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O T T A W A   November 13th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1532.

Examination of Welds Cut from Compressed Air Reservoirs, C Mk. 1A (E. Leonard & Sons, London, Ontario).

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(Copy No. 10.)

Bureau of Mines
Division of Metallic Minerals
-
Ore Dressing and Metallurgical Laboratories

CANADA

DEPARTMENT OF MINES AND RESOURCES

Mines and Geology Branch

O T T A W A November 13th, 1943.

REPORT

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Origin of Material:

On October 6th, 1943, Mr. H. R. Frizzle, of the Gun Production Branch, Department of Munitions and Supply, Ottawa, Ontario, submitted samples of welds from compressed air reservoirs. These welds are at the top and bottom of the reservoirs, joining the top and bottom heads to the main body of seamless piping. These reservoirs were made by Messrs. E. Leonard and Sons, London, Ontario.

The Department of National Defense Spec. No. 4/9/15 E states that the steel is to conform to B.S.S. 15 specification and is to be fabricated by the arc welding process. The drawing of the reservoir requires that the joints to be welded shall be bevelled to a 60° included angle and also specifies a 1/8" root gap to permit complete penetration.

(Continued on next page)

(Origin of Material, cont'd) -

A letter (November 2nd, File No. 4/21/7/G&C/RES) from Mr. Paul R. McGrath of the Inspection Board of the United Kingdom and Canada, Hamilton, Ontario, gives the following additional information:

> The welding is done with a Westinghouse "Flex Arc" D.C. machine operated on reverse polarity and using hollop "Sure Weld" type B electrodes. The welds examined in this investigation are reported to be made in three passes, the first with 1/8"-diam. electrodes and the second and third with 3/16"-diam. electrodes. It is further stated that the welding machine has an automatic control set to hold 300 amperes and 550 volts constant welding conditions.

The working pressure of the reservoirs is 1,800 pounds per square inch (p.s.i.). After fabrication, they are submitted to a hydraulic stretch test by the "water jacket" method, using a 3,000-p.s.i. pressure. Subsequently they are subjected to a 2,000-p.s.i. interior gas pressure test. Any leakers on this test are rejected.

Object of Investigation:

To examine the welding of the reservoirs as typified by the samples and to submit recommendations for improvement if necessary.

Procedure:

(1) All samples were submitted to an x-ray examination at the National Research Council. Figures 1 to 8 are reproductions of the exographs. In examining these reproductions it should be borne in mind that there is an inevitable loss of sensitivity in the reproduction process.

(2) Figure 9 and Figure 10 are photographs of the samples as received. Samples from top weld are lettered A, B, C, and D, and those from bottom weld are lettered E, F, G, and H. Also indicated on the samples are the locations from which micro-samples were removed.

(3) Macro samples were machined from areas in which the x-ray examination reveals typical defects. Figures 11 and 12 show the samples after polishing and etching.

(Continued on next page)

(Procedure, cont'd) -

(4) Figure 13 shows the coarse-grained structure adjacent to weld in Sample A, and Figure 14 is the banded structure of the tube remote from the weld of Sample A. Figure 15 is the fine-grained structure adjacent to weld of Sample C. Figure 16 is a typical normalized structure of the tube remote from the weld of Sample C.

(5) A micro sample from weld of Sample A was normalized at 1600° F. for 30 minutes in spent carburizer. Figure 17 shows the structure in the same area as Figure 13, after normalizing. Figure 18 shows the structure in the same area as Figure 14, after normalizing. Note the change brought about by normalizing.

(6) A chemical analysis of the tube gave the following results, compared to the specified analysis:

		Analysis Obtained	Specified Analysis
		- Per cent -	
Carbon	-	0.16	0.15-0.25
Phosphorus	-	0.006	0.05 max.
Sulphur	-	0.028	0.05 max.
Manganese	-	0.53	0.30-0.60
Silicon	-	0.19	0.01-0.02

Discussion:

As is shown by the exographs, the welding defects are numerous and of a serious nature. This is confirmed by the macro and micro samples. The defects found (see Figures 11 and 12) are lack of penetration, lack of fusion, entrapped slag, high piled-up welds, and improper alignment of edges to be welded.

