FILE COPY

OTTAWA January 7th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1567.

(Subsequent to Report of Investigation No. 1513, October 9th, 1943.)

Examination of Additional Welded Splash Strips.

(Copy No. 6.)

Bureau of Mines
Division of Metallic
Minerals

Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA January 7th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1567.

(Subsequent to Report of Investiga-)
(tion No. 1513, October 9th, 1943.)

Examination of Additional Welded Splash Strips.

==========

Introduction:

In October 1943, a ballistically tested sample steel plate with ferritic and austenitic welded splash strips was submitted, for examination, by Mr. V. G. Morris, for Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario. The examination revealed that there was considerable variation in the welding technique from strip to strip and that cracking in testing was due to welding defects, "hard" cracks, and sulphide inclusions. In the report covering this investigation (Investigation No. 1513, dated October 9th, 1943) photographs of these defects were shown and their probable causes were outlined, together with recommendations for their elimination.

The present report covers an investigation of two additional sample plates with splash strips. Both had been welded with the same technique. One had been tested ballistically and found satisfactory. The other had not been tested

(Introduction, cont'd) -

and was submitted for the purpose of comparison. It is shown herein that on these plates, received in November 1943, there has been a considerable improvement in the welding technique employed.

Object of Investigation:

To examine the welding of the two sample plates with welded splash strips and compare with the previous unsatisfactory sample.

PROCEDURE:

1. The plates and welds were given a thorough visual examination.

2. Both samples were photographed in the "as received" condition. Figure 1 shows the untested plate. Welds were numbered 1 to 4 for purposes of identification. Figure 2 shows the tested plate. Welds were numbered 1 to 4 for purposes of identification. In both figures the white rectangles show areas from which macro and micro samples were machined.

3. Sections of the welds were removed, polished, and etched. Figure 3 shows sections of all welds of the untested plate. Figure 4 shows sections of all welds of tested plate.

4. Transverse sections of all welds were examined under the microscope. Figure 5 shows a small crack in a plug weld of the tested plate, originating at an area of lack of penetration at the root of the weld. Figure 6 shows a small crack originating at a slag inclusion at the root of Weld 4 of the tested plate.

Figure 7 shows a typical fusion zone structure between a ferritic weld and the armour plate. Figure 8 is the structure typical of all heat-affected zones. Figure 9 is the typical structure of the transition zone of all welds. Figure 10 is the

(Procedure, cont'd) -

typical structure of the unaffected armour plate.

5. Hardness readings, using a Vickers machine with a 10-kilogram load, were taken on all welds and heat-affected zones. The averages of four readings in each case are given below:

FERRITIC WELDS		AUSTENITIC WELDS		NORMAL ARMOUR PLATE
Weld Metal	Heat-Affected Zone	Weld Metal	Heat-Affected Zone	
247	373-413	183-468	383-530	330

DISCUSSION:

A visual examination of the test plates indicates that the plates were welded from the outside towards the centre. This is good welding technique in that this reduces locked-up stresses. It is also noted that the location of the welds (see Figure 3 and 4) is irregular in that in some cases the weld metal is washed up to the top of the splash strip and in others only 2/3 of the distance. The areas of impact of the tested sample show only short cracks.

As in the previous examination (Report of Investigation No. 1513), there would seem to be considerable variation in welding technique from bead to bead on the same test plate. This is shown by the variation in depth and width of the heat-affected zones. However, it is noted that there is a considerable improvement in penetration and bead contour. It is probable that the variations in the heat-affected zones can be accounted for in variations of welding speed. All fillet welds are greatly improved over those previously examined and there was found only one slag inclusion in the roots of these welds. The extent of these improvements may be best appreciated by comparing Figures 3 and 4 of this report with comparable figures of the previous

(Discussion, cont'd) -

report.

The plug welds also indicate a considerable improvement in welding technique. The average penetration is greater, and slag inclusions at the root of the weld are much smaller. Due to the stress-raising effect of slag inclusions, every effort should be made to eliminate them entirely. On plug welds the procedure recommended in Report of Investigation No. 1513 should be followed and this will eliminate slag inclusions.

