O T T A W A   December 6th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1549.

Examination of Samples of Welded
Joints of a T.16 Universal Carrier.

(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

OTTAWA December 6th, 1943.

REPORT

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Origin of Material:

On November 10th, 1943, Mr. J. A. Balcom, S.T.O. (Tanks), for the Deputy Director (Mechanization), Inspection Board of United Kingdom and Canada, Detroit, Michigan, submitted ten (10) samples of welded joints of a T.16 Universal Carrier for examination. These samples were cut from the carrier after ballistic testing at the Aberdeen Proving Centre, Aberdeen, Maryland.

The armour plate was made by the Ford Motor Company, heat-treated by the Standard Steel Spring Company, and welded by the Ford Motors Corporation, Somerville, Mass. All welding was done manually, using Crucible Steel Co. "Rezistal #14 Armourized" electrodes. The work was positioned such that all

(Origin of Material, cont'd) -

welding was done in the flat or downhand position.

The samples (numbered 1 to 10, inclusive) were identified as follows:

Test No.	Position of Joint
1	Upper left side panel to upper rear panel.
2	Upper left side panel to gunner panel, left.
3	Upper left side panel to front panel, lower.
4	Front panel lower to floor plate.
5	Front panel upper to front panel lower.
6	Front centre panel to front panel upper.
7	Front panel right to gunner panel right.
8	Gunner panel right to front panel upper.
9	Front panel upper right to side panel right.
10	Side panel lower right to floor panel.

The following additional information was gleaned from the report of Mr. J. A. Balcom's visit (No. 56) to Aberdeen on September 21st and 22nd, 1943:

> Prior to ballistic testing, 400 inches of welding was subjected to radiographic examination. About 34 per cent of the welds showed defects, consisting of small amounts of slag, incomplete penetration, and incomplete fusion. The action taken by Ordnance (U.S.) will be to advise their inspection at the fabrication plant to improve their welding technique.
>
> Shock attack results with 37-mm. H.E. on both welds and armour were considered good. Officers at Aberdeen expressed the opinion that poor H.E. results on the front end of the carrier were due to "too many corners", "too many joints", "quality of welding generally inconclusive because of plate failure", "armour plate failures contributed to by design, inside corners and small plates".

Object of Investigation:

To determine the quality of the welding done by Ford Motors Corporation on the T.16 Universal Carrier.

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Procedure:

(1) All samples were given a careful visual examination.

(2) Micro samples were machined from each sample, polished, and etched. Figures 1 and 2 are macro photographs of the sections.

(3) All samples were examined under a microscope. Figure 3 shows a typical fusion zone between weld and armour plate. Figure 4 shows a structure typical of all heat-affected zones. Figure 5 shows a structure typical of all fusion zones. Figure 6 is the typical structure of the armour plate. Figure 7 is the structure typical of the ferritic root passes.

Figure 8 shows a banded structure and numerous sulphide inclusions in the wide heat-affected zone of the larger plate of Sample No. 4.

(4) A chemical analysis sample was machined from one sample. The results of analysis are shown below:

		Percent
Carbon	-	0.27
Phosphorus	-	0.008
Sulphur	-	0.018
Manganese	-	1.24
Silicon	-	0.28
Chromium	-	0.58
Nickel	-	0.13
Molybdenum	-	0.28
Vanadium	-	Not detected.

(5) Hardness tests, using a Vickers machine and a 10-kilogram load, were made on all specimens. The table below shows the results obtained:

Armour Plate	Austenitic Weld	Ferritic Weld	Heat-Affected Zones Double Bead	Heat-Affected Zones Single Bead
312	176-219	251-380	339-483	442-560

Discussion:

A visual examination of the samples as received reveals indications of undercutting, welds of excessive reinforcement, evidence of poor fit-up requiring buttering, and improperly located welds.

Unfortunately the samples submitted for examination were so small that in all cases it was impossible to machine specimens to illustrate the above defects. In nearly all cases it was necessary to remove specimens from the end of the sample remote from the flame-cut edge. Apparently the samples were selected with a view to sectioning through defects, without recognition that the heat effect of flame cutting would mask evidence of metallurgical significance.