In the majority of cases the penetration secured does not exceed 50 per cent, the figure being based on the thickness of the thinnest section. This is the result of ignoring the specified 1/8" root gap. As shown by the macro samples, the root gap has varied from zero to 1/8". Where the

(Discussion, cont'd) -

proper root gap has been used the specified angle of bevel (60° included angle) had been ignored. The function of the 1/8"-root gap is to permit complete penetration of the molten weld metal.

Samples from the top weld show two passes (Sample C) and others from the same weld only one pass (Sample B). It would appear that this is the result of the use of a small diameter electrode in the root pass to secure improved penetration and to cope with variations in root gap. This points to an irregular technique varying considerably from that stated to be used.

High piled-up welds are common, apparently in an attempt to mask defects known to be present or to provide additional strength. It is a common belief that this added weld metal enhances the strength of the weld, whereas the complete reverse is actually the case.

To summarize, all defects found act as stress raisers and, as such, materially reduce the impact strength of the welds at all temperatures and particularly at low temperatures. Since in service the reservoirs may be subjected to low-temperature impacts, the welding is definitely considered to be unsatisfactory. Since the operating pressure is 1,800 p.s.i., these reservoirs are defective and their use is dangerous in the extreme.

Although all samples were stated to have come from the same reservoir (No. 712), it is apparent from the micro-structures that such is not the case. Some have been removed from a normalized reservoir and some from "as-welded" reservoirs.

The chemical analysis conforms to the specified analysis except that it is killed steel rather than rimmed. This would have no effect on the weldability of the steel.

The operating conditions during welding that are

(Discussion, cont'd) -

outlined in Mr. McGrath's letter are obviously in error. It would be impossible to weld using the electrode sizes specified at such high amperages. Probably the 550 voltage figure comes from the input of line voltage.

The electrode used conforms to the A.W.S. E 6010 specification and should be satisfactory for this type of welding.

CONCLUSIONS:

1. As evidenced by the nature and the frequency of the defects found, the welding technique employed is open to strong criticism and there is room for great improvement.

2. The defects are of such a nature as to act as stress raisers arising from a notch effect. These seriously reduce impact strength at all temperatures and would be particularly serious at low temperatures.

3. Improper alignment of welded plate edges indicates faulty assembly.

4. It is evident that drawing requirements for edge preparation have not been followed; some edges show no bevelling at all and others are bevelled to a point.

5. The root gap specified is designed to permit complete penetration. It is apparent that this has not been consistently followed.

6. The samples examined have not all been cut from the same reservoir.

7. The welds are mainly made in one pass, not in three passes as stated.

8. Should the samples submitted be representative of the welding of a large number of reservoirs, all should be rejected. In the event that there is a possibility that these samples are not representative, salvage should be attempted by means of an x-ray examination. If this is not practicable,

(Continued on next page)

(Conclusions, cont'd) -

all reservoirs should be rejected.

Recommendations:

1. The edge preparation specified, if followed, would permit production of a good weld. It is recommended that these instructions be rigidly followed.

2. The welding technique outlined in Mr. McGrath's letter, if actually used, would greatly improve the welding. It is recommended that this practice be followed.

3. Welders should be required to identify their own work and should be informed that random checks would be made from time to time on the quality of the welds produced. This would deter individual welders from employing welding techniques known to be unsatisfactory.

4. The sections to be welded should be rigidly jigged to permit accurate alignment of edges to be welded.

5. Every effort should be made to secure the specified root gap to permit complete penetration.

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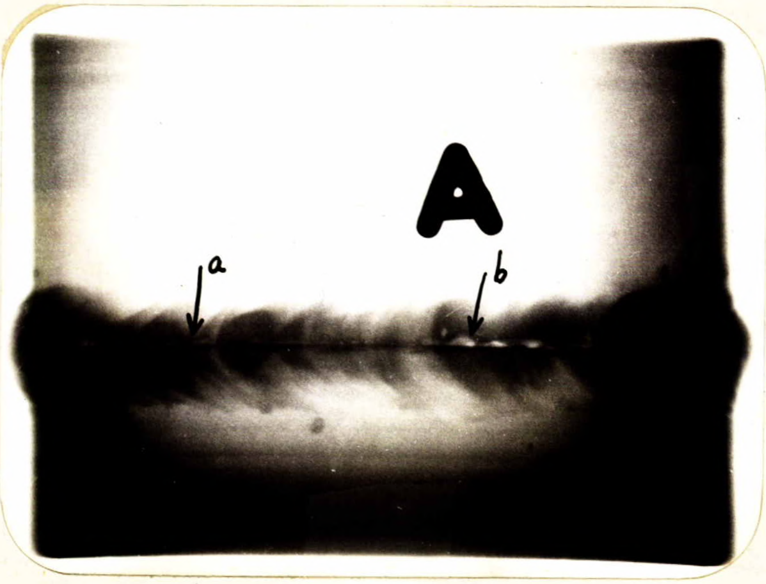
Figure 1.