A close visual examination of all heat-affected zones and all welds failed to reveal "hard" cracks. This is to be expected, in view of the considerably lower hardness values obtained. In all but one case the hardnesses obtained in the present investigation were considerably lower than in the previous examination. In one case (fired plate, Weld 4) the hardnesses of the heat-affected zones and weld metal (530 and 468 respectively) were comparable to those previously found. In this weld there was a crack originating in a small slag inclusion at the root of the weld. The slag inclusion has acted as a stress raiser, and impact stresses have been absorbed by cracking in the harder-than-normal weld metal. A similar cause and effect was found in the plug weld of the fired plate (Figure 5), which emphasizes the necessity of eliminating the defect.

The structures of the heat-affected zones, fusion zones and transition zones show nothing abnormal.

CONCLUSIONS:

1. The welding technique employed to produce these test plates shows a considerable improvement over that used on previously examined material.

2. The hardnesses of the heat-affected zones in the majority of welds are considerably less than those in the previous report. This has resulted in the absence of "hard" cracks and better ballistic properties. The two welds showing higher hardnesses have both cracked.

3. Plug welds show small slag inclusions at the roots of the weld which have resulted in a crack. The previously recommended technique for these welds will eliminate these defects.

oooooooooo
oooooo
oo

HJN:GHB.

Figure 1.

UNTESTED PLATE AS RECEIVED.

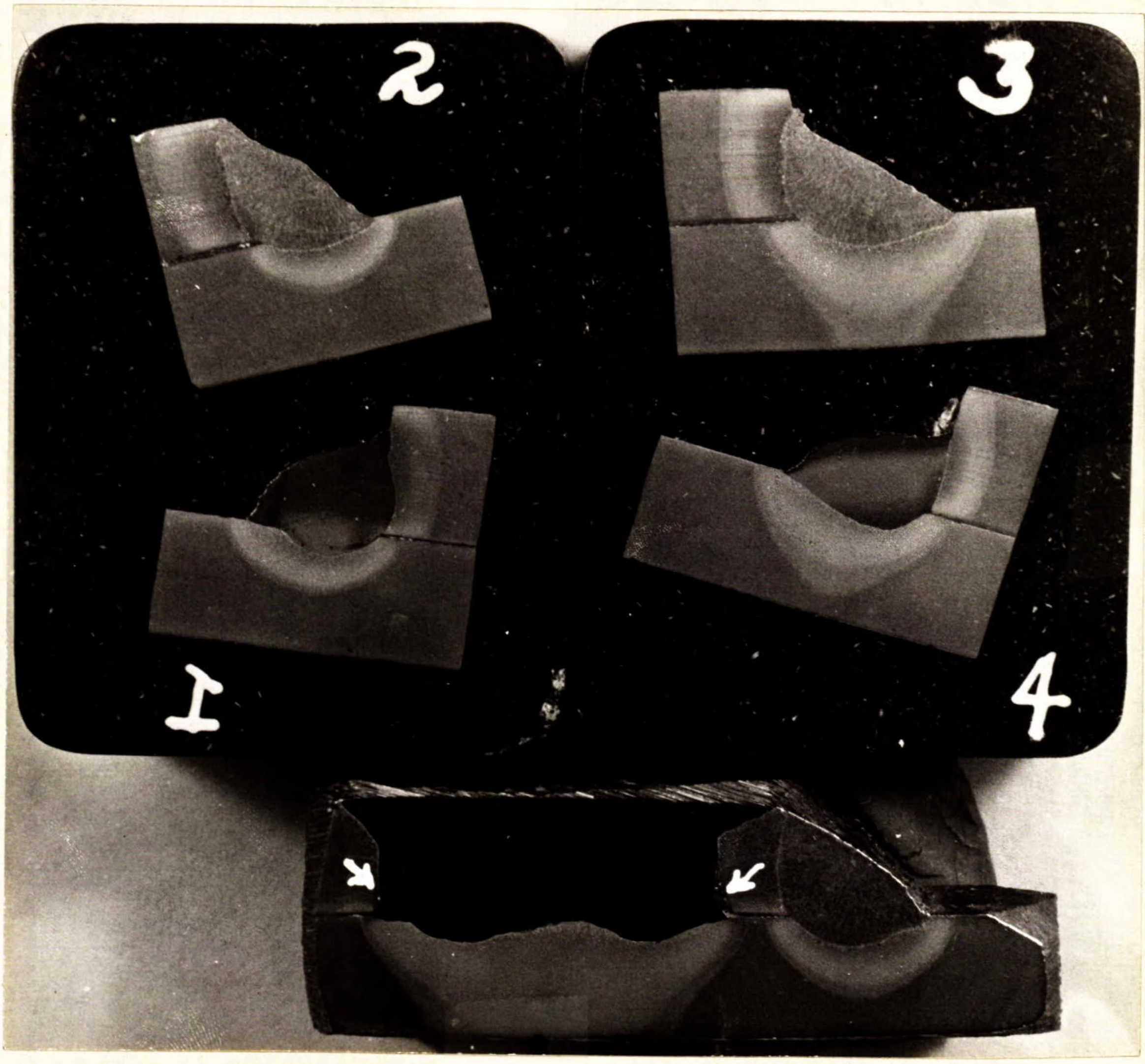
White rectangles indicate areas from which micro and macro samples were machined.

