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O T T A W A February 25th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1604.

Examination of Two Welded Propeller Shaft Flange Assemblies for Snowmobiles.

(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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Examination of Two Welded Propeller Shaft
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Origin of Material:

On January 15th, 1944, two snowmobile propeller shaft assemblies from Farand & Delorme, Montreal, Quebec, were submitted by Mr. H. J. Stevenson, Assistant Director General, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, for examination. In the accompanying Requisition No. 623, AEDB Lot No. 511, Report 107D, Test No. 5, it was requested that the quality of the welding be determined. In these assemblies the face plate is attached to the coupling by means of one internal and one external 3/16-inch fillet welds.

Two drawings (Nos. C-38126 and B-24141) were submitted to show the detail of the assembly. From the drawings the

(Origin of Material, cont'd) -

following additional information was obtained:

The face plate is made from SAE 1020 steel and the coupling from a Ford EE forging. The coupling is supplied to Farand & Delorme by an American source. The couplings, as received, are fully quenched and drawn. The welding of the face plate to the couplings is done without preheat and there is no subsequent stress-relieving treatment.

The plant of Farand & Delorme, 433 St. Martin Street, Montreal, Quebec, was visited on February 16th, 1944, to acquire information and to observe welding procedures. It was learned that after welding, approximately 75 to 90 per cent of the weld metal is machined away to allow close fitting of other parts. The design and subsequent machining operation results in a joint of lower strength than is obtainable with a minor design change. It should be emphasized that this assembly is expected to absorb the complete thrust of the motor and to transmit that thrust to the driving mechanism. This being the case, every effort should be made to secure a joint of the highest possible efficiency.

All welding is done with Hollup Sureweld "N" (AWS E 6012) electrodes, using direct current welding machines.

Object of Investigation:

(1) To determine the quality of the welding of the assemblies.

(2) To suggest means of improving the welding technique, if this is possible.

Procedure:

(1) The samples submitted were subjected to a careful visual examination. Figures 1 and 2 show the general shape of the assembly and the location of the welds.

(2) Both samples were subjected to an x-ray examination

(Procedure, cont'd) -

at the National Research Council, Ottawa. Figures 3 to 10 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 and that the colours in the reproductions are the reverse of the exograph itself.

(3) Macro and micro samples were machined from areas in which defects were shown in the exographs. The white rectangles of Figures 1 and 2 show the general location of these samples.

The macro samples were polished and etched. Figures 11 and 12 show the results of this procedure. The welding defects were then photographed at higher magnification, to reveal their nature more clearly. Figures 13 to 19 are these photographs.

(4) All samples were examined under the microscope. Figures 20 to 25 show, respectively, normal coupling structure, normal face plate structure, transition zone of coupling, heat-affected zone of coupling close to the fusion line, fusion line structure, and a crack in the coupling material just under the fusion line.

(5) Hardness tests were made on the coupling material, using a Vickers machine and a 10-kilogram load. The table below shows the averages of four readings in cracked samples:

Test Area		Vickers Hardness Numbers
Normal coupling material	-	300
Transition zone of coupling material	-	280
Heat-affected zone of coupling material	-	488
Normal face plate material	-	155
Weld metal	-	266

(6) A chemical analysis of the coupling material

(Procedure, cont'd) -

produced the following results (in the table below, these results are compared with the Ford EE specification):

		Ford EE Specification	Analysis Obtained
		- Per cent -	
Carbon	-	0.35-0.40	0.40
Phosphorus	-	0.03 max.	0.030
Sulphur	-	0.05 max.	0.031
Manganese	-	0.70-0.90	0.83
Silicon	-	0.07-0.15	0.15
Chromium	-	None.	0.08
Nickel	-	None.	0.39
Molybdenum	-	None.	0.08

Discussion:

A visual examination revealed that the outside weld was nearly completely machined away whereas the inside weld was not machined at all. The outside weld showed some evidence of undercutting, probably due to incorrect electrode inclination during welding. The inside weld showed a greater degree of convexity of contour than is desirable, probably as a result of too low welding current.

The x-ray examination revealed that both welds contained slag trapped in the roots and this extended almost completely around the weld. This was confirmed by the macro and micro samples. The danger associated with this defect is that it acts as a potent stress raiser and is therefore a fertile source of cracks in highly stressed parts. As previously shown, some of the macro samples are cracked both in the weld metal and coupling material, and these cracks have originated at the slag inclusion. Even if cracking had not occurred subsequent to welding it is most probable that service stresses would be sufficient to initiate cracking.

The cracking in the coupling material is not surprising, (Discussion, cont'd) -

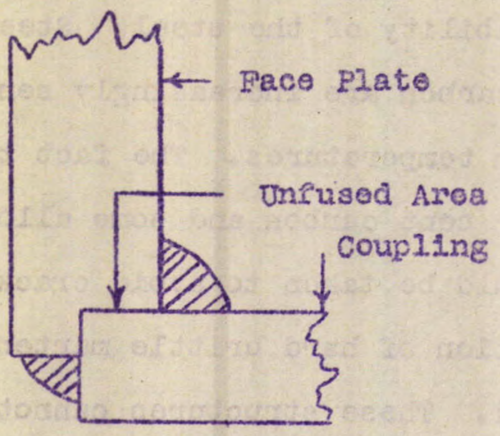
in view of the composition of this material. It is apparent that the alloys are residuals, but even in small amounts they materially increase the hardenability of the steel. Steels containing over 0.30 per cent carbon are increasingly sensitive to cracking when welded at room temperatures. The fact that this material contains 0.40 per cent carbon and some alloy indicates that precautions should be taken to avoid cracking, which is a result of the formation of hard brittle martensitic structures adjacent to the weld. These structures cannot yield to the shrinkage stresses of the weld metal, and cracking results. The most practical way to avoid the formation of martensitic structures is to retard the cooling rate by preheating the assembly before welding. Preheating to 500° F. would have the desired effect. Even after this treatment, high locked-up stresses may produce cracking and, as a further precaution, a stress-relieving treatment at 900° F. is desirable.

