension side. The usual criterion of acceptability in this test, as used in the qualification of welding operators, is that no cracks larger than $^1/_8$ in. in major dimension shall develop on the tension side of the specimen when it is fully bent. This criterion was not used in the tests of welds made on painted plates, because it was incompatible with the criteria for X-ray acceptability, which are shown in Fig. 4. The root-bend test is primarily intended as a severe test of welders' skill and the weld metal has to be not only ductile, but virtually free of defects, at least near the tension surface, in order that the usual criterion of acceptability will be met. The X-ray standard permits the presence of a limited amount of porosity (depending on the class of service to which the weld will be put), and it is reasonable to assume that many welds of Group 3 or even Group 2 X-ray quality would fail in the guided-bend test, if some of the defects permitted by the X-ray standard were in the tension side of the specimen.

Therefore, the performance of the root-bend specimens of welds on painted plates was graded according to an arbitrary classification, in which the tolerance for weld-metal porosity (but not for gross lack of fusion or low ductility) was approximately of the same order as given in the X-ray standards. This arbitrary root-bend test standard is shown in Fig. 9.

The specimens for the root-bend tests were taken either from the welded plates used for transverse tension specimens (Fig. 5), or from similar plates welded especially for root-bend specimens. The welds were made in the vertical position with $^5/_{32}$-in. E6010 electrodes, and in the flat position with $^1/_4$-in. E6020 electrodes. The groove dimensions were the same for all welds, but a wider root opening ($^1/_8$ to $^3/_{16}$ in.) was used with the E6020 electrodes. The plates and backing strips were grit blasted and painted with 1 to 3 mils of several types of red lead base (both high and reduced red lead content) and zinc chromate base paints. The welded plates were radiographed, and specimens then removed and machined for the bend test.

The test results are given in Table 6. Without exception, all of the welds had acceptable radiographic ratings

* Refer to A.W.S. Standard for Guided Bend Test, Welding Handbook, 1942 (1942).

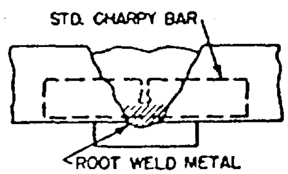


Fig. 10—Location of Charpy Bars in Weld Joint

(Group 2 or better). The soundest welds were those made on unpainted plates, and on plates coated with one of the zinc chromate base paints. The specimens painted with the red lead base paints, and with another of the zinc chromate base paints, had an average soundness of Group 2. The welds made in the flat position with E6020 electrodes were generally sounder than the vertical welds made with E6010 electrodes. The majority of defects disclosed by the radiographs, and by subsequent bending, were at the root of the weld.

The bend tests indicated that all of the weld metals had good ductility, even though some of the bent specimens had moderately large or extensive root fissures (bend rating D) or breaks (bend rating E). The cracks or breaks were induced by the presence of root defects, such as slag entrapment and incomplete fusion; away from these defects, the weld metal showed adequate ductility.

The most satisfactory root bends were obtained with unpainted specimens, and with the specimens coated with Paint Z2. Satisfactory bend results, based on the standard shown in Fig. 9, were also obtained with most of the specimens painted with the red lead base paints. In general, the appearance of the tension (root) side of the bend specimens could be correlated with the degree of soundness shown by the radiographs. Of the 25 specimens with an "A" bend rating, 24 were of Group 1 or Group 2 soundness, with Group 1 predominant. Of the 21 specimens with a "B" bend rating, 19 were in Group 1 or Group 2, with Group 2 predominant. Most of the specimens with "C," "D" and "E" bend ratings had a soundness rated as Group 2.

The root-bend tests indicate that for most of the paints tested, some root defects can be expected in welds on painted plates, and particularly in welds made in the vertical position. While these defects are usually not serious, and do not influence the tensile strength of the joints, the broad conclusion is that where superior root-metal quality is required, the joint should be unpainted, or only very thin coats of paint should be used.

Notched-Bar Tests

In view of the mounting interest in the notched bar properties at various temperatures of welds and weld joints, a brief series of notched bar tests was made on specimens taken from welds made on painted plates.

The welds were made in the flat position with ⁵⁄₃₂ in. E6010 electrodes, in 60° single V grooves in ¾ in. steel plate, with a root opening of ⅛ in. and mild steel backing strip. One plate was welded in the unpainted condition; the grooves and backing strips of other plates were coated with about 3 mils of L1, L8, L9, L10, L11 and L12 red lead base and Z1 and Z2 zinc chromate base paints.