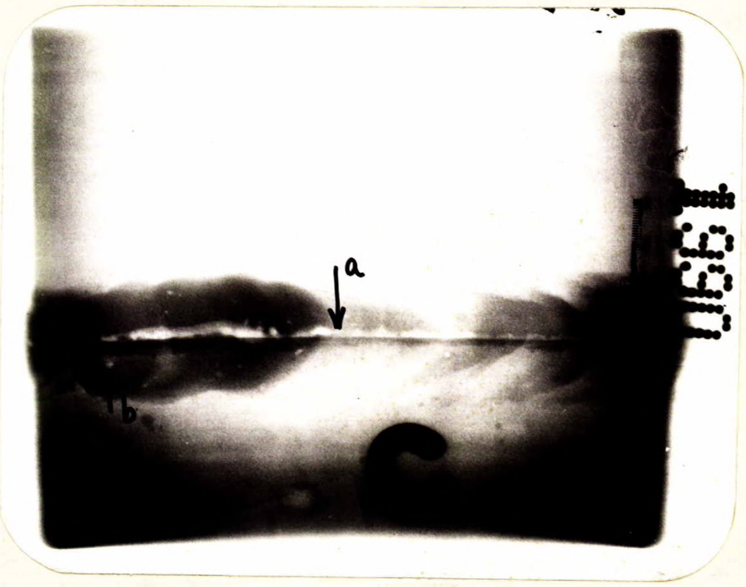
SECTION A - TOP WELD.

Figure 2.

SECTION B - TOP WELD.

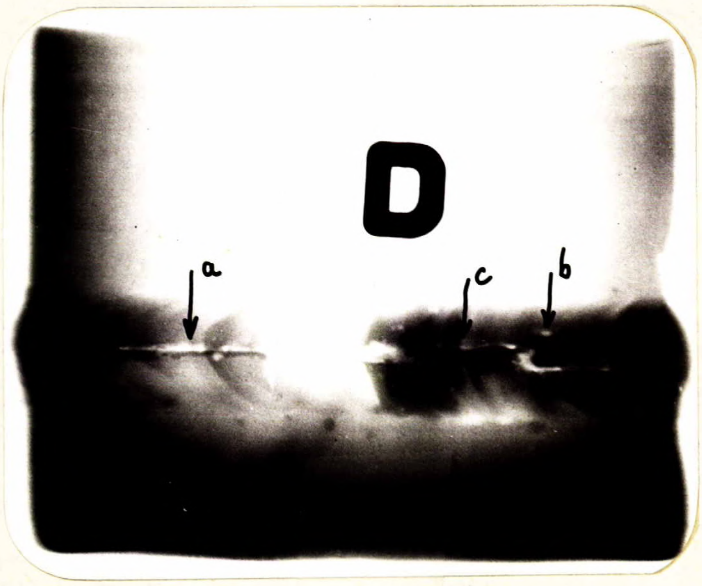
Legend:
a - lack of penetration.
b - entrapped slag.
c - lack of fusion.

Figure 3.



SECTION C - TOP WELD.

