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OTTAWA June 24th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1436.

Examination of Welded Universal Carrier Nose.

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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

OTTAWA June 24th, 1943.

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Investigation No. 1436.

Examination of Welded Universal Carrier Nose.

Origin of Material:

On June 1, 1943, Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, submitted a welded Universal Carrier nose for examination. The nose had failed ballistic tests at the junction of 5-mm. and 10-mm. plates. (Lot No. 616, Requisition No. 470).

In conversation with Dr. Drury on June 10th, it was learned that this nose is hand-welded with Lincoln "Armourweld" electrodes (A.W.30) in seven passes. Two sizes of electrodes, 5/32" diameter and 3/16" diameter, were used with reverse polarity and varying root gap.

The sections submitted for examination revealed that ball ammunition striking near the edge of the weld had passed completely through the 5-mm. plate. Where the ball struck approximately one inch from the edge of the weld the 5-mm. plate had successfully withstood the impact. In no case had the weld metal failed, all fractures occurring in the 5-mm. plate.

Object of Investigation:

To ascertain the reason for extensive ballistic failure at the junction of the 5-mm. and 10-mm. plate.

Procedure:

(1) Figures 1 and 2 show the two sections of carrier nose as received and the general areas of ballistic attack. Figures 3 and 4 are close-up views of typical areas of failure from Sections 1 and 2 respectively.

(2) Micro samples were removed from both sections and identified as shown in Figures 3 and 4. Figure 5 shows four typical samples. The weld metal of each of these samples was tested with a magnet and found to be strongly magnetic.

(3) Hardness tests, using a Vickers machine with a 10-kg. load, were made on each of the above samples in weld metal, 5-mm. and 10-mm. plate. The following table shows the averages of the tests on the four samples:

	5-mm. plate	10-mm. plate	Weld metal
Vickers hardness numbers	363	375	404

(4) Chemical analysis of both 5-mm. and 10-mm. plate showed the following results. A specified analysis is given for comparison.

		5 mm.	10 mm.	Specified Analysis
Carbon	-	0.20	0.26	0.20 - 0.30
Phosphorus	-	0.018	0.010	
Sulphur	-	0.016	0.019	
Manganese	-	0.71	0.60	0.70 - 0.90
Silicon	-	0.57	0.38	0.40 - 0.60
Chromium	-	0.88	0.83	0.80 - 1.10
Nickel	-	0.66	0.69	0.70 - 0.90
Molybdenum	-	0.15	0.10	0.20 - 0.30

(5) All of the above samples were examined under the microscope. Figure 6 shows a typical structure of the weld metal adjacent to areas of ballistic failure.

(6) A chemical analysis sample was machined from the weld metal of Sections 1 and 2. The following table gives the results of the chemical analysis as compared with specified analysis for A.W.3C welding electrodes:

Weld Metal Analysis			Specified Analysis
Carbon	0.10	-	0.07 - 0.14
Manganese	3.00	-	3.50 - 4.50
Chromium	14.95	-	18.70 -20.00
Nickel	8.50	-	8.50 -10.50
Molybdenum	0.08	-	1.10 max.

(7) Sample 1E was examined under the microscope. Figure 7 shows the structure of the 5-mm. plate from the edge towards the centre.

Discussion of Results:

It will be noted from the chemical analysis obtained that the 5-mm. plate, with the exception of the molybdenum content, are within the specified ranges. On the other hand, the 10-mm. plate is slightly low in manganese, silicon, nickel, and molybdenum. It is our opinion that deviations from the specified chemical analysis are of minor importance.

It will be noted from our examination of Figures 3 and 4 that the ball has penetrated the 5-mm. plate but the weld metal itself has not cracked. An examination of Figure 5 confirms that the failure is confined to the thinner plate and, in main, the fractures occur outside of the heat-affected zone.

The micro-examination of all welds show a fine martensitic structure with some retained austenite. That the weld metal is mostly ferritic is confirmed by the magnetic response, and hardness tests. This can only be brought about by dilution of the austenitic weld metal by the plate metal. While the deviation of the chemical analysis of the deposited weld metal from that as specified is small, tests with magnets along the length of the weld indicate that the dilution in some areas at least is considerably greater than in others. The analysis shown of the deposited weld metal is the result of an analysis of a sample taken over a length of 8" of weld. From the analysis of the weld metal obtained it would be expected that it would remain fully austenitic. It is our opinion that the variations over the length of the sample have accounted for an analysis of this type. If it were possible to obtain an analysis from areas through which the ball has penetrated, it is highly probable that this analysis would differ considerably from that shown. This is confirmed by the magnetic response of the microstructure, both of which indicate a ferritic condition.