Figure 2.

TESTED PLATE AS RECEIVED.

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

Figure 3.



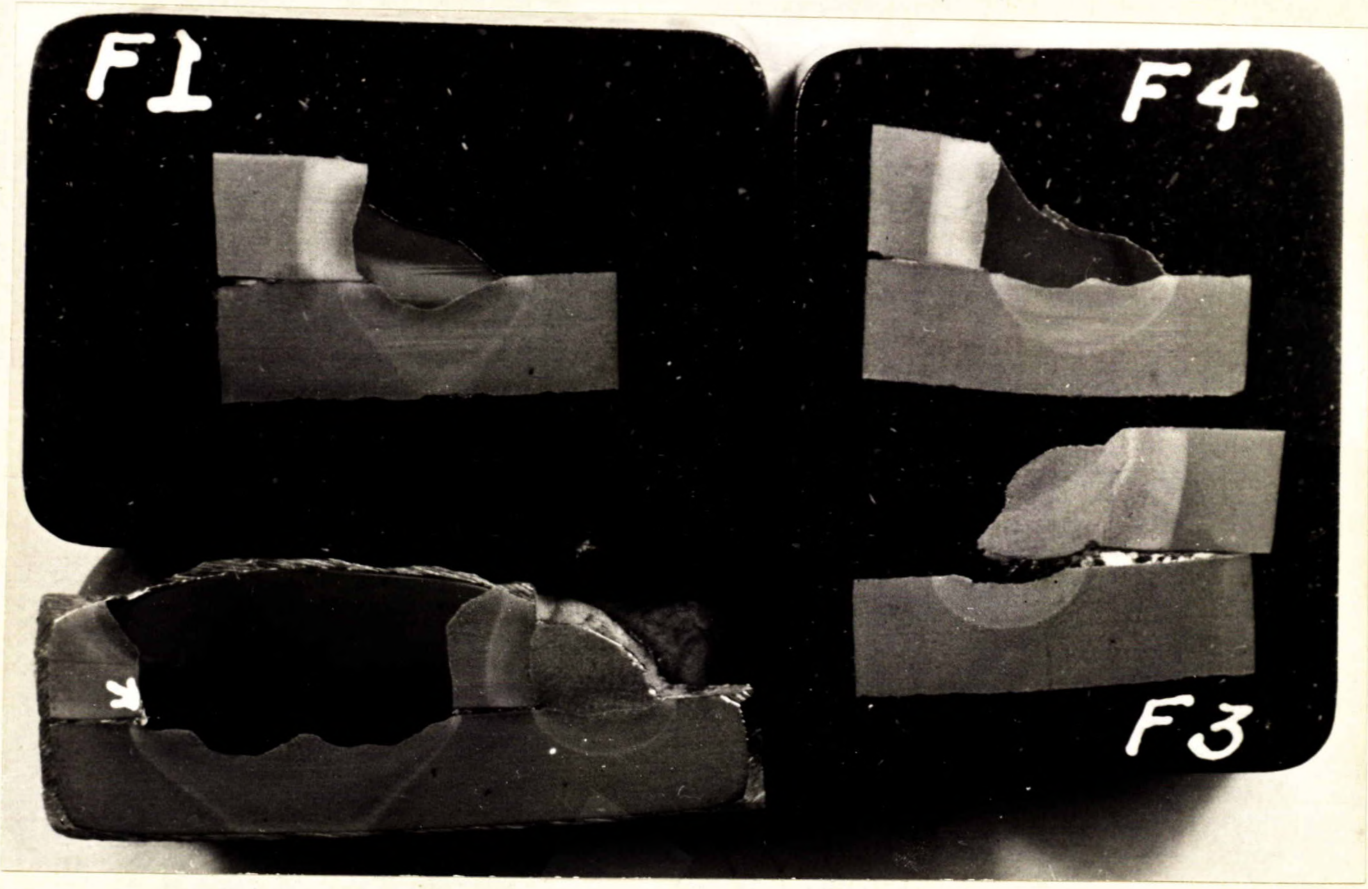
X2, etched in 2 per cent nital.