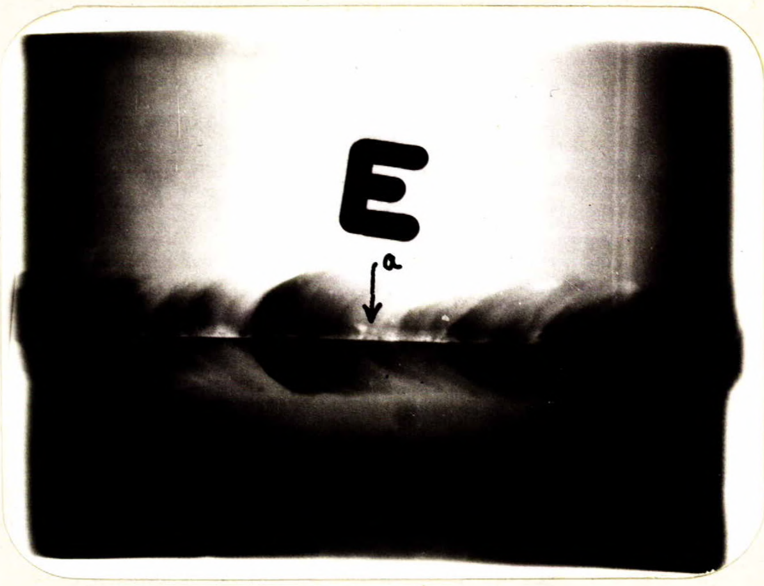
Figure 4.



SECTION D - TOP WELD.

(Legend:)
(a - lack of penetration.)
(b - entrapped slag.)
(c - lack of fusion.)

Figure 5.



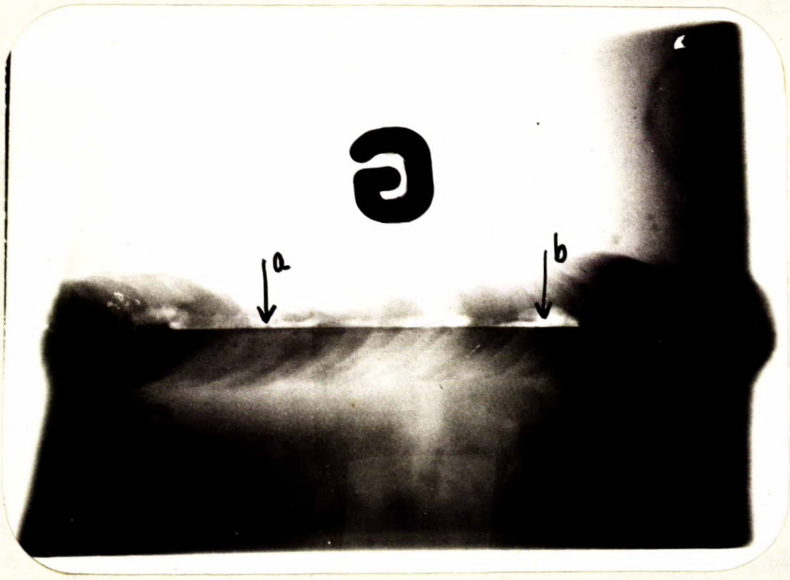
SECTION E - BOTTOM WELD.

Figure 6.

SECTION F - BOTTOM WELD.

(Legend:
a - lack of penetration.
b - entrapped slag.
c - lack of fusion.)

Figure 7.