The variations in the composition of the deposited weld metal along the length of the weld, were confirmed by a magnetic test of iron filings on which the chemical analysis was made. Some of these filings were definitely magnetic whereas others showed no magnetic response at all.

Where the projectile struck approximately one inch from the weld, the ductile 5-mm. plate "dished" and the energy of the impact was absorbed and the plate unpenetrated. On the other hand, where the ball struck close to the weld the 5-mm. plate was penetrated. Here any dishing action is impossible due to the high weld metal hardness and the resistance of the 10 mm. plate. It is possible that if the weld metal had remained austenitic it would have been sufficiently ductile to permit yielding sufficiently to the impact to prevent penetration of the thinner plate.

A visual examination of the welds indicates that there is considerable room for improvement of welding technique. The following defects were found. High piled-up beads (Figure 5, sample 1A), undercutting (Figure 5, sample 1D), poor penetration and gas holes. In addition, all samples in Figure 5 show extensive incomplete fusion at the root gap. It is also apparent that the welds are made in three passes at the most and not seven as reported.

The presence of undercutting, high beads, and incomplete fusion at the root gap might very probably lead to fatigue failure in service, since all of these welding defects act as stress raisers. It is our understanding that such service failures have already been reported in welded vehicles.

It is worthy of note that the 5-mm. plate shows a band of decarburized metal along each surface, approximately 0.017" in depth (Figure 6). While this has probably not contributed to the failure of this plate, it is an undesirable condition which would be expected to lower both ballistic properties and fatigue strength.

Conclusions:

(1) Ballistic failure may be attributed to dilution of the weld metal by the plate metal, resulting in high weld metal hardness and low ductility.

(2) There is room for considerable improvement in welding technique.

(3) Welding defects detected would probably lead to fatigue failure in service.

(4) There is considerable decarburization of the 5-mm. plate.

(5) The welds have been made in two or three passes, not in seven as reported.

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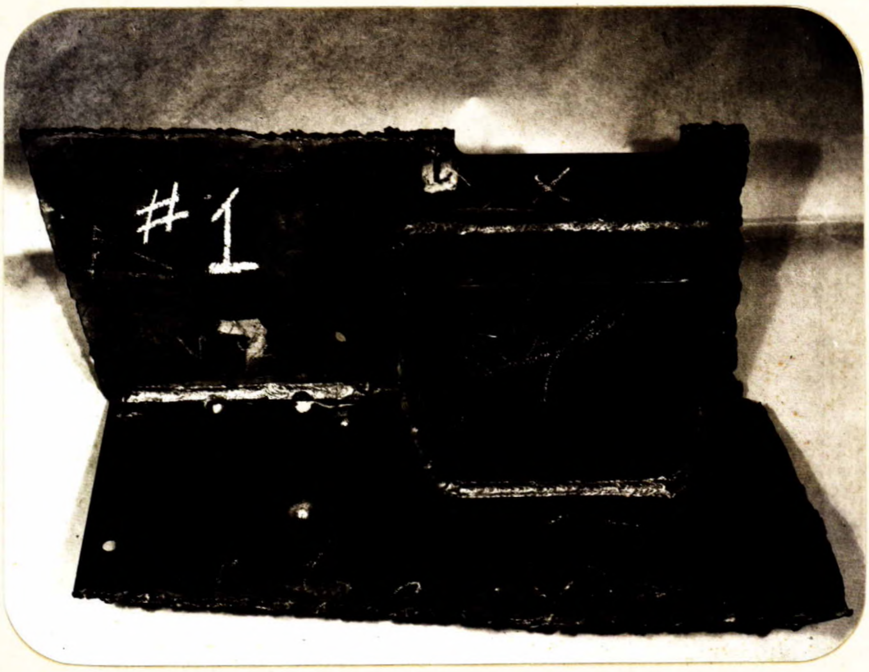
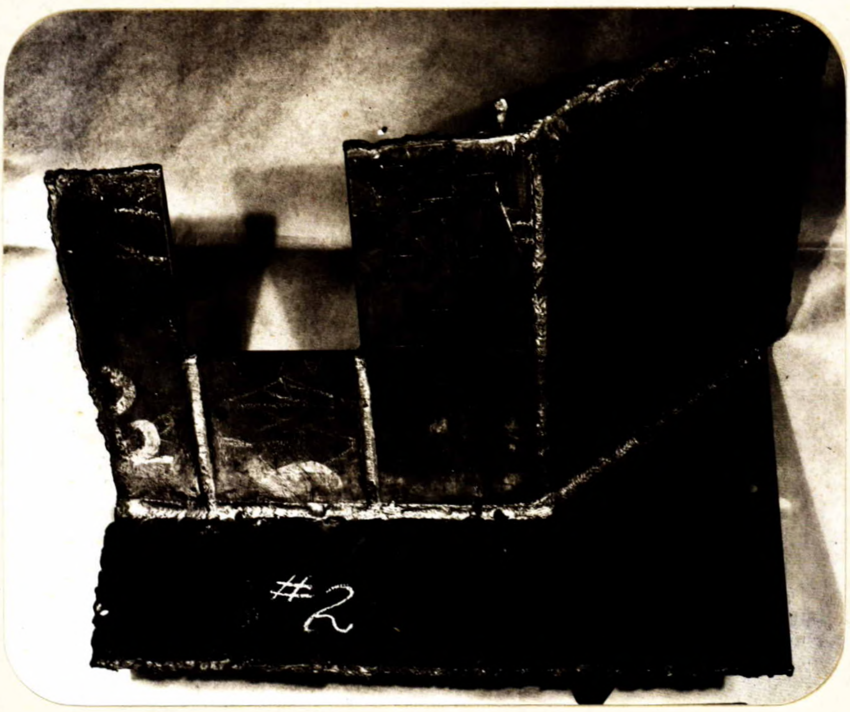
HJN:MMD.