Most of the radiographs of the welded plates indicated a soundness of Group 1; the joints coated with L1 and L11 paints were of Group 2. Most of the defects present in the latter were small, and concentrated in the root weld bead near the toes of the original bevels.

Standard Charpy bars were cut transversely to the weld joints, with the weld metal at the center of the bar, and with the keyhole notch so located that the metal beneath the notch was principally that of the root weld bead (Fig. 10). The bars were tested at temperatures ranging from +80° F. to −80° F.

The results, shown in Fig. 11, indicate that the notched-bar strength of the weld metal was not influenced by the presence of the various test paints. The scatter in energy-absorption values at any given temperature is within normal limits, and no significance is attached to the *relative values for different paints at the same temperature*. The decrease in notched-bar strength that begins at about 0° F. and below is characteristic of the type of weld metal tested, as shown by the values for the unpainted specimens, and is not caused by the influence of the paints on the weld metal.

Summary

This paper described the results of tests to determine the effects of several types of red lead base and zinc chromate base priming paints on the quality of metal-arc welds in plain-carbon structural steel. Various types of joints, coated with 1 to 10 mils of paint, were welded in the flat, horizontal, or vertical position with several types of mild-steel electrodes. The influence of the paint on welding was evaluated by observations of the ease of welding, by radiographic inspection of welds for internal defects, and by tension, bend and Charpy tests of weld joints.

In general, all of the paints tested had a noticeable, and sometimes detrimental, effect on the ease with which welds could be made. This effect varied with the position of welding, the type of electrode, the composition of the paint and increased markedly with the thickness of the paint film. It also varied from welder to welder; more highly skilled operators had less difficulty than did other welders with less experience with painted surfaces, but this difference was not consistent.

Although clean steel surfaces free from mill scale provided the best conditions for welding, a 3-mil coat of the red lead mixed-pigment paints and the zinc chromate base paints gave very little trouble (though the influence of the paint was noticeable) in the making of welds, even in the vertical position.

Red lead base and zinc chromate base paint films not exceeding a dry film thickness of 3 mils had no significant effect on the tensile strength of weld metal, groove-welded butt joints, and fillet-welded tee joints, nor on the notched bar properties of weld metal in the range +80° F. to −80° F. Except for a few isolated specimens, the soundness of the welds was satisfactory for all paints tested, and *within the acceptable limits for weld porosity* given in the Navy Department X-Ray Standards for Production and Repair Welds.

The strength, ductility and soundness of the welds depended more on the ability of the welder to overcome the interference of the paint film, than on the direct effect of the paint on the weld metal. The influence of paint was most evident in vertical welding, and was confined largely to the first weld pass. After the first pass in multiple-pass welds, the paint was badly charred or burned away, and most of the residue was removed during scaling or wire brushing in preparation for the next pass.

The most pronounced effects of paint on weld quality were the porosity and occasional incomplete fusion at the bottom edges of the root pass in groove welds, and incomplete penetration at the *root of fillet* welds. These defects were usually minor in character. They were more in evidence with the red lead base paints, but were usually overcome by reducing the paint film thickness, and through the skill of the welder.

The root bend tests of welds on painted plates showed rather erratic results and, in general, were inferior to tests of welds on unpainted plates. Root bending magnified the influence of localized defects on weld-joint strength, and it might be concluded that to avoid such defects, in weldments where top-notch quality is required, the use of priming paints should be avoided or limited. However, the root bend tests described in this investigation did not give sufficiently consistent data from which definite conclusions could be drawn, and it is believed that more extensive tests of this kind need to be made.

Satisfactory welds were made on steel coated with 1- to 2-mil films of paints having a high red lead content in the pigmentation, but adverse effects of these paints on weld metal deposition and quality became evident as the film thickness increased, as the welding current decreased and when welding was done in the vertical position. The red lead mixed-pigment paints were found to overcome *these restrictions to a very large degree, and the tests* reported here suggest that, in thicknesses up to 3 mils, they can be satisfactorily used as priming coats under most welding conditions. However, since all the paints, regardless of composition, behaved like other surface contaminants, it appears desirable to limit priming coats to the minimum thickness consistent with ease of application of the paint, proper coverage of the steel surface and good workmanship in welding.

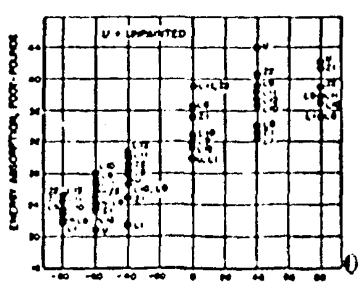


Fig. 11—Notched Bar Tests of Weld Metal Deposited in Painted Groove Joints with E6010 Electrodes

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