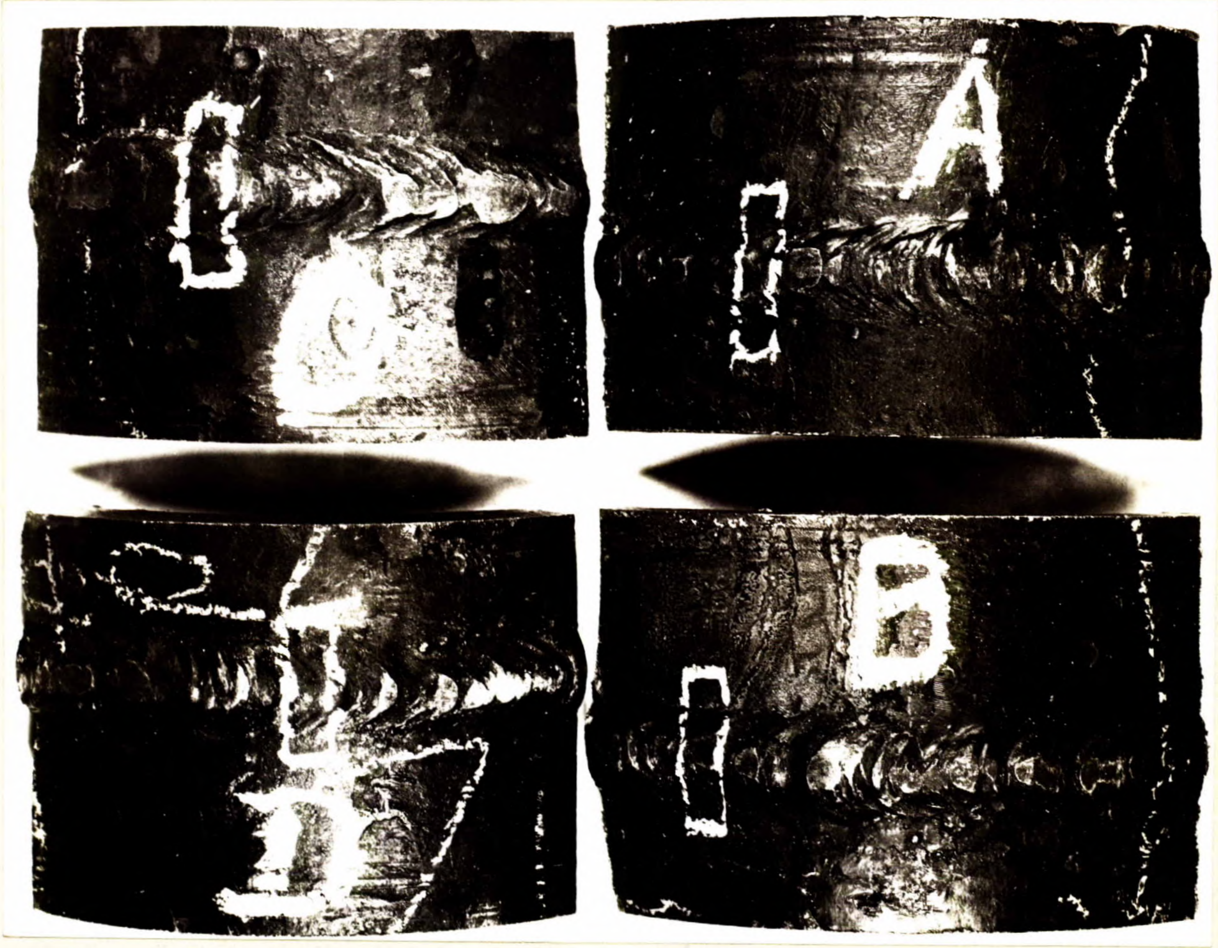
SECTION G - BOTTOM WELD.

Figure 8.

SECTION H - BOTTOM WELD.

Legend:
a - lack of penetration.
b - entrapped slag.
c - lack of fusion.

Figure 9.



SAMPLES A, B, C, and D - TOP WELD AS RECEIVED.