Figure 1.



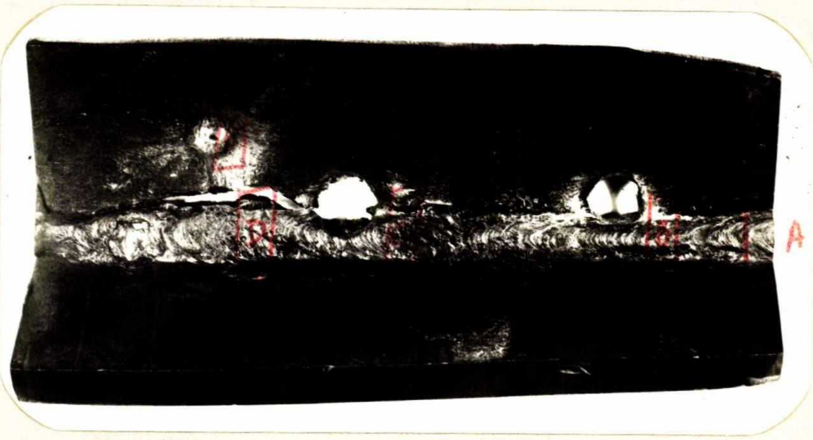
SECTION 1 OF CARRIER NOSE AS RECEIVED, SHOWING GENERAL AREAS OF BALLISTIC ATTACK.

Figure 2.



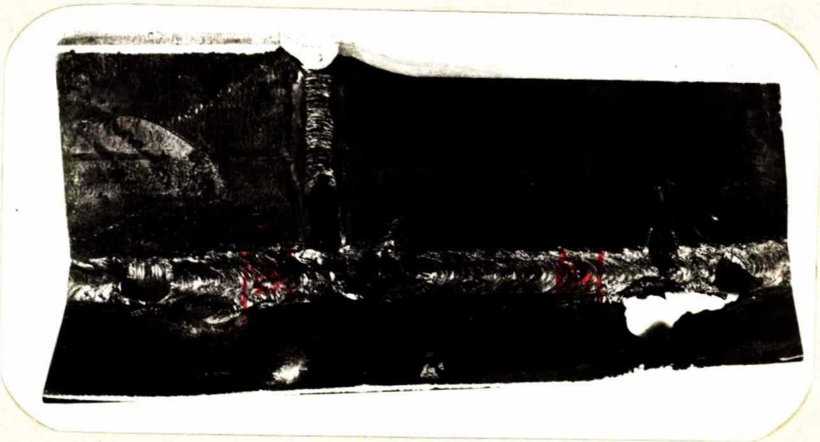
SECTION 2 OF CARRIER NOSE AS RECEIVED, SHOWING GENERAL AREAS OF BALLISTIC ATTACK.

Figure 3.