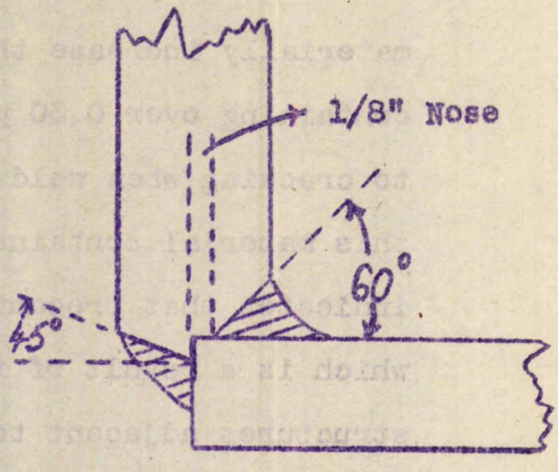
The hardness tests and the microstructure both reveal the formation of a hard, brittle, martensitic structure adjacent to the weld and point to the necessity of corrective treatment.

When it is considered that this coupling absorbs and transmits the entire engine thrust it is apparent that the machining away of a large part of the weld metal seriously reduces the strength of the joint and may be expected to result in premature service failures. It would appear that this machining is necessary to permit close fitting of adjacent parts. This being the case, a change in joint design is highly desirable. Even without machining it is probable that the unfused area between the two welds would act as a stress raiser and promote cracking. The present joint design and the recommended design

(Discussion, cont'd) -

are shown below:





Present Design. Recommended Design.

The recommended design with 1/8-inch nose will permit complete penetration of the joint, the nose being completely fused during welding. The nose will also permit assembling so that the face plate and coupling are concentric.

The use of Hollup Sureweld "N" electrode, together with too low welding current, is responsible for the slag trapped at the root of the weld. This electrode conforms to AWS Specification E 6012 and is sometimes known as the "poor fit-up" electrode type. This name is due to the property of this electrode of readily bridging fairly wide gaps between materials to be welded, and in consequence the penetration is low. In the above recommended joint design an AWS E 6030 electrode, such as Hollup Sureweld "A", should be used. This electrode is designed to give good operating characteristics and penetration in narrow V joints.

CONCLUSIONS:

1. There is some undercutting on the assemblies, probably due to improper electrode inclination during welding.

2. There is considerable slag trapped at the roots of the weld, probably due to too low welding current and to use of a "poor fit-up" type of electrode.

3. Cracks in coupling and welds are due to formation of martensite adjacent to weld. On steels of the composition of the coupling these cracks are almost inevitable when welding is performed at room temperature.

4. The alloys present in the coupling material are probably residuals but tend to aggravate the crack sensitivity.

5. The machining away of a large fraction of the welds dangerously weakens the joint.

Recommendations:

1. The assembly should be preheated to 500° F. before welding.

2. The assembly should be stress-relieved at 900° F. for 1 hour after welding.

3. The design of the joint should be changed so that the necessary machining will not weaken the joint. The design recommended above should prove satisfactory.

4. Should the recommended design be approved, an electrode conforming to the AWS E 6030 specification should be used in making the weld.

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oooooo
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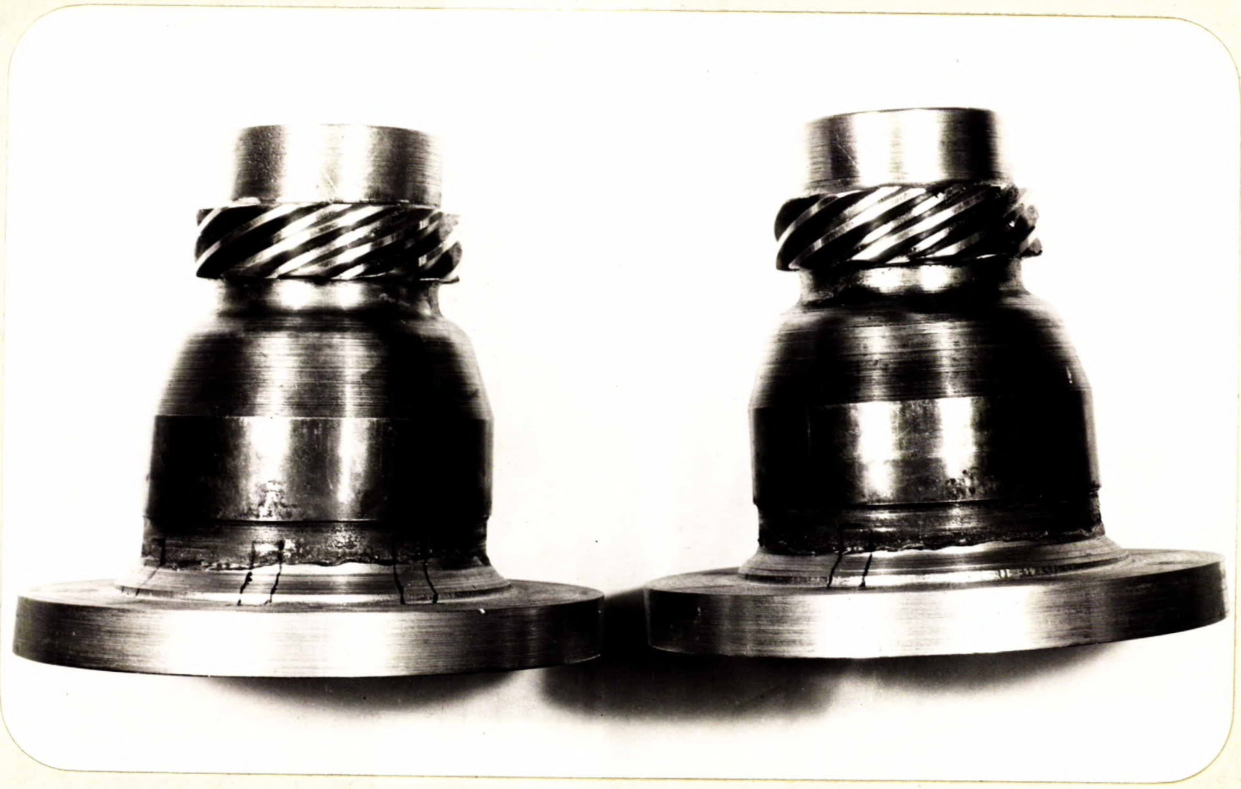
HJN:GHB.

