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O T T A W A November 25th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1540.

(Subsequent to Report of Investiga-)
(tion No. 1532, November 13th, 1943)

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

(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

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Introduction:

In November, 1943, examples of welds cut from these air reservoirs (made by E. Leonard & Sons, London, Ontario) were submitted, for examination, by Mr. H. R. Frizzle of the Gun Production Branch, Department of Munitions and Supply, Ottawa, Ontario. It was found that these samples contained numerous serious defects, such as lack of penetration, lack of fusion, high piled-up welds, improper alignment, and entrapped slag. In the report covering this investigation (Investigation No. 1532, dated November 13th, 1943), photographs of these defects were shown and their probable cause and recommendations for elimination were given.

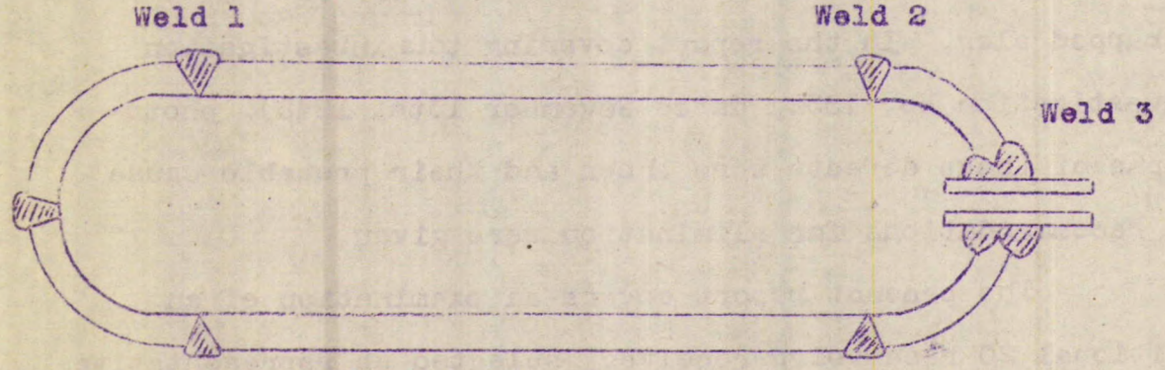
The present report covers an examination of an additional 20 reservoirs received, selected as representative of the welding done prior to approximately October 15th (Group 1, 15 samples) and within the three weeks between October 25th and November 18th (Group 2, 5 samples). It is shown that the welding is, if anything, worse than that of the original samples.

Origin of Material:

On November 13th, 1943, Mr. Paul R. McGrath, on behalf of Mr. Ian McMillan, Inspector of Carriages, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, submitted 20 reservoirs for examination. These reservoirs were identified as follows:

GROUP 1. (Welded prior to approximately October 15th, 1943.) Reservoir No.	GROUP 2. (Welded between October 25th and November 15th, 1943.) Reservoir No.
C 2166	C 246
C 1585	C 928
C 1608	C 300
C 984	C 1013
C 1630	C 313
C 1609	
C 1052	
C 1759	
C 230	
C 258	
C 285	
C 210	
C 422	
C 491	
C 428	

For convenience, the welds were numbered as in the sketch below:



Mr. McGrath also submitted, for examination, exographs of each of the welds of the 20 cylinders and written reports covering the interpretation of the exographs.

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Object of Investigation:

To examine the welding of these reservoirs as typified by the samples.

PROCEDURE:

(1) All exographs were carefully examined and checked against the interpretation reports submitted. Reproductions were made of the exographs of two reservoirs of the first group and one of the last. These were selected as showing typical defects. In examining these reproductions it should be borne in mind that there is an inevitable loss of sensitivity in the reproduction process and that the colours are the reverse of those shown by an exograph. Figures 1 to 10 show the reproductions.

(2) All samples were visually examined. Samples representative of those showing defects visible on the surface were photographed. Figures 11 to 16 indicate the types of defects found.

(3) From the exographs, samples were chosen from each group which showed typical defects. These samples were sectioned and polished. Figures 17 to 22 are photographs of these sections.

(4) The above sections were examined under the microscope. It was found that some had been normalized after welding and some had not. Figure 23 shows a structure of weld metal of a section which has not been normalized. Figure 24 shows a structure of weld metal of a normalized section. Note the considerable difference between these structures.

DISCUSSION:

As shown by the exographs, the defects are continuous, numerous, and of a serious nature. This is confirmed by macro and micro examinations. The defects found (See Figures 1-23) are

(Discussion, cont'd) -

lack of penetration, lack of fusion, entrapped slag, scattered porosity, undercutting, high piled-up welds, "burn through" and weld metal icicles, and improper alignment of edges to be welded.

The defects found and their probable causes are listed below:

(1) Lack of penetration, partly due to too low welding current but mainly due to insufficient root gap and the use of too large an electrode in the root pass.

(2) Lack of fusion, partly due to too low welding current but mainly due to improperly cleaned scarf faces.

(3) Entrapped slag, too low welding current and improper pass sequence.

(4) Porosity, partly due to too long arc length or excessive welding current.

(5) Undercutting, due to either too long an arc length or excessive welding current.

(6) Burn through and icicles, due to either excessive welding current or to too wide a root gap.

(7) High piled-up welds, due to effort to mask welding defects or to the erroneous belief that the weld strength is thereby increased.

(8) Improper alignment, due to inaccurate measurement and preparation of parts to be fitted together.

It will be noted that all of the above defects would be easy to eliminate by the use of well-known welding principles and techniques. It is apparent, from the frequency and nature of the defects, that they are the product of inexperienced welders making to a faulty pattern.

As in the previous report, it is clear that the root gap specified has not been used. Macro samples show root gaps varying from zero to well over $\frac{1}{4}$ inch. In addition, welds have been made with varying numbers of passes, showing that no regular technique has been employed. It is our understanding that Welds 1 and 2 should be made in three passes, but actually

(Discussion, cont'd) -

anywhere between one and three passes have been used. Weld 3, supposedly made in five passes, has been made in three passes.

Of the twenty cylinders examined, three show a fourth weld which is a plug weld in the base of the reservoir. This weld is not shown on the drawing or referred to in the specification. As shown by Figures 10, 16, and 21, this weld exhibits the same types of defects as all the other welds and should not be permitted.