The macro-examination reveals that all samples, with the exception of Nos. 3 and 5, are three-pass welds. Sample No. 3 is a double-pass fillet weld. Sample No. 5 is a four-pass weld which should have been made in two passes. In this particular case it is apparent that poor fit-up has necessitated buttering and an excessive use of weld metal to bridge the gap. Sample No. 10 shows the same type of defect. Nearly all samples show a wider root gap than is desirable. This has resulted in excessive dilution of the weld metal in the root pass, brought about by a weaving motion of the electrode necessary to close the gap. The resulting dilution has produced a ferrite condition in the weld metal of the root pass. The above data should be compared with operation sheets to determine whether the proper technique is being followed.

Samples Nos. 1, 3, 4, 5, 9 and 10 all show slag inclusions at the roots of the welds. These are probably due to the weaving technique in the root pass which enhances the probability of slag being trapped.

A microscopic examination failed to reveal any cracks

(Discussion, cont'd) -

in the heat-affected zones or the armour plate. Structures of the heat-affected zones, fusion zones, transition zones, and unaffected armour plate are normal. No evidence was found, in the samples submitted, of lack of fusion. One sample (No. 4) showed a banded structure in the heat-affected zone of the thinner plate, and sulphide inclusions considerably greater than normal. The banding indicates chemical inhomogeneity. The remaining samples show normal small sulphide and oxide inclusions.

In summary, the welding defects found, such as undercutting, excessive reinforcements, ferritic bands and slag inclusions, act as stress raisers and, as such, reduce impact properties. Every effort should be made to eliminate these defects.

The chemical analysis of the armour plate indicates that it is a carbon-manganese-chromium-molybdenum type, of good hardenability. The structure indicates that the armour plate is receiving a satisfactory heat treatment.

Hardness tests show nothing abnormal, with the possible exception of fairly high hardnesses in the heat-affected zones of the top passes of welds. Hardnesses would indicate a brittle condition in the areas but there is little possibility of altering this without annealing beads, which are impracticable in welds of this size. The hardness ranges of the ferritic root passes may be attributed to the variations in the annealing effect, produced by subsequent beads. Every effort should be made to avoid dilution of such a magnitude as to produce ferritic conditions since shock properties are consequently lowered.

CONCLUSIONS:

1. The welding technique employed is open to some criticism, as shown by this investigation. It is realized, however, that under practical production conditions it is not always possible to produce ideal welds.

2. The following welding defects were found: undercutting, slag inclusions, excessive reinforcement, poor fit-up, improper location of welds, and excessive dilution in root passes. All of these act as stress raisers and reduce impact strength.

3. One sample of armour plate contains more sulphide inclusions than is normal. The remaining samples would be considered satisfactory, according to commercial standards.

4. A microscopic examination shows nothing abnormal in the structures and no cracks were found.

5. The chemical analysis of the armour plate indicates that it is a carbon-manganese-chromium-molybdenum type, of good hardenability.