12 cc
16R4
AJN

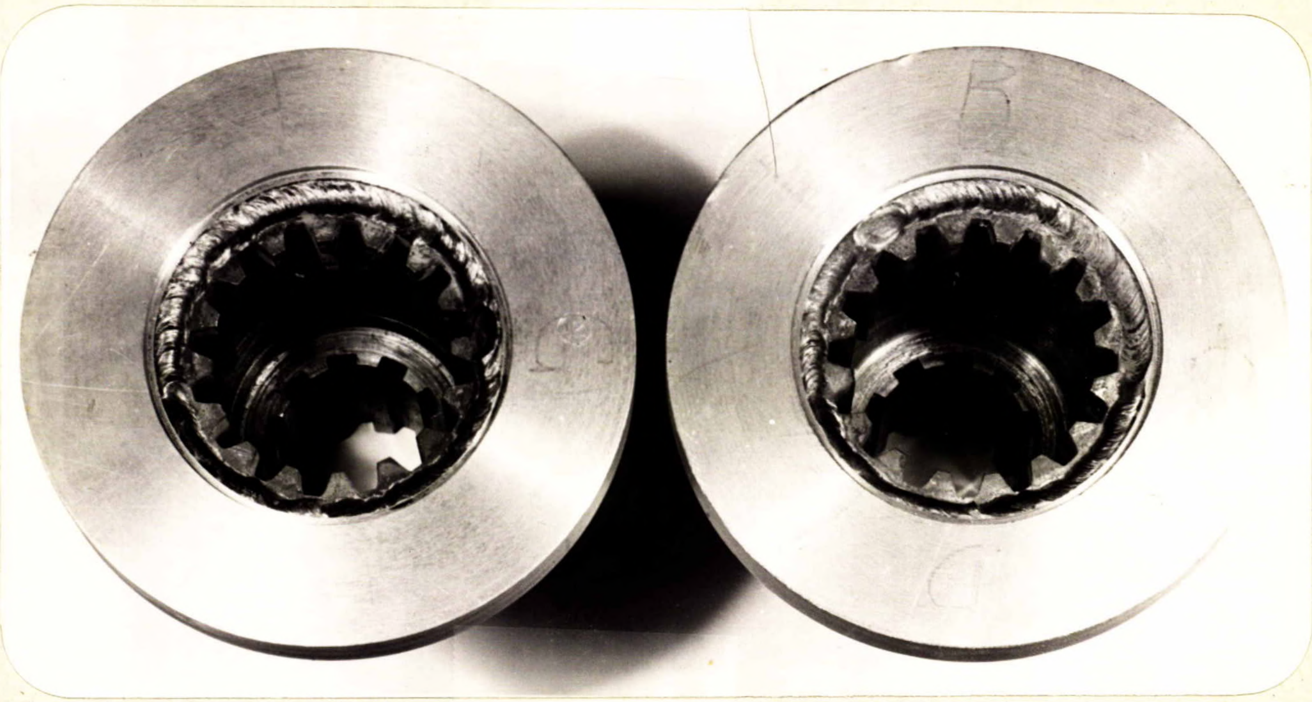
Figure 1.



GENERAL SHAPE OF PROPELLER FLANGE ASSEMBLY.

White rectangles indicate areas from which macro and micro samples were machined.

Figure 2.



BOTTOM OF ASSEMBLY, SHOWING INSIDE WELD.

Figure 3.

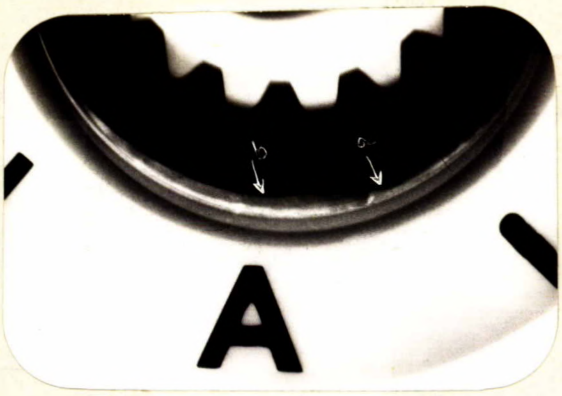


Figure 4.

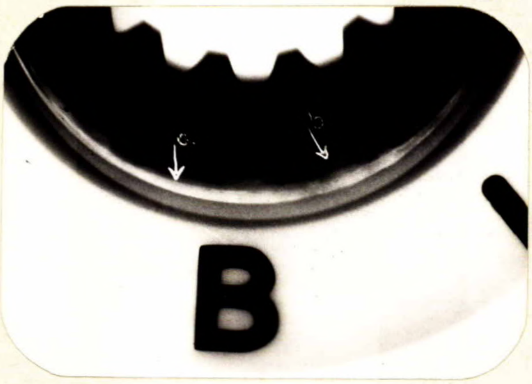
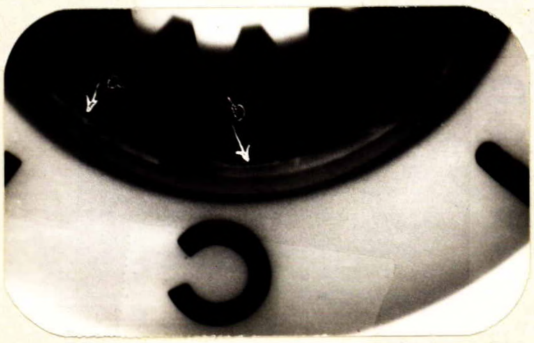


Figure 5.