MACRO SAMPLES OF WELDS OF UNTESTED PLATE.

Note absence of slag inclusions at roots of fillet welds. Arrows point to small slag inclusions at roots of plug weld. Weld contours good.

-

Figure 4.



X2, etched in 2 per cent nital.

MACRO SAMPLES OF WELDS OF TESTED PLATE.
WELD 2, SAME SECTION AS PLUG WELD.

Note absence of slag inclusions at roots of fillet welds. Arrow points to slag inclusion at root of plug weld. Weld location irregular. Note failure of Weld 3 occurred through the fusion line.

Figure 5.

X10, etched in 2 per cent nital.

PLUG WELD OF FIRED PLATE.

Note crack originating at a small slag inclusion at the root of the weld.

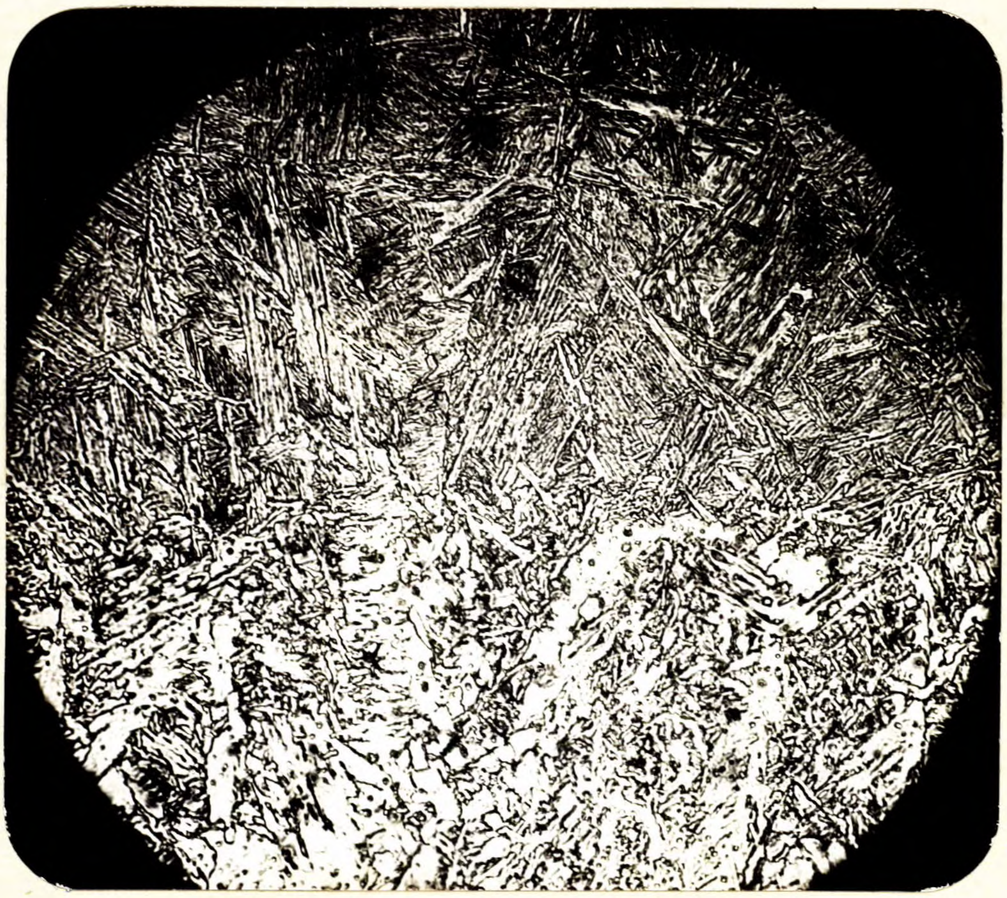
Figure 6.