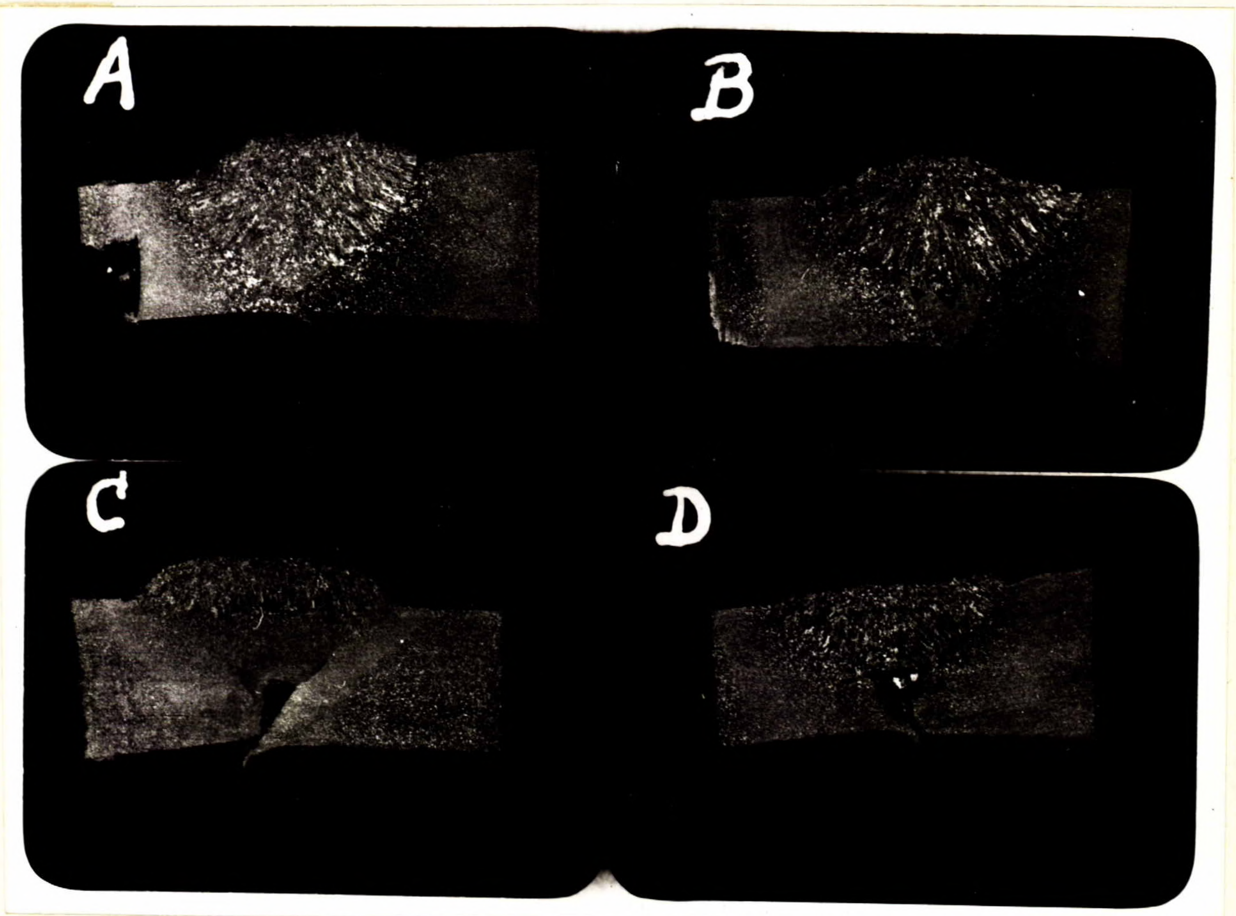
Note high piled-up welds. White rectangles indicate areas from which macro samples were machined.

Figure 10.

SAMPLES E, F, G and H - BOTTOM WELD AS RECEIVED.

Note high piled-up welds. White rectangles indicate areas from which macro samples were machined.