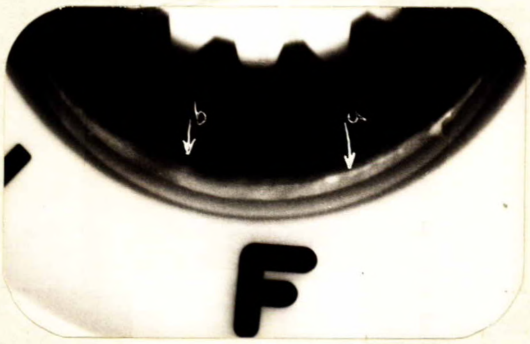
REPRODUCTIONS OF EXOGRAPHS OF WELDS.
LETTERS SAME AS ON MACRO AND MICRO SAMPLES.

Legend: a = Slag in root of outside weld.
b = " " " " inside weld.

Figure 6.

Figure 7.

Figure 8.



REPRODUCTIONS OF EXOGRAPHS OF WELDS.
LETTERS SAME AS ON MACRO AND MICRO SAMPLES.

Legend: a = Slag in root of outside weld.
b = " " " " inside weld.

1200
1604
HJN

Figure 9.

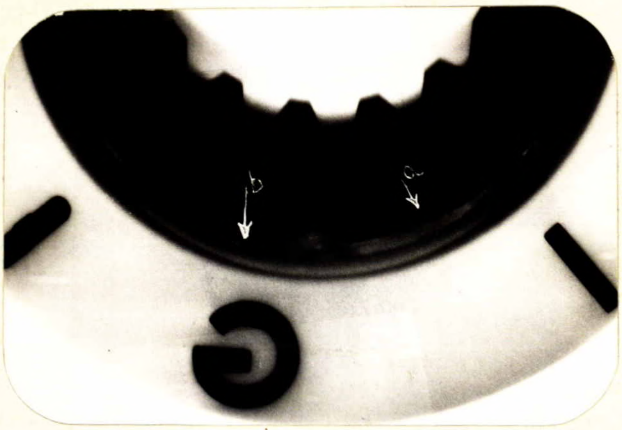
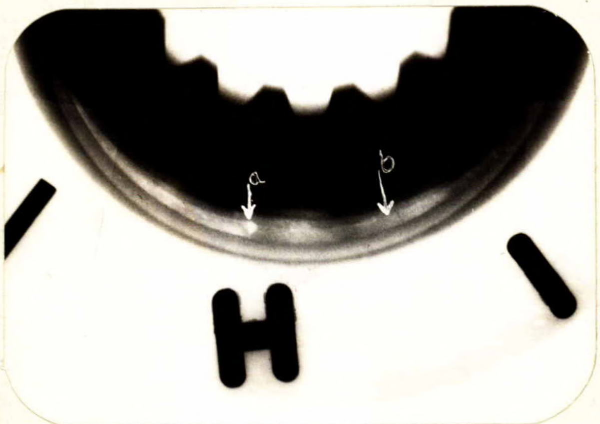


Figure 10.