X50, etched in 2 per cent nital.

WELD 4 OF FIRED PLATE.

Note small crack originating at a small slag inclusion at the root of the weld.

Figure 7.

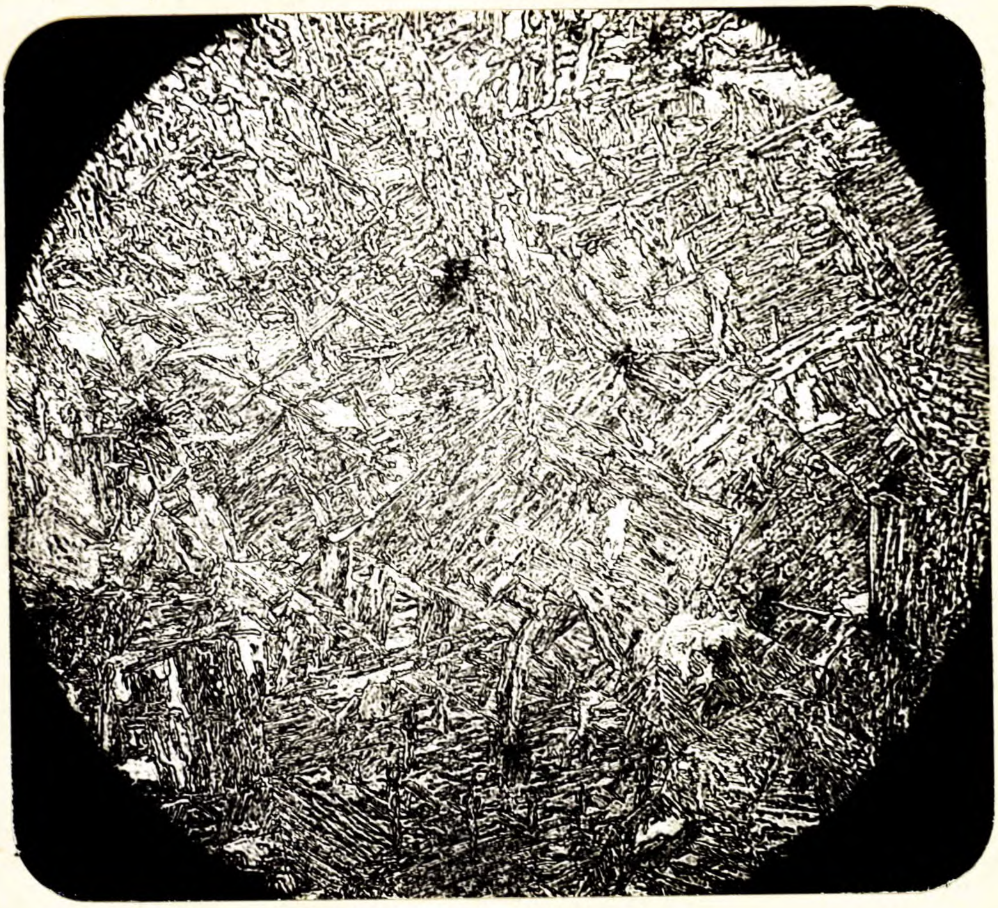


X500, etched in 2 per cent nital.

TYPICAL FUSION ZONE OF A FERRITIC WELD.

-

Figure 8.



X500, etched in 2 per cent nital.

TYPICAL STRUCTURE (COARSE MARTENSITE) OF ALL HEAT-AFFECTED ZONES.

Figure 9.

X500, etched in 2 per cent nital.

TYPICAL STRUCTURE OF TRANSITION ZONES OF ALL WELDS.

Figure 10.

X500, etched in 2 per cent nital.

STRUCTURE OF NORMAL ARMOUR PLATE.
TEMPERED MARTENSITE.

HJN:GHB.