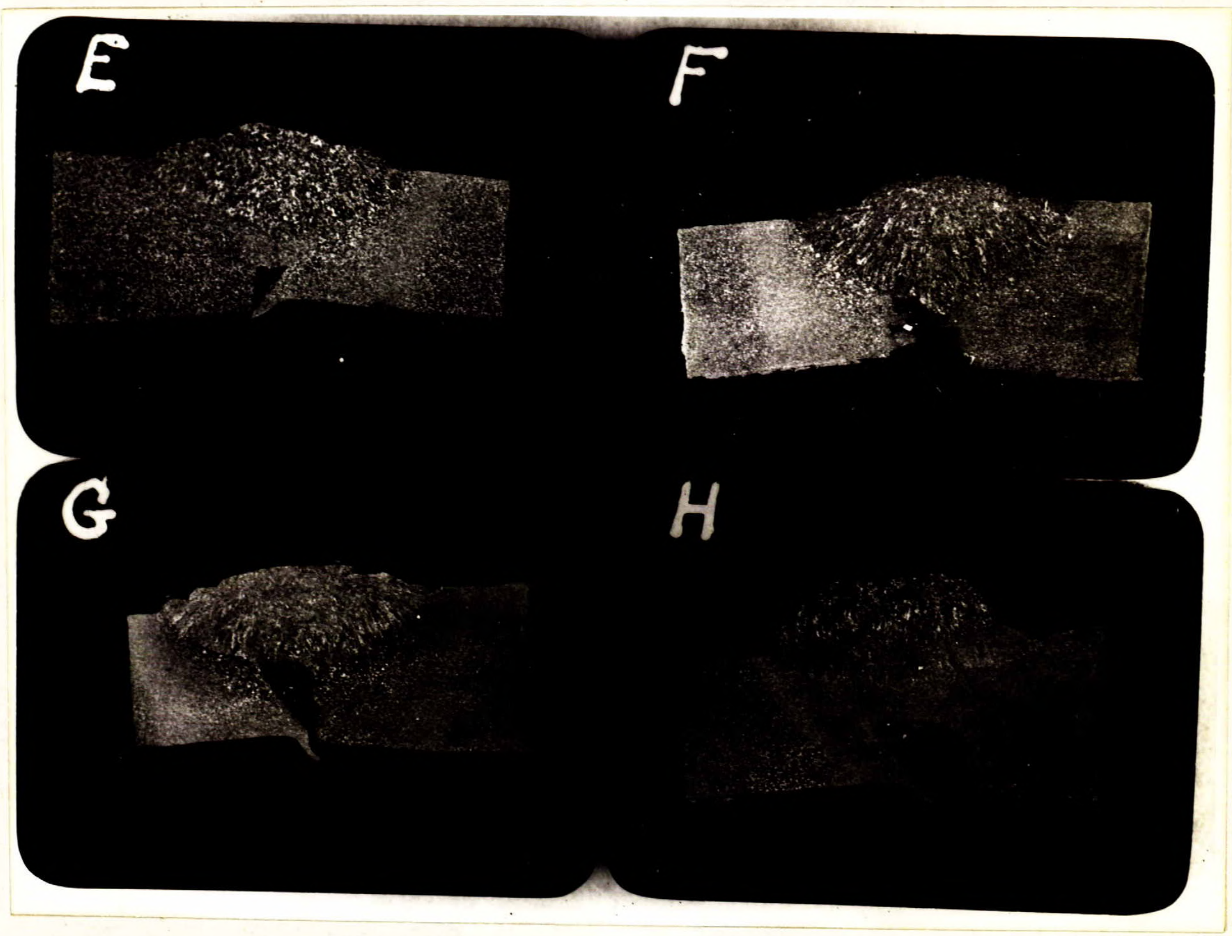
Figure 11.



MACRO SAMPLES OF TOP WELD.

Note incomplete penetration, slag inclusions, and lack of fusion. Note also varying number of passes.

Figure 12.



MACRO SAMPLES OF BOTTOM WELD.

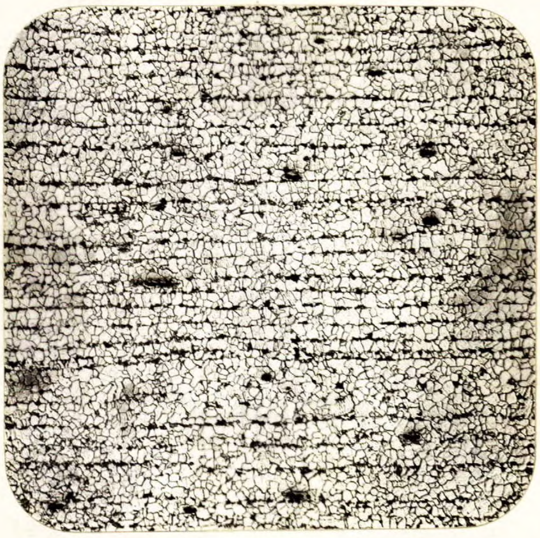
Note incomplete penetration, slag inclusions, and lack of fusion. Note also variations in root gap.

Figure 13.

X100, etched in 2
per cent nital.

SECTION A; COARSE-GRAINED STRUCTURE ADJACENT TO WELD.

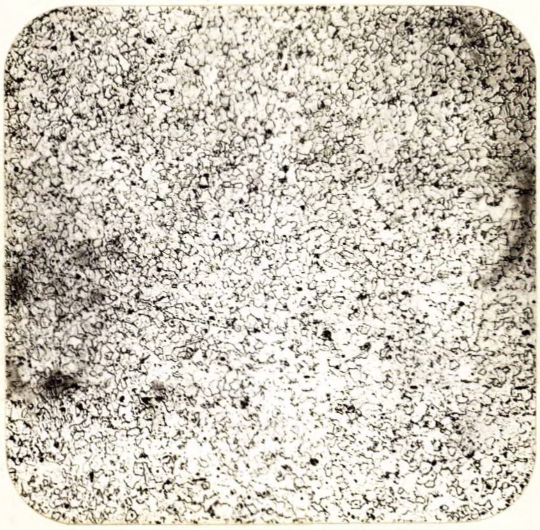
Figure 14.