REPRODUCTIONS OF EXOGRAPHS OF WELDS.
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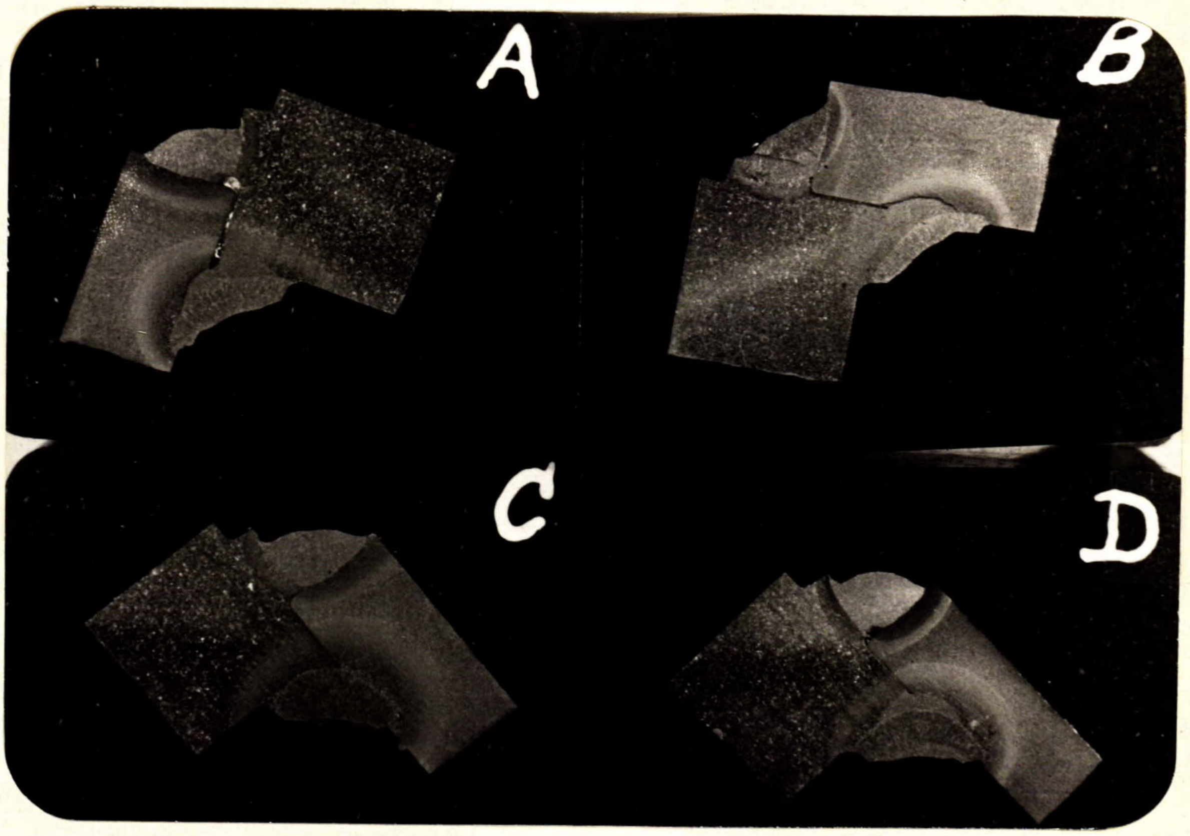
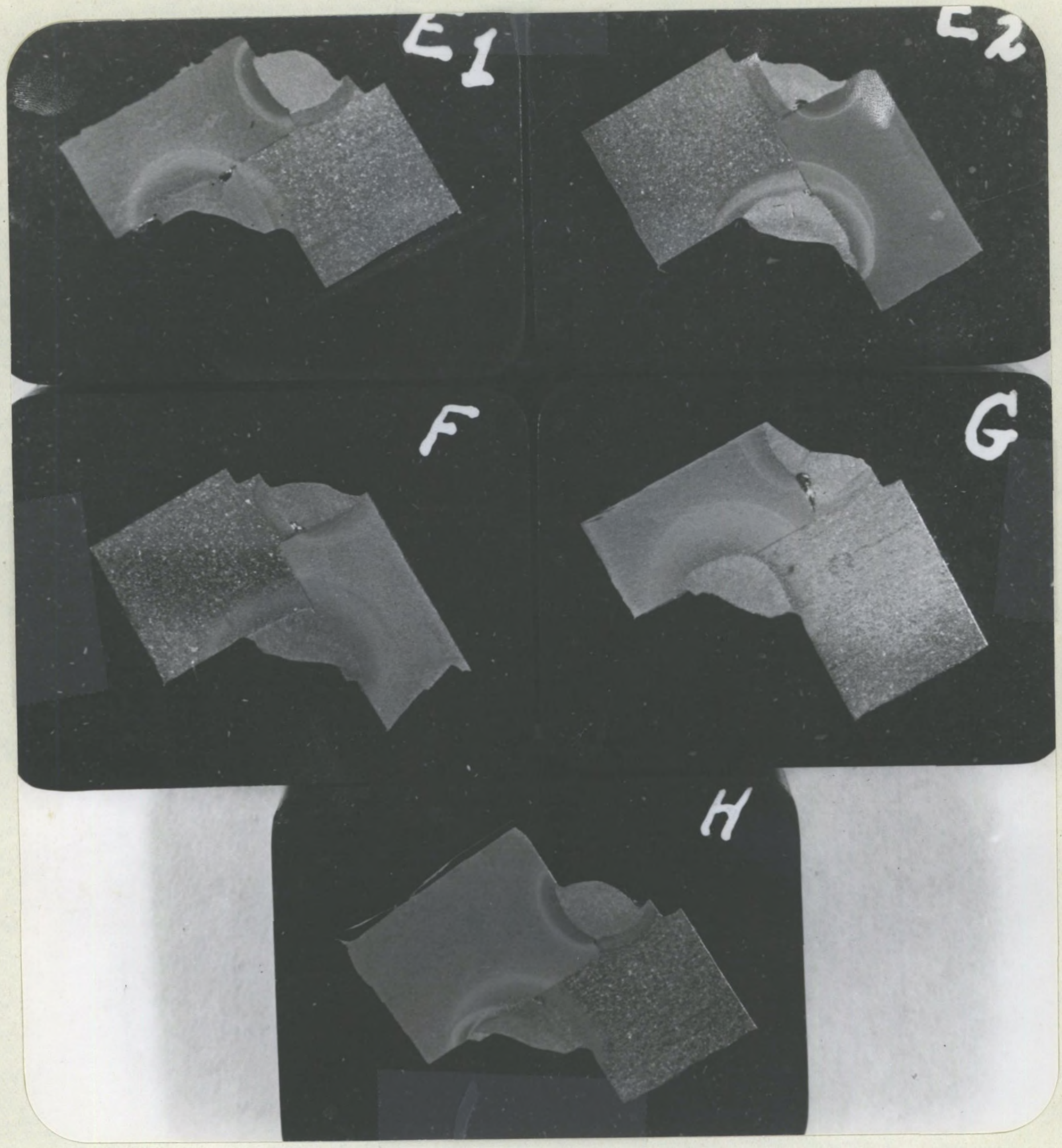
Figure 11.



MACRO SAMPLES OF WELDS.

Note slag inclusions at roots of welds, also cracks in Samples A and B.