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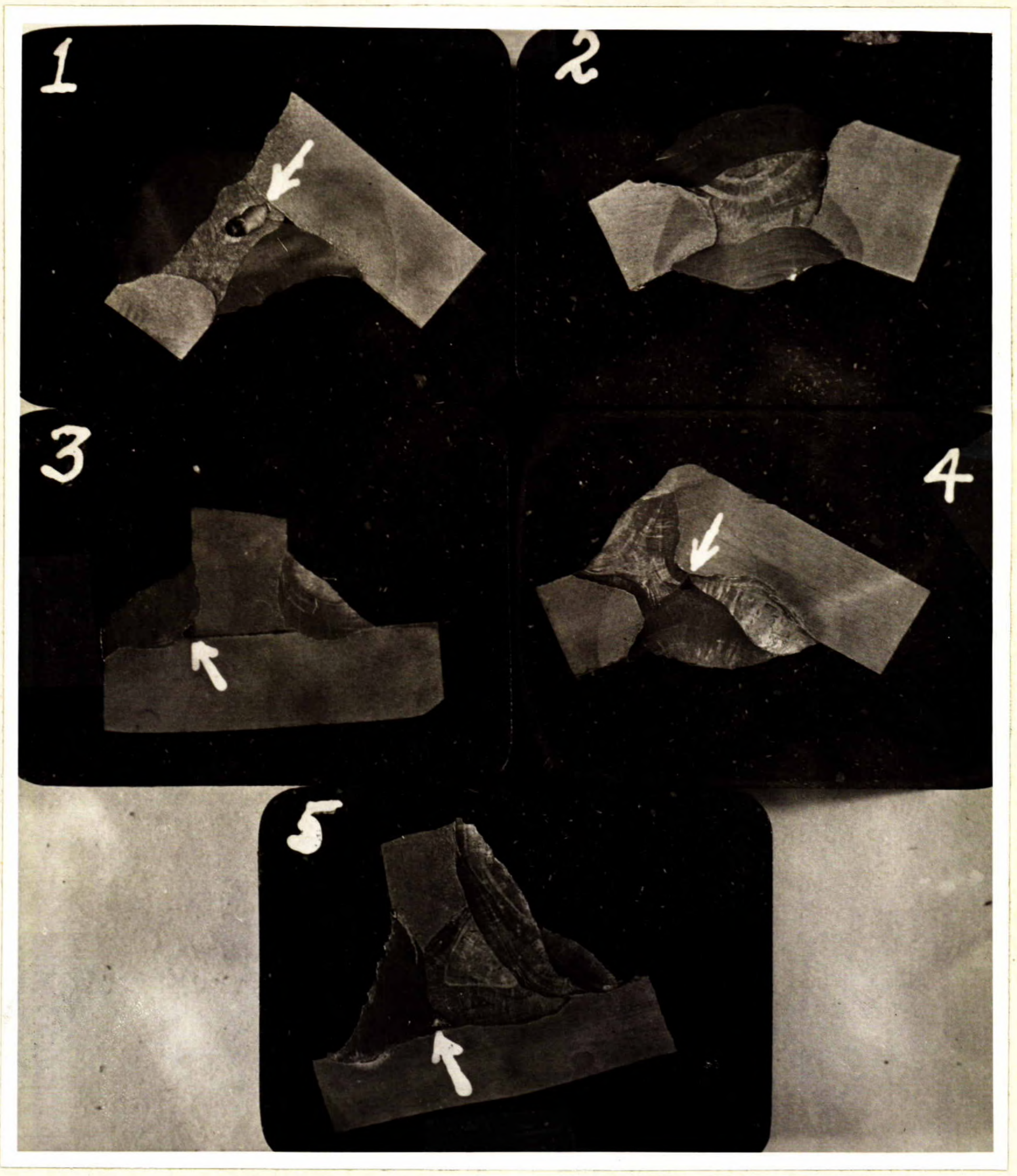
Figure 1.