All defects found act as stress raisers and, as such, materially reduce the impact strength at all temperatures and particularly at low temperatures. This being the case, the welding is considered to be decidedly unsatisfactory.

According to specification, all reservoirs are to be normalized after welding. As in our previous examination, some reservoirs were found to be normalized and some were in the "as-welded" condition.

It is our opinion that the reservoirs are defective and would be exceedingly dangerous to use.

CONCLUSIONS:

1. As shown by our two investigations, welding defects are frequent and of a serious nature. The welding technique is open to strong criticism and is decidedly unsatisfactory.

2. The defects are of such a nature as to act as stress raisers due to the notch effect. This would seriously reduce impact strengths at all temperatures and particularly at low temperatures.

3. Misalignment of plate edges indicates faulty assembly.

4. Drawing requirements in regard to bevelling, root

(Conclusions, cont'd) -

gap, welding sequence, etc., have not been followed.

5. Plug welds (present, although not allowed in specification or drawing) show the same defects as the other welds and their use should be rigorously forbidden.

6. In some cases, root gaps far in excess of that allowed on drawing have been used. This has resulted in "burn through" and weld metal icicles.

7. If the reservoirs submitted for examination are representative of reservoirs going into use, accurate checks should be made to ensure that all are normalized as required by specification. Two investigations have shown that not all reservoirs are being normalized.

8. It is our opinion that these reservoirs should not be put to field use. Should reservoirs be in use they should be recalled and rigorously examined before returning to use.

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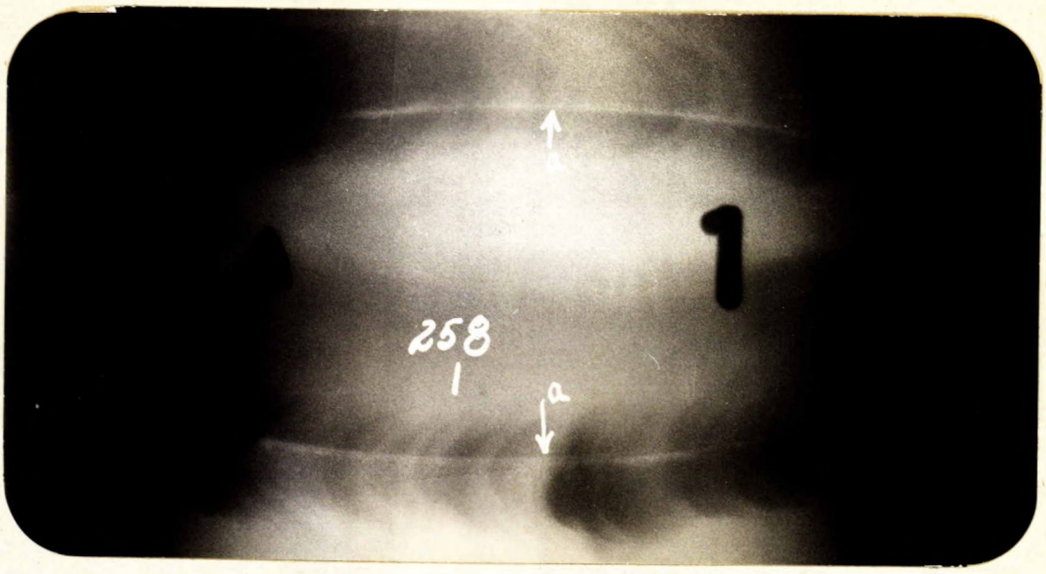
HJN:GHB.

Figure 1.



GROUP 1: RESERVOIR NO. C 258, WELD 1.

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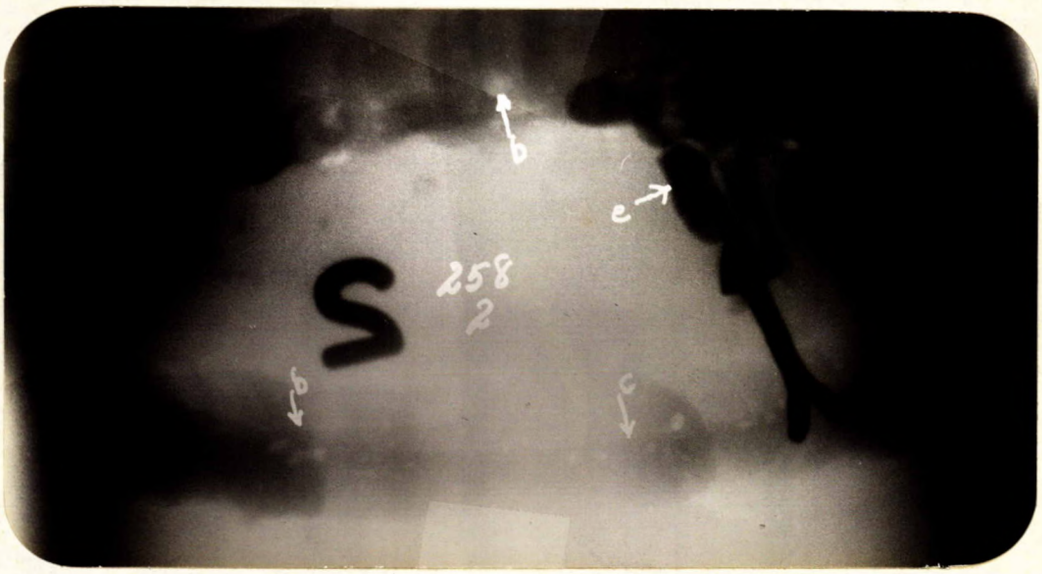
Figure 2.



GROUP 1: RESERVOIR NO. C 258, WELD 2.