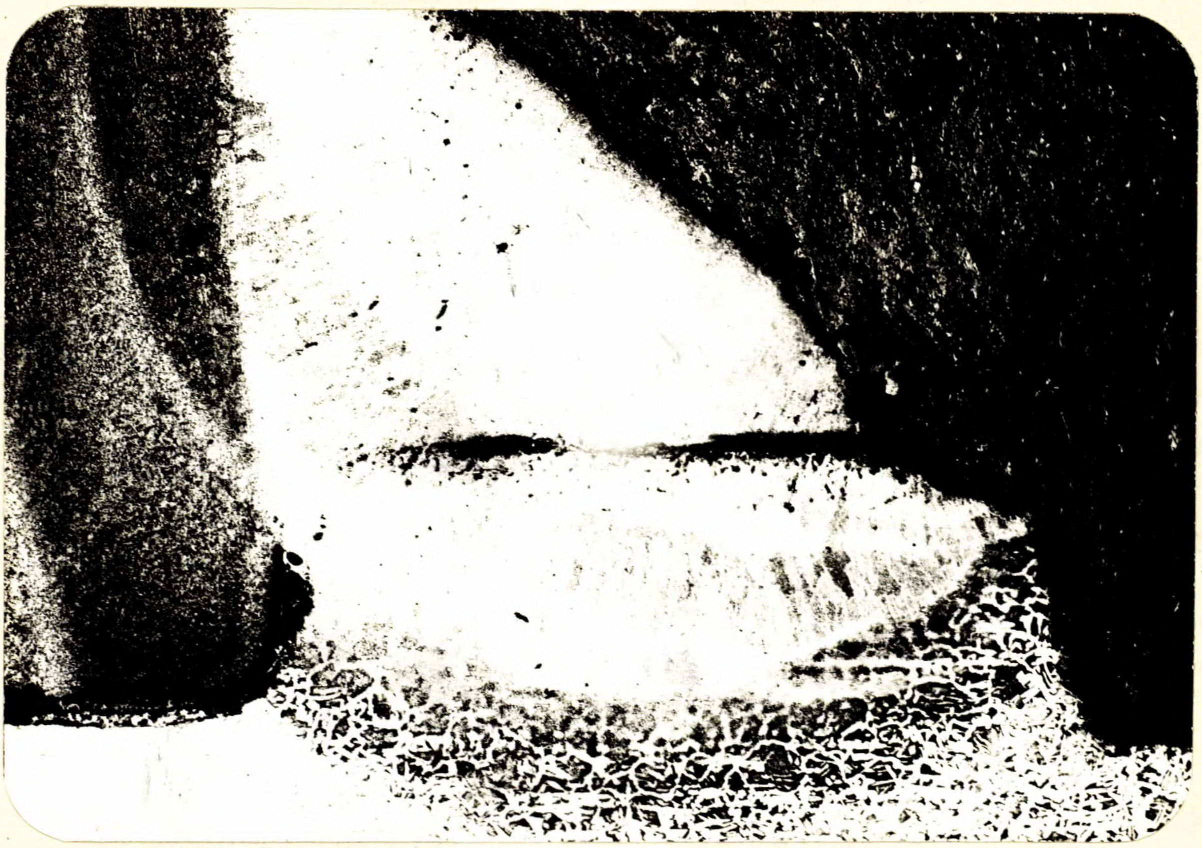
Figure 12.



MACRO SAMPLES OF WELDS.

Note slag inclusions at roots of welds, cracks in Samples G, E, and porosity in weld of Sample E.

Figure 13.

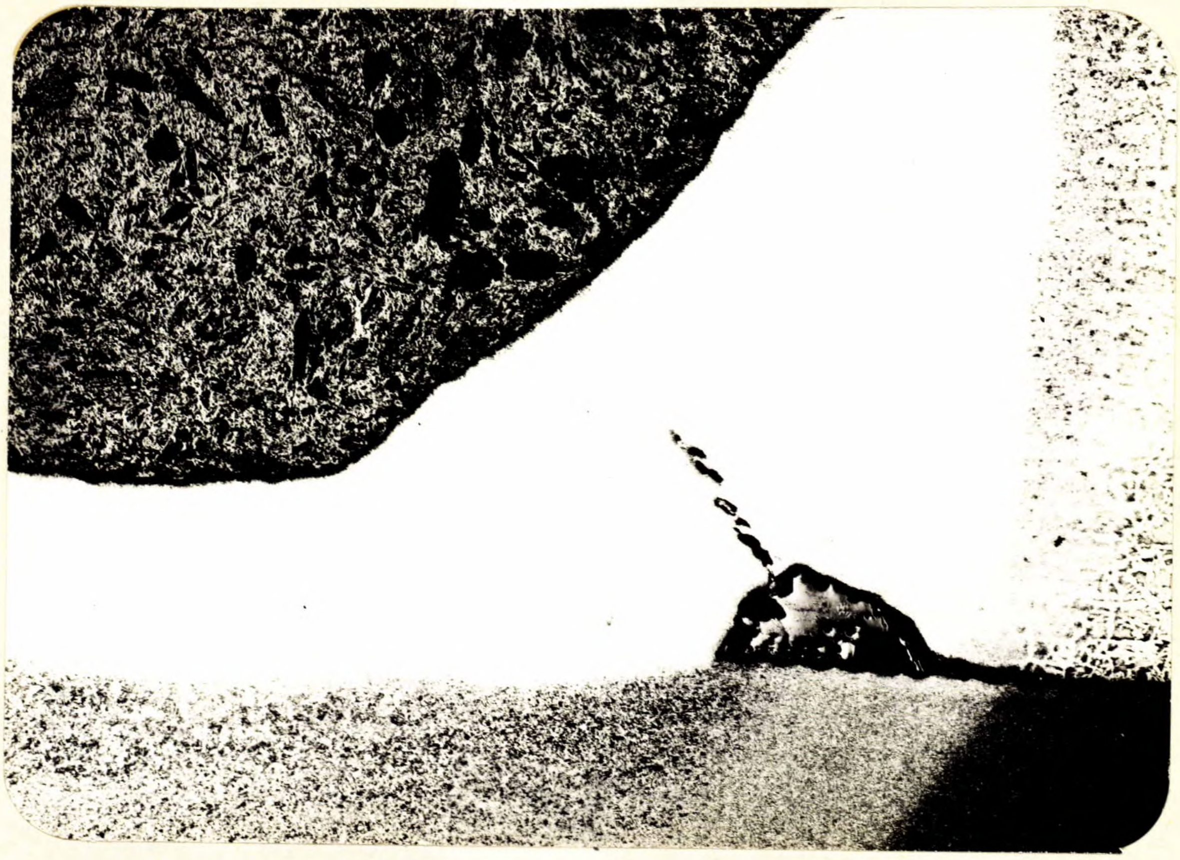


X20, nital etch.

WELD AREA B.

Note crack in weld metal.

Figure 14.



X20, nital etch.

WELD AREA E.

Note crack in weld metal, originating at slag inclusion at root of weld.

Figure 15.

X20, nital etch.

WELD AREA B.

Note crack in fusion zone
of coupling material.