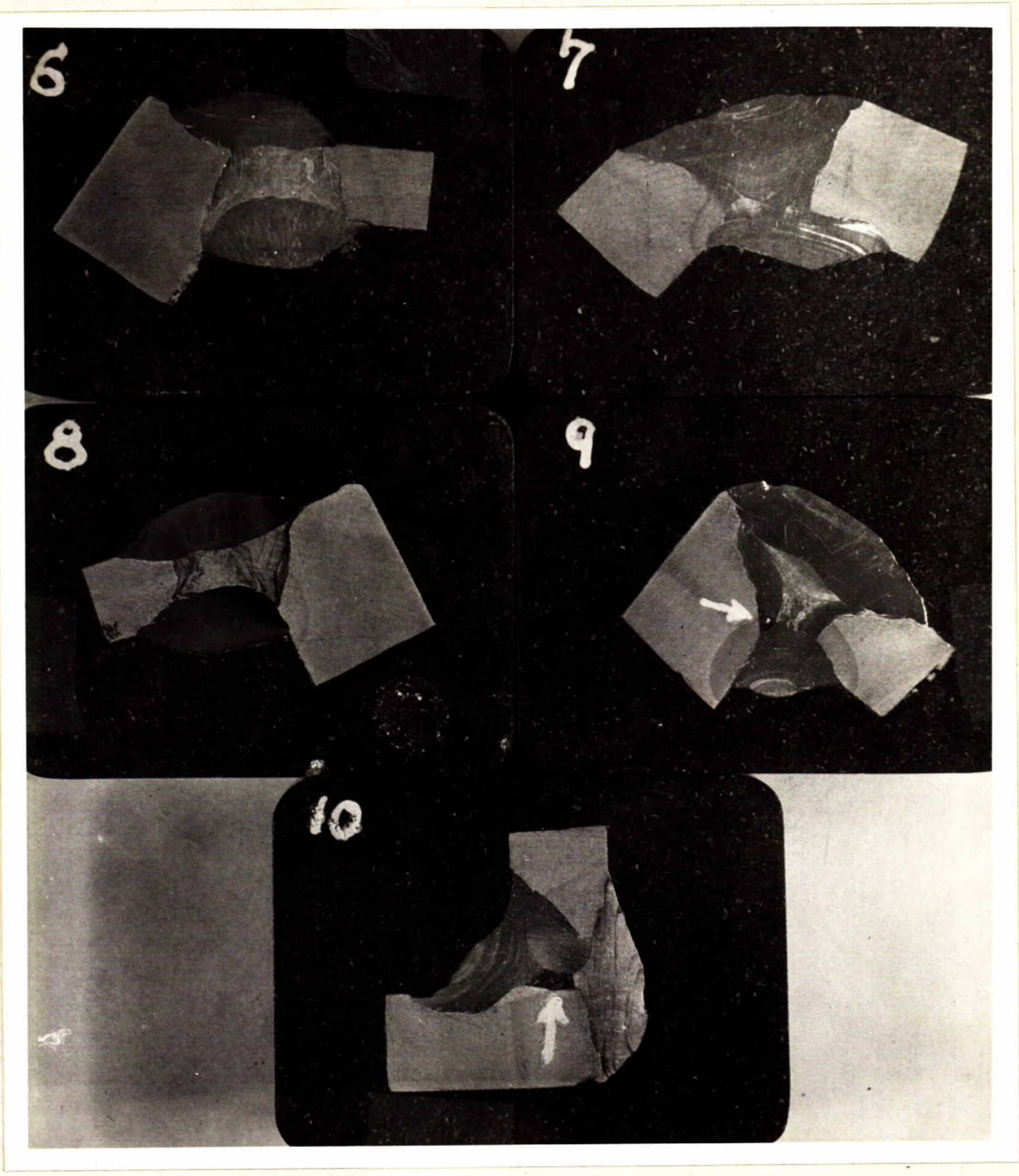


Etched in 1 per cent picric,
4 per cent HCl in alcohol.

SPECIMENS FROM SAMPLES NOS. 1 TO 5, INCLUSIVE.

White arrows point to slag inclusions. Note darker etch in root pass of Specimens 1 and 2. Note improper placement of weld metal of first pass on underside of large plate of 4. Note also excessive use of weld metal to counteract poor fit-up in Specimen 5.

Figure 2.

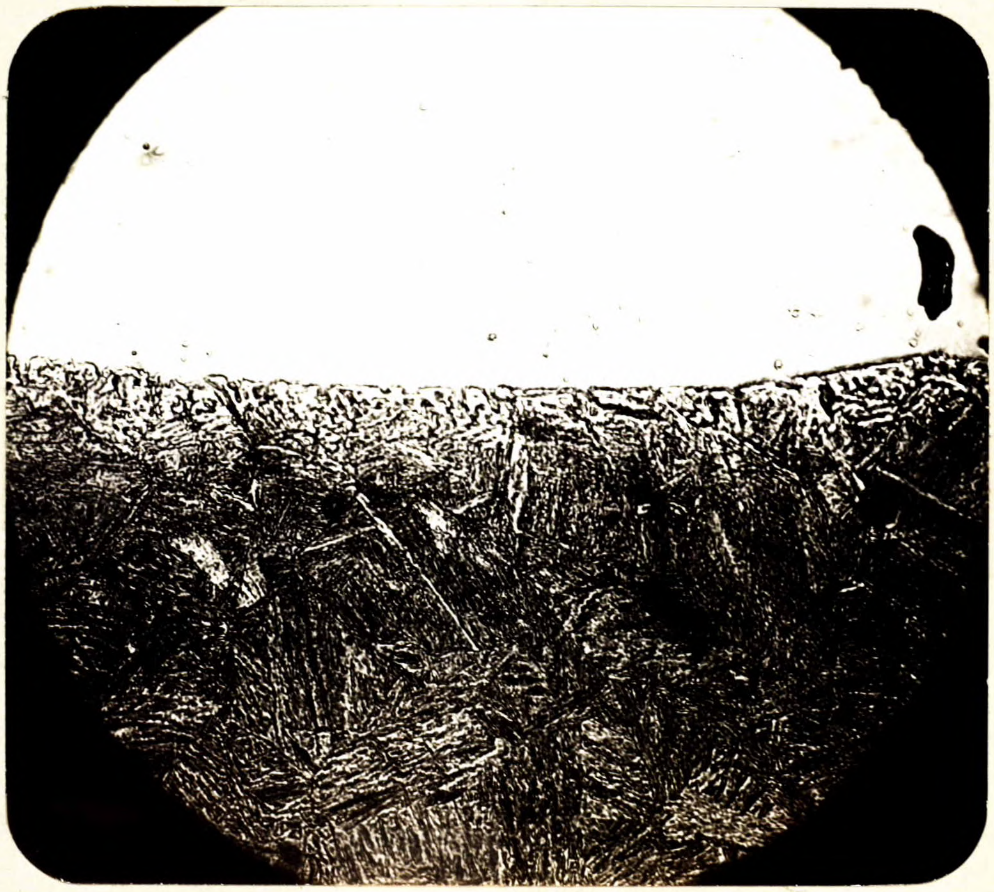


Etched in 1 per cent picric,
4 per cent HCl in alcohol.

SPECIMENS FROM SAMPLES NOS. 6 TO 10, INCLUSIVE.

White arrows point to slag inclusions. Note darker etch of root pass of Specimens 6, 7, 8, and 9. Note wide root gaps. Note that in Specimen 10 the edge of small plate has been buttered to counteract poor fit-up. Note also excessive weld reinforcement.

Figure 3.



X500, etched in 2 per cent nital.

STRUCTURE OF TYPICAL FUSION ZONE.

Pearlite adjacent to weld metal and martensite in the heat-affected zone.

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Figure 4.

X500, etched in 2 per cent nital.

TYPICAL MARTENSITIC STRUCTURE OF ALL HEAT-AFFECTED ZONES.

Figure 5.

X500, etched in 2 per cent nital.

TYPICAL STRUCTURE OF TRANSITION ZONES.
NODULAR TROOSTITE IN HEAT-AFFECTED ZONE
AND TEMPERED MARTENSITE OF UNAFFECTED
ARMOUR PLATE.

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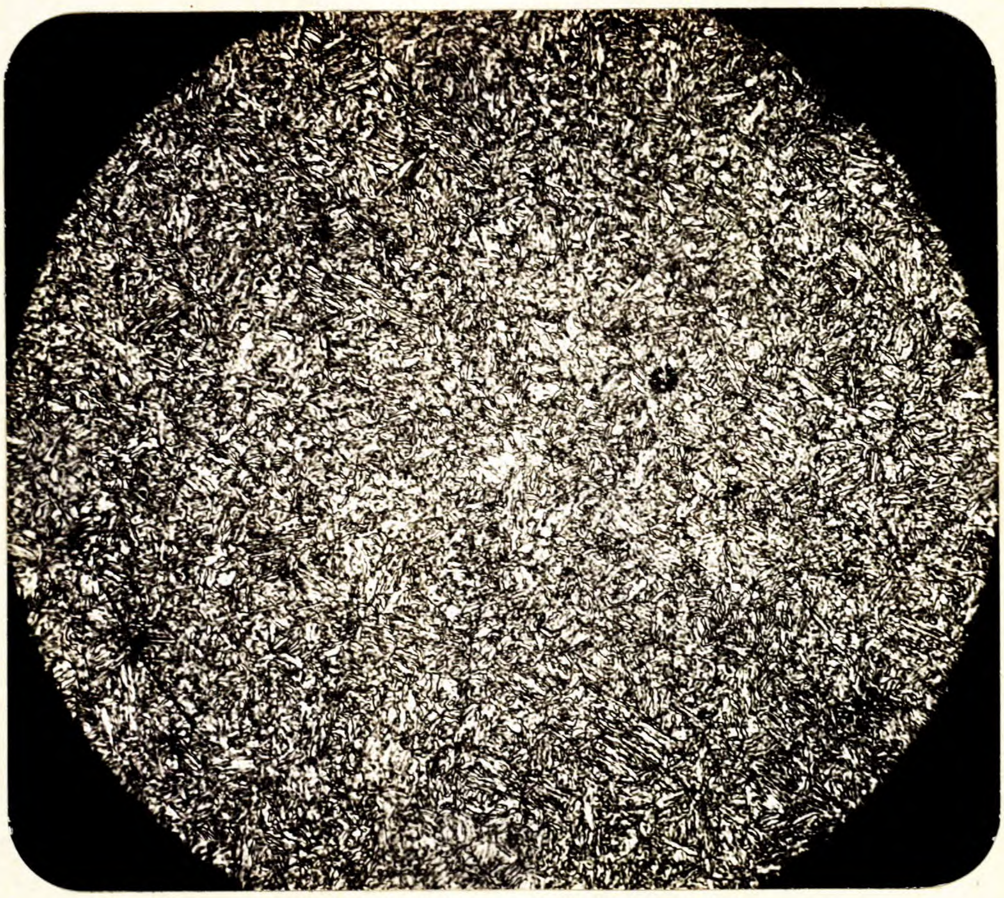
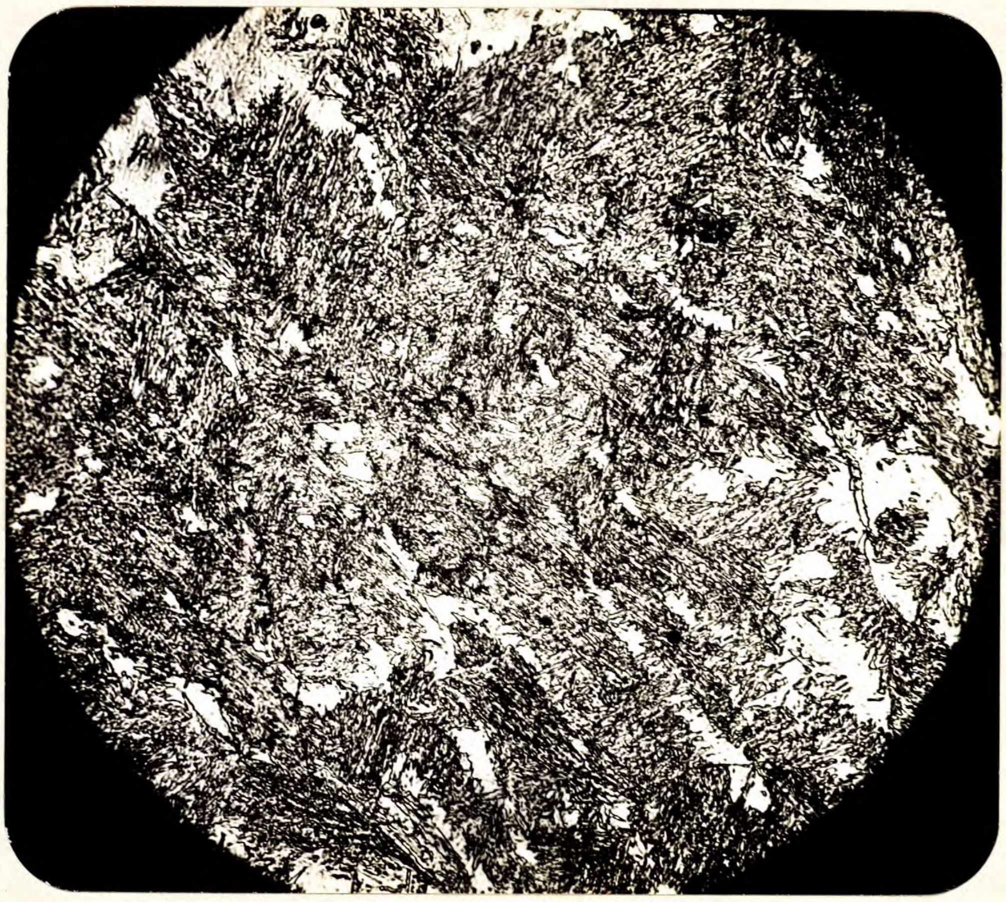
Figure 6.



X500, etched in 2 per cent nital.

TEMPERED MARTENSITIC STRUCTURE OF ARMOUR PLATE.

Figure 7.

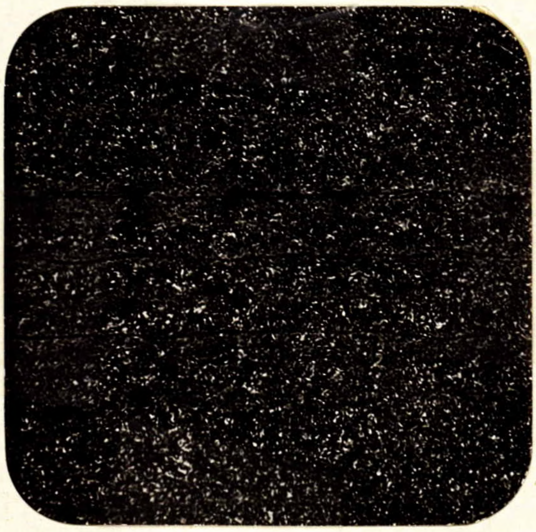


X500, etched in 1 per cent picric acid,
4 per cent hydrochloric acid in alcohol.

TEMPERED MARTENSITIC STRUCTURE TYPICAL
OF THE FERRITIC ROOT PASSES.

White constituent is retained austenite.

Figure 8.



X250, etched in 2 per cent picral.

BANDED STRUCTURE OF HEAT-AFFECTED ZONE OF ARMOUR PLATE.

Note sulphide inclusions.

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