X100, etched in 2
per cent nital.

SECTION A; FINE-GRAINED BANDED STRUCTURE TYPICAL
OF HOT-ROLLED STEEL IN AREA REMOTE FROM WELD.

Figure 15.

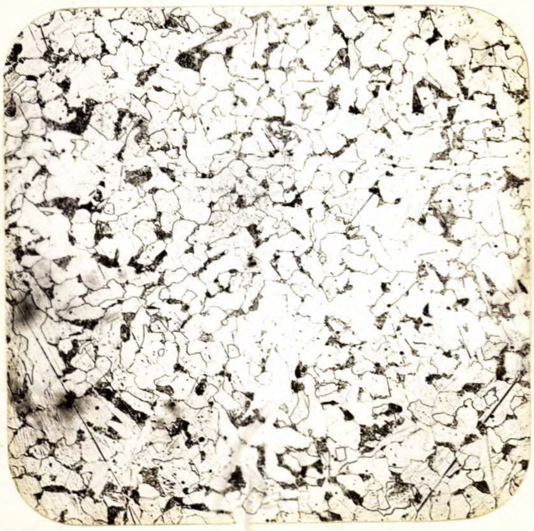


X100, etched in 2
per cent nital.

SECTION C; FINE-GRAINED STRUCTURE ADJACENT TO WELD, INDICATING NORMALIZING TREATMENT.

Compare with Figures 13 and 17.

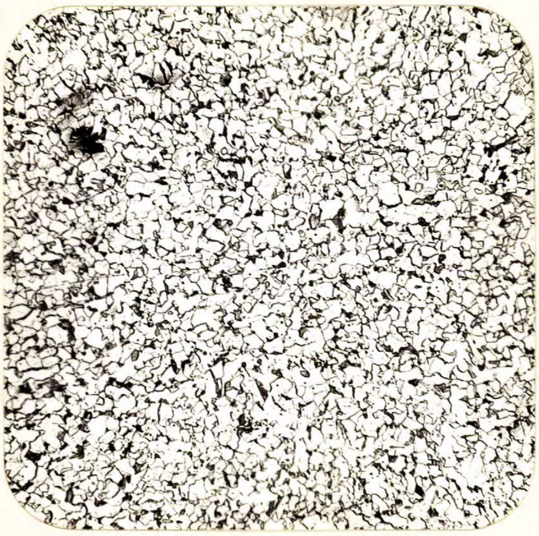
Figure 16.



X100, etched in 2
per cent nital.

SECTION C; NORMALIZED STRUCTURE OF PIPING REMOTE FROM WELD.

Figure 17.

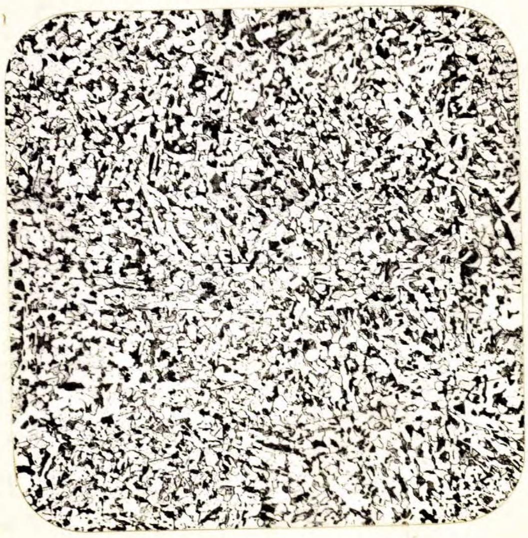


X100, etched in 2
per cent nital.

SECOND SECTION FROM SAMPLE A; STRUCTURE OF PIPING ADJACENT TO WELD AFTER NORMALIZING AT 1600° F. FOR 30 MINUTES.

Compare with Figure 13.

Figure 18.



X100, etched in 2
per cent nital.

SAME SAMPLE AS ABOVE; STRUCTURE OF PIPING REMOTE FROM WELD AFTER NORMALIZING AT 1600° F. FOR 30 MINUTES.

Compare with Figure 14.

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