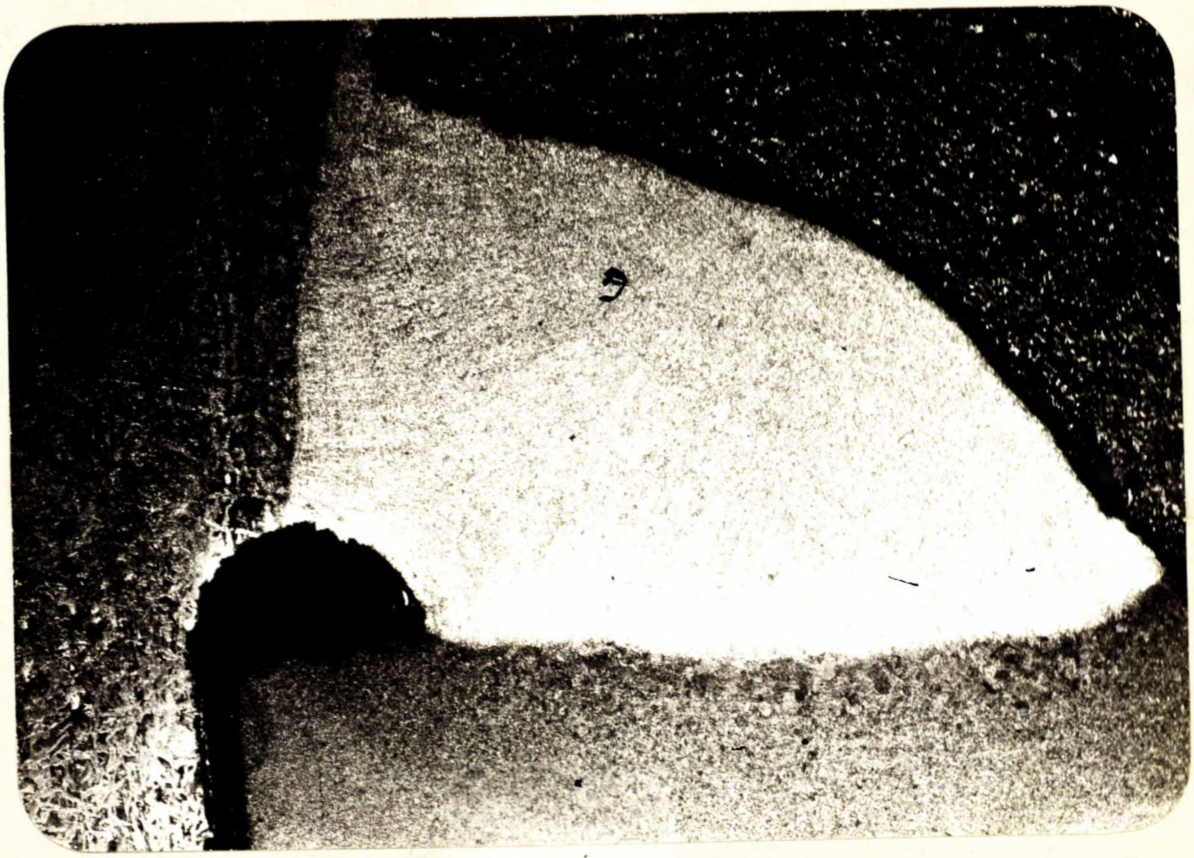
Figure 16.

X20, nital etch.

WELD AREA A.

Note crack beginning at
slag inclusion at root of weld.

Figure 17.



X20, nital etch.

WELD AREA D.

Note slag inclusion at root of weld.

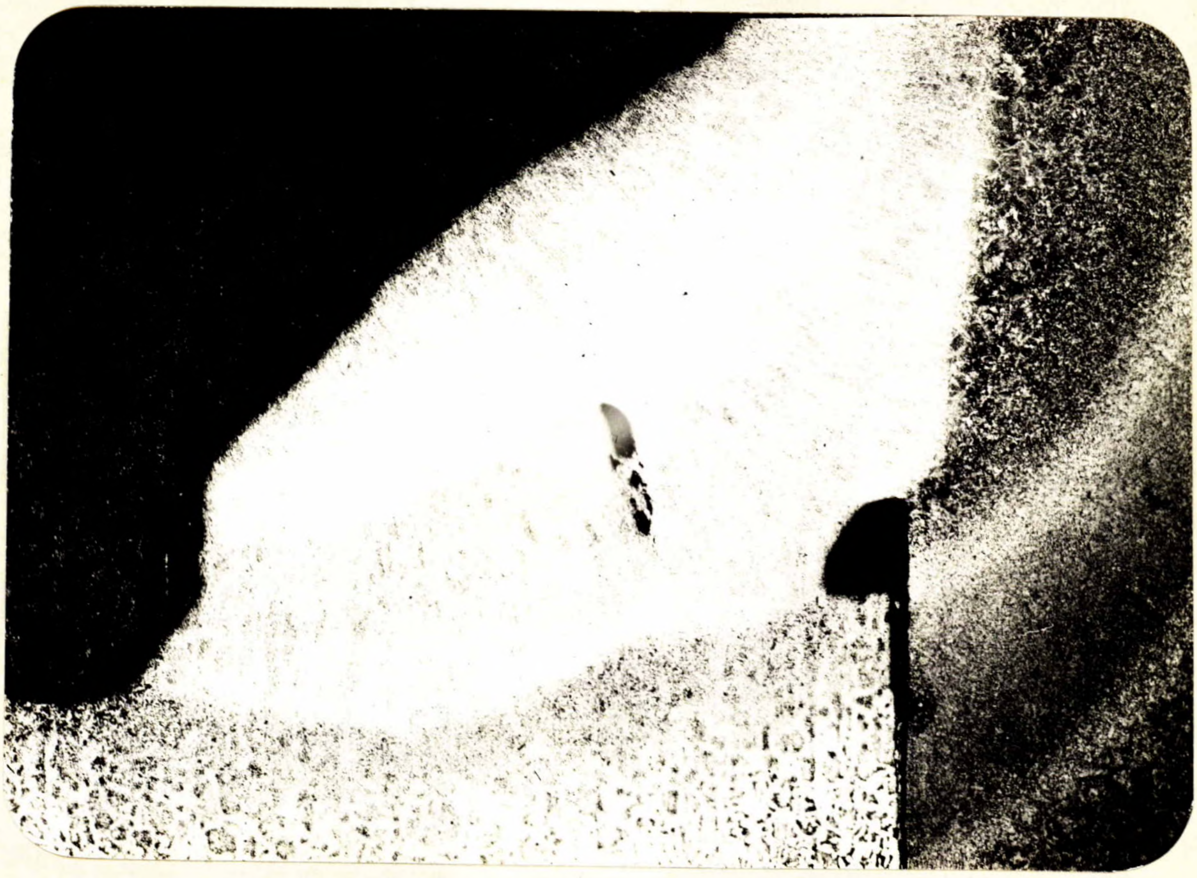
Figure 18.