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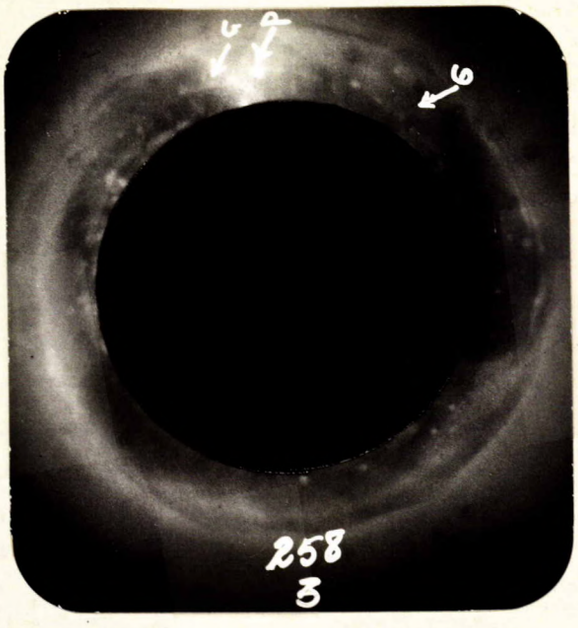
(Legend: a = lack of penetration.
b = entrapped slag.
c = lack of fusion.
d = porosity.
e = weld metal icicles.)

Figure 3.



GROUP 1: RESERVOIR NO. C 258, WELD 3.

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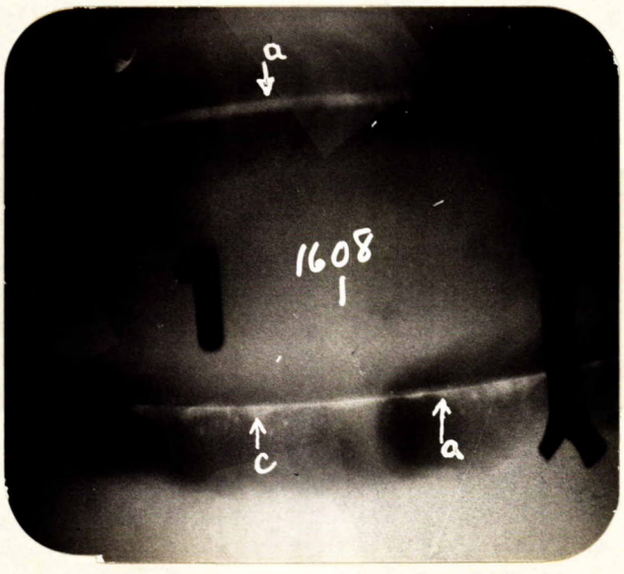
Figure 4.



GROUP 1: RESERVOIR NO. C 1608, WELD 1.

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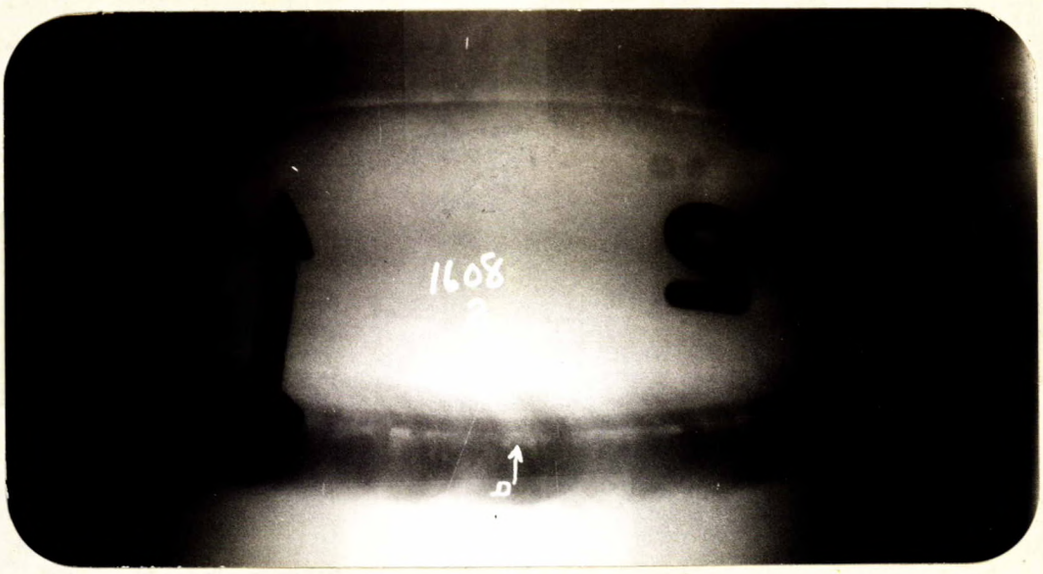
(Legend:	a	= lack of penetration.)
(	b	= entrapped slag.)
(	c	= lack of fusion.)
(	d	= porosity.)
(	e	= weld metal icicles.)

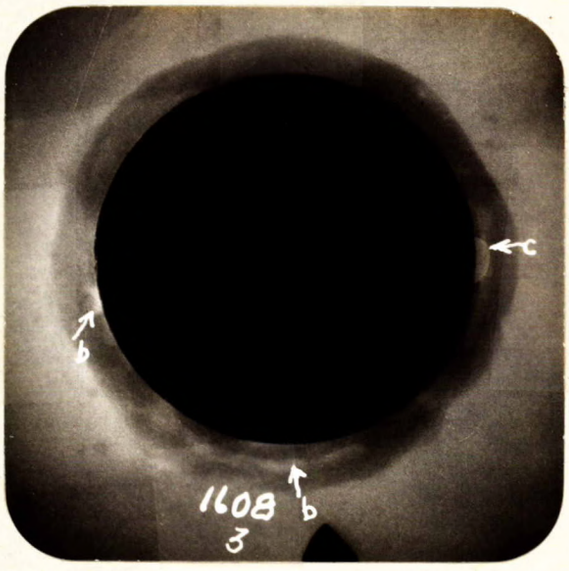
Figure 5.



GROUP 1: RESERVOIR NO. C 1608, WELD 2.

—

Figure 6.

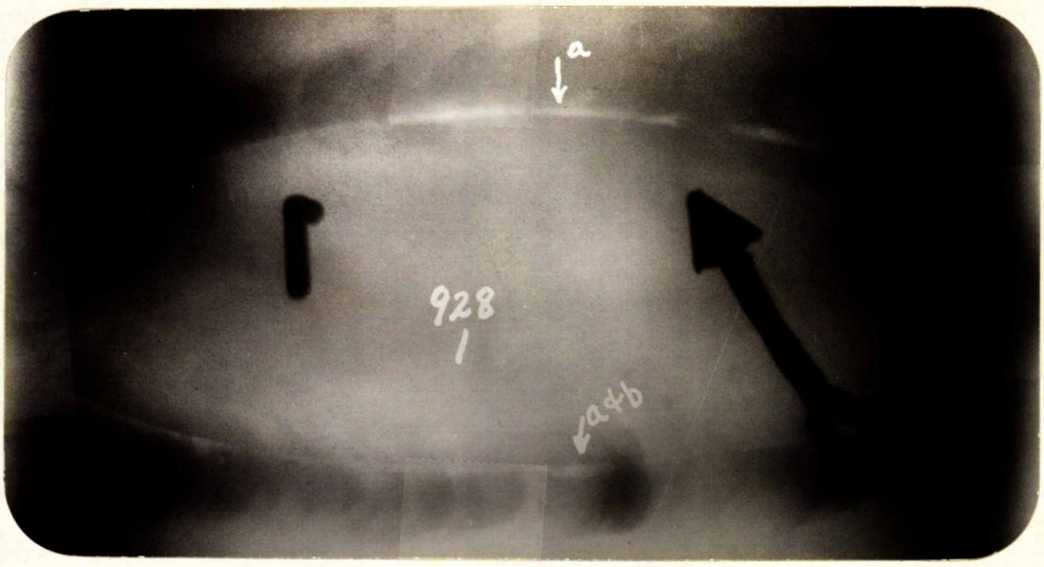


GROUP 1: RESERVOIR NO. C 1608, WELD 3.

—

(Legend: a - lack of penetration.
b - entrapped slag.
c - lack of fusion.
d - porosity.
e - weld metal icicles.)

Figure 7.



GROUP 2: RESERVOIR NO. C 928, WELD 1.

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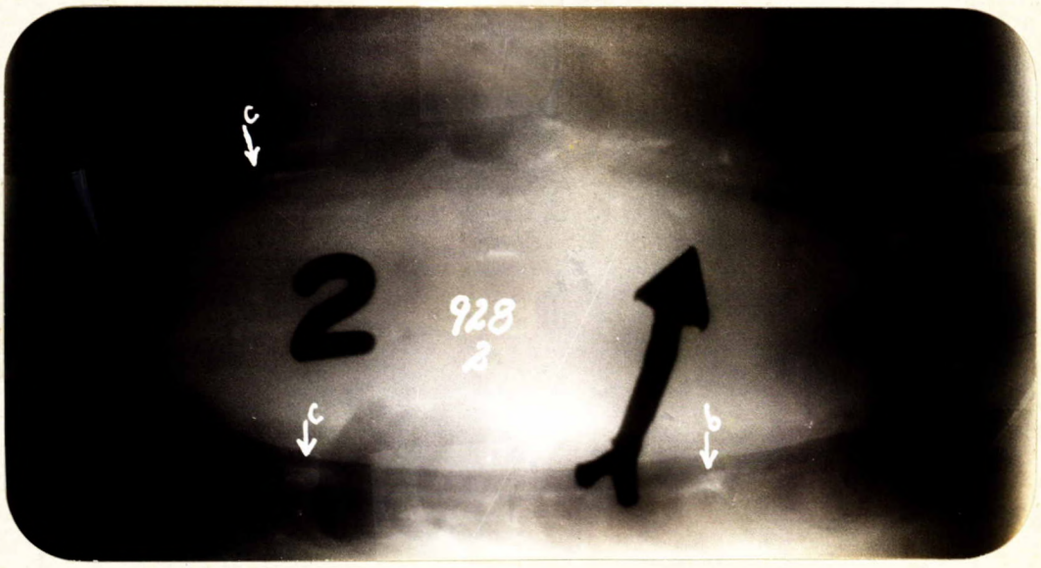
Figure 8.



GROUP 2: RESERVOIR NO. C 928, WELD 2.

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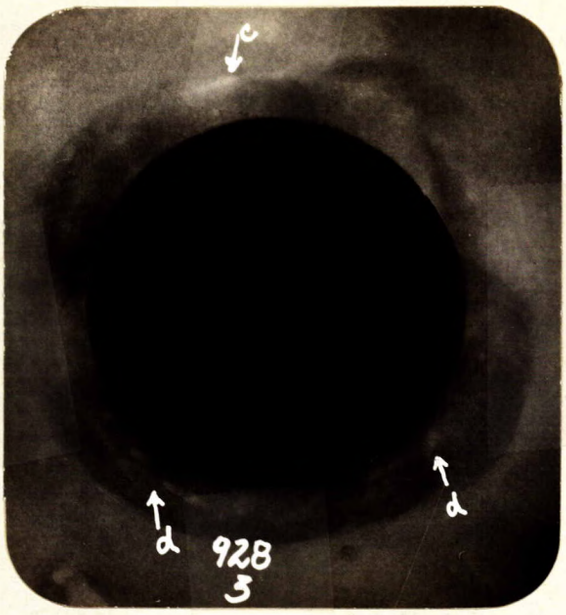
(Legend: a = lack of penetration.
b = entrapped slag.
c = lack of fusion.
d = porosity.
e = weld metal icicles.)

Figure 9.



GROUP 2: RESERVOIR NO. C 928, WELD 3.

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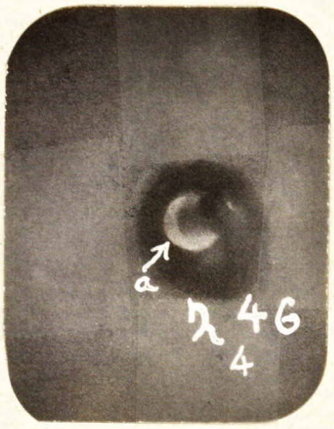
Figure 10.



GROUP 2: RESERVOIR NO. C 246, WELD 4.

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(Legend: a - lack of penetration.
b - entrapped slag.
c - lack of fusion.
d - porosity.
e - weld metal icicles.)

Figure 11.

GROUP 1: RESERVOIR NO. C 258, WELD 2.

Photograph of outside of weld. Arrow points to a high piled-up weld. White rectangle shows location of micro sample.

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Figure 12.

GROUP 1: RESERVOIR NO. C 258, WELD 2.

Photograph of inside of weld shown above. Note weld metal icicles and porosity at right cut edge.

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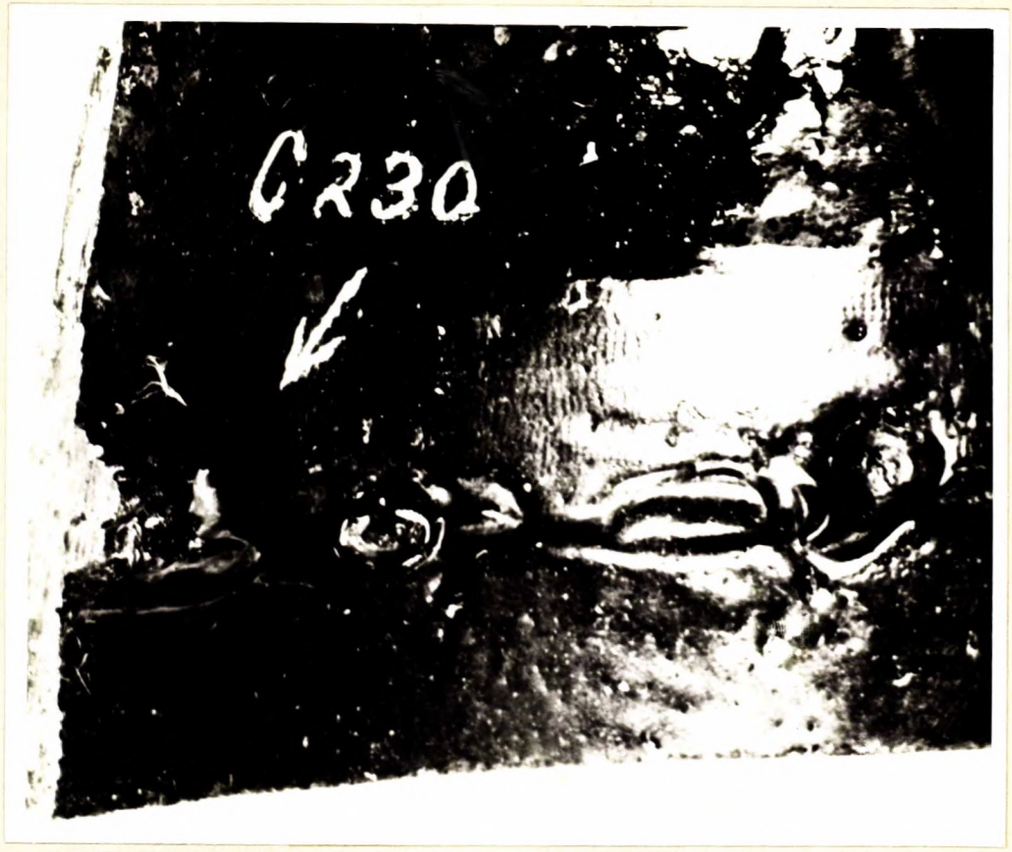

GROUP 1: RESERVOIR NO. C 230, WELD 1.

Photograph of inside of weld. Arrow points to weld metal icicles.

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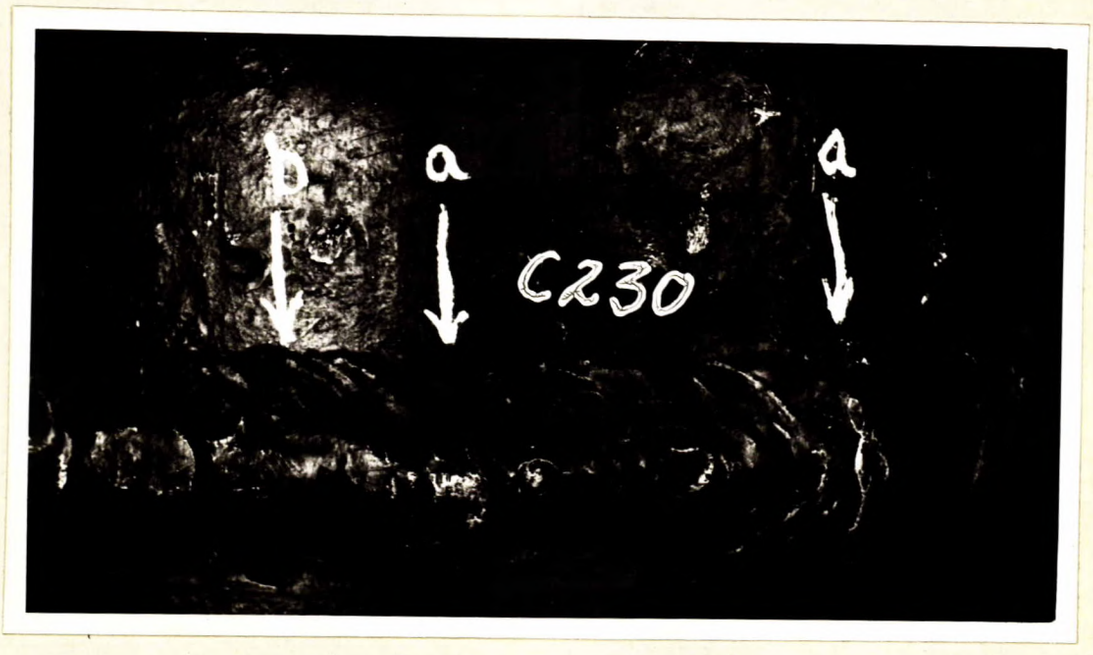
Figure 14.



GROUP 1: RESERVOIR NO. C 230, WELD 1.

Photograph of outside of weld shown above. Note irregular weld contour. Arrow points to areas of undercutting.

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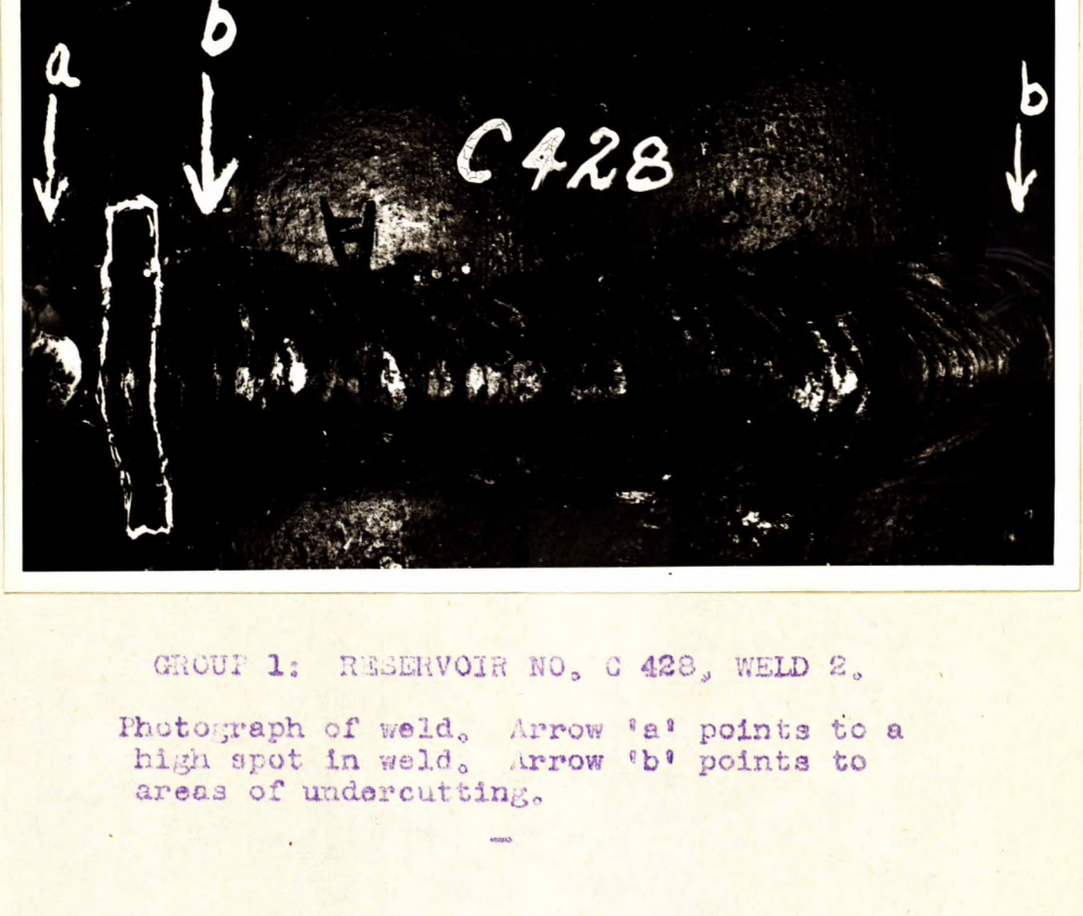
Figure 15.



GROUP 1: RESERVOIR NO. C 428, WELD 2.

Photograph of weld. Arrow 'a' points to a high spot in weld. Arrow 'b' points to areas of undercutting.

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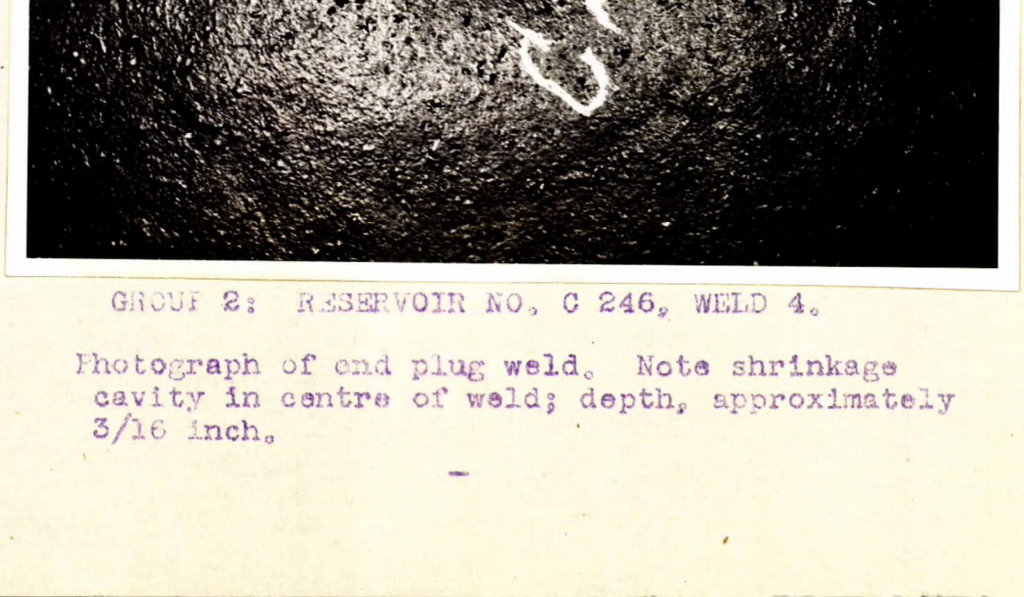
Figure 16.



GROUP 2: RESERVOIR NO. C 246, WELD 4.

Photograph of end plug weld. Note shrinkage cavity in centre of weld; depth, approximately 3/16 inch.

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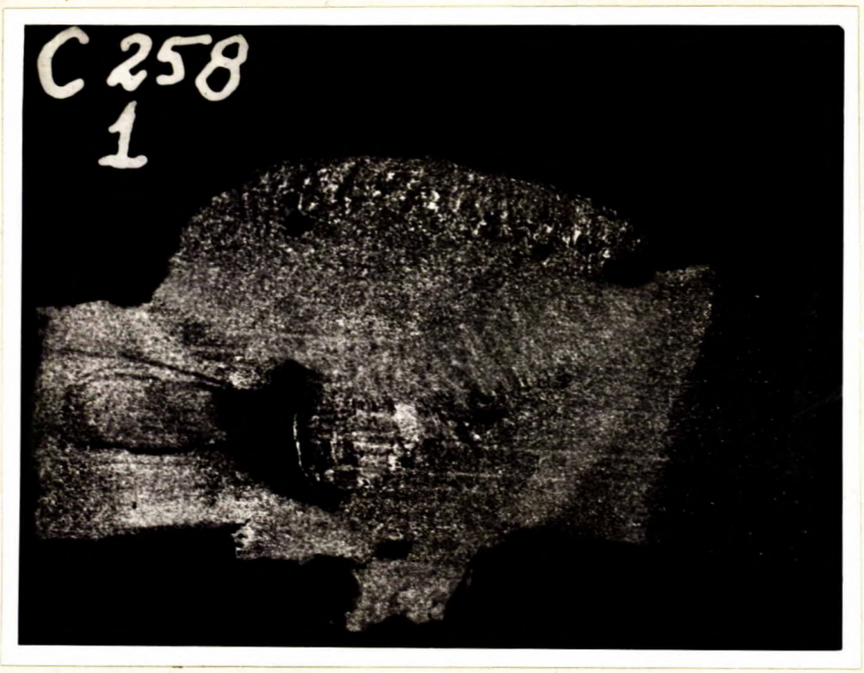
Figure 17.



X3.5, etched in 5 per cent nital.

GROUP 1: RESERVOIR NO. C 258, WELD 1.

Note undercutting, high piled-up weld, scattered porosity, slag entrapment, lack of fusion, and weld metal icicles. Note also wide root gap. A three-pass weld.

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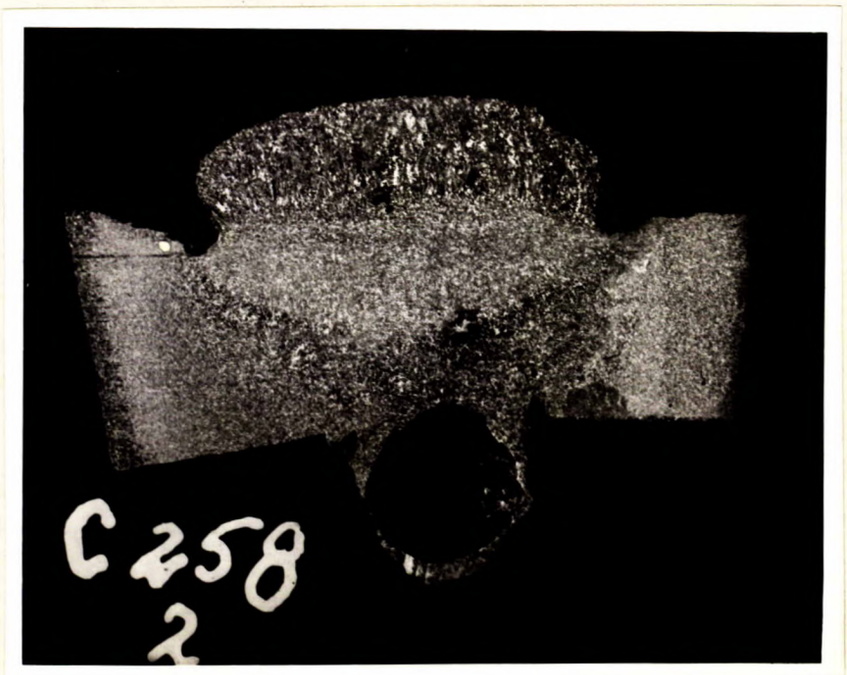
Figure 18.



X3.5, etched in 5 per cent nital.

GROUP 1: RESERVOIR NO. C 258, WELD 2.

Note high piled-up weld, severe undercutting, porosity, weld metal icicles, and wide root gap. A three-pass weld.

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Figure 19.

X3.5, etched in 5 per cent nital.

GROUP 1: RESERVOIR NO. C 258, WELD 1.

Note high piled-up weld, excessive porosity and slag, lack of fusion, weld metal icicle, and wide root gap. A three-pass weld.

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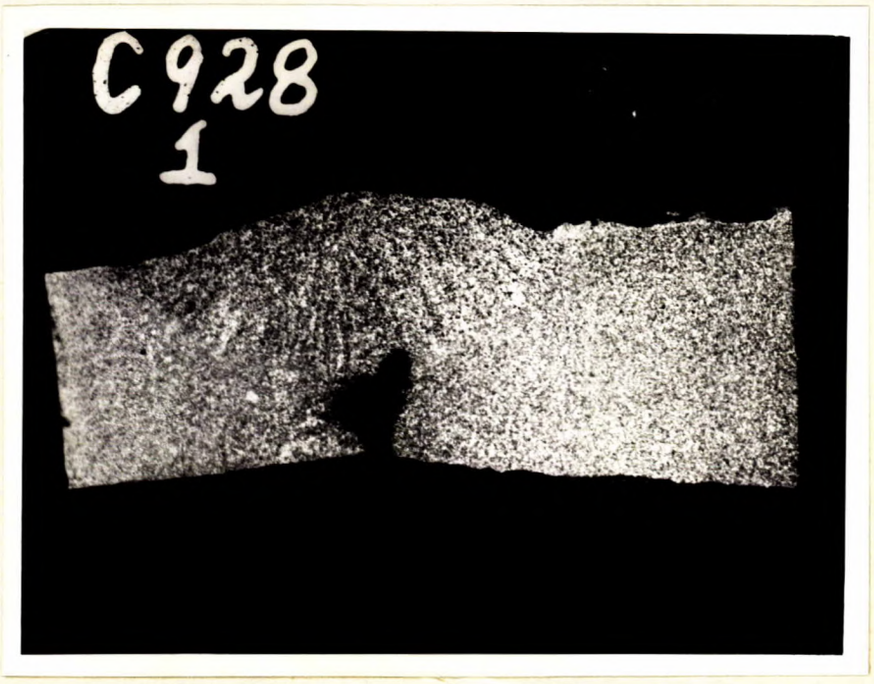
Figure 20.



X3.5, etched in 5 per cent nital.

GROUP 2: RESERVOIR NO. C 928, WELD 1.

Note lack of penetration; also narrow root gap. A one-pass weld.

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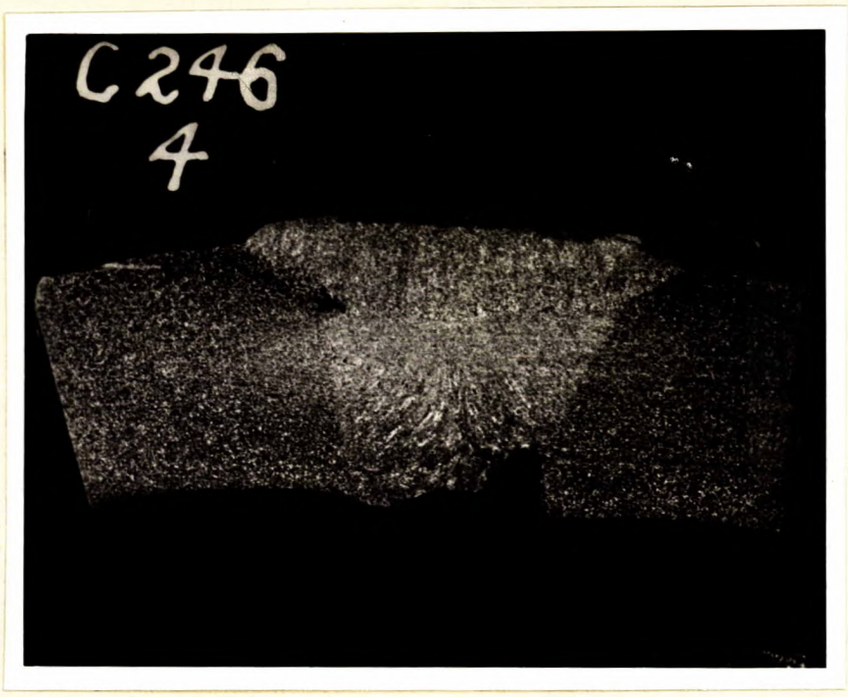
Figure 21.

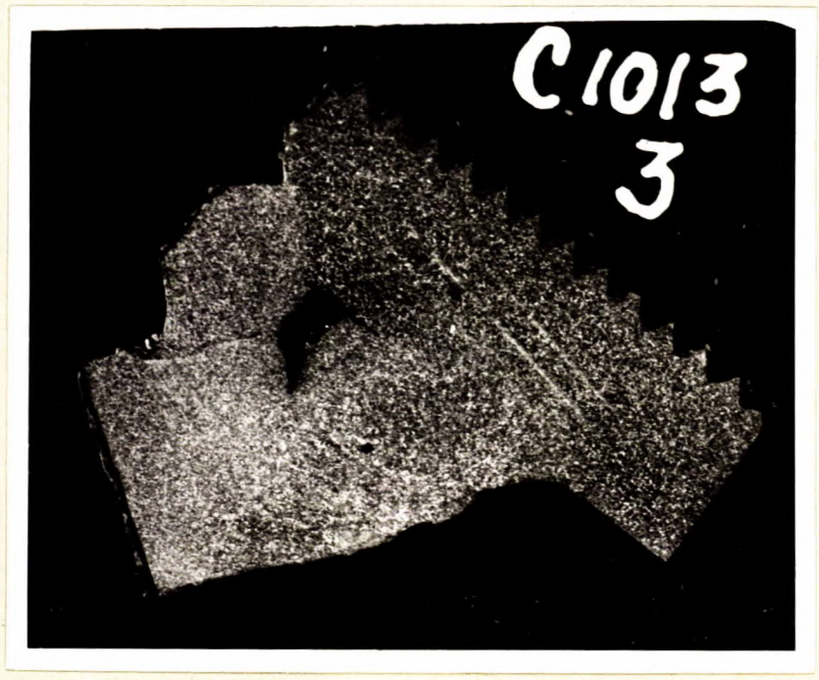


X3.5, etched in 5 per cent nital.

GROUP 2: RESERVOIR NO. C 246, WELD 4.

Note slag entrapped and lack of penetration. A two-pass weld.

Figure 22.



X3.5, etched in 5 per cent nital.

GROUP 2: RESERVOIR NO. C 1013, WELD 3.

Note lack of penetration and also slag entrapment. A three-pass weld.

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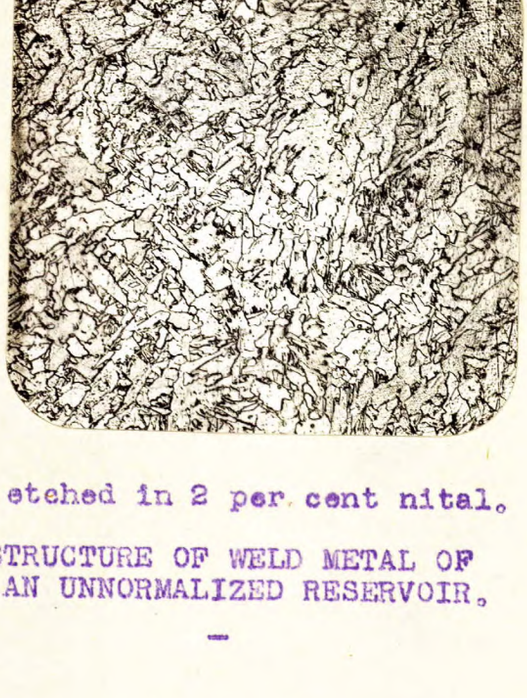
Figure 23.



X100, etched in 2 per cent nital.

STRUCTURE OF WELD METAL OF
AN UNNORMALIZED RESERVOIR.

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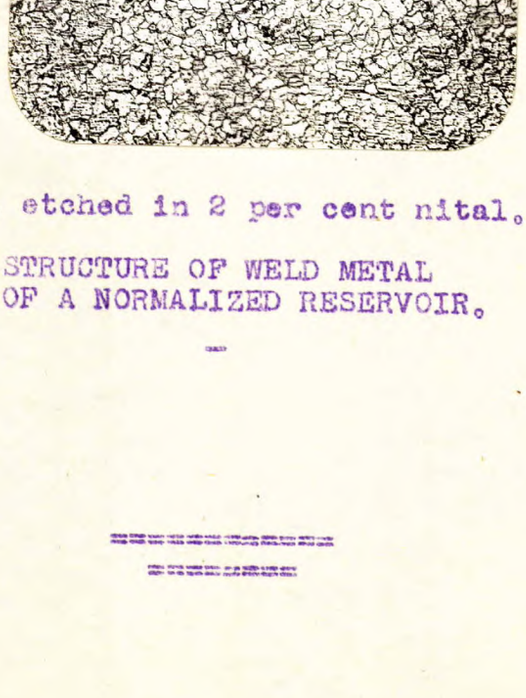
Figure 24.



X100, etched in 2 per cent nital.

STRUCTURE OF WELD METAL
OF A NORMALIZED RESERVOIR.

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