X20, nital etch.

WELD AREA G.

Note crack originating at slag inclusion at root of weld.

Figure 19.

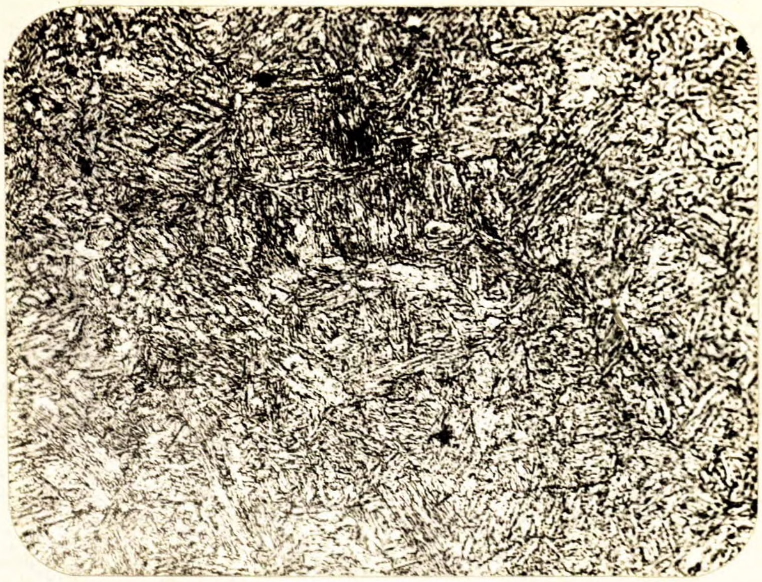


X20, nital etch.

WELD AREA E.

Note small slag inclusion at root of weld,
and porosity in weld metal.

Figure 20.



X500, etched in 4 per cent picral.

NORMAL COUPLING STRUCTURE.

Tempered martensite.

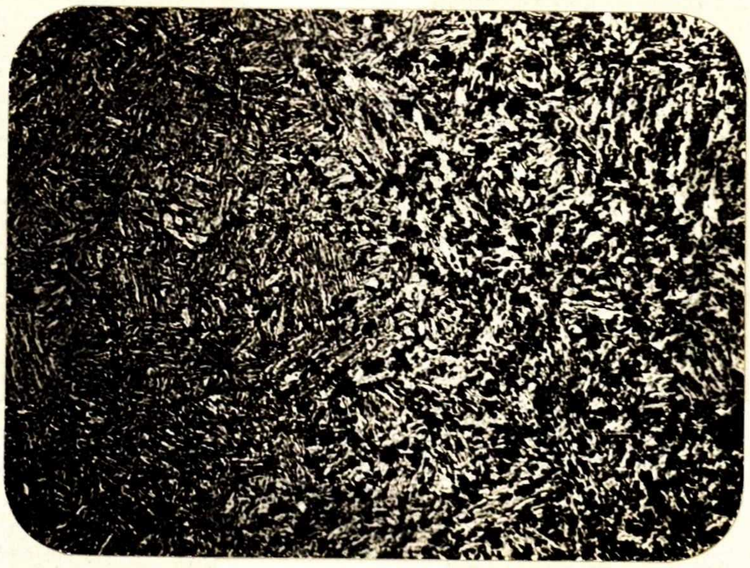
Figure 21.

X500, etched in 4 per cent picral.

NORMAL FACE PLATE STRUCTURE.

Pearlite in a matrix of ferrite.

Figure 22.

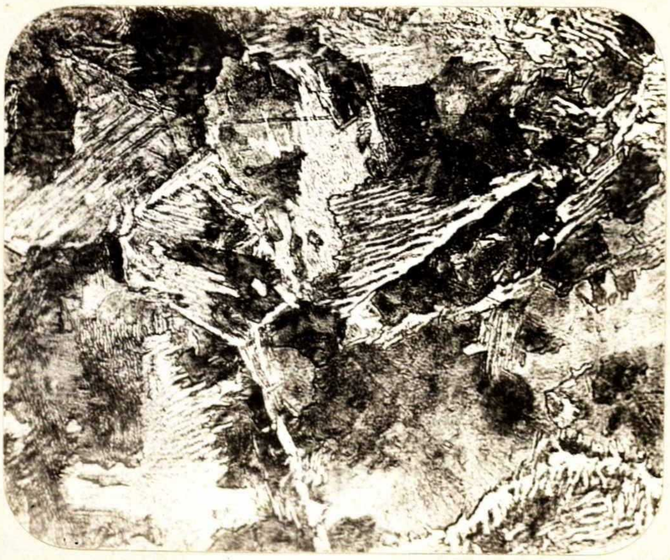


X500, etched in 4 per cent picral.

TRANSITION ZONE STRUCTURE OF COUPLING MATERIAL.

Nodular pearlite in ferrite matrix.

Figure 23.



X500, etched in 4 per cent picral.

STRUCTURE OF HEAT-AFFECTED ZONE OF COUPLING MATERIAL.

Coarse martensite.

Figure 24.

X500, etched in 4 per cent picral.

STRUCTURE AT FUSION LINE OF COUPLING MATERIAL.

Weld metal above, coupling material below.

Figure 25.

X100, etched in 2 per cent nital.

END OF CRACK IN FUSION ZONE OF COUPLING MATERIAL.

HJN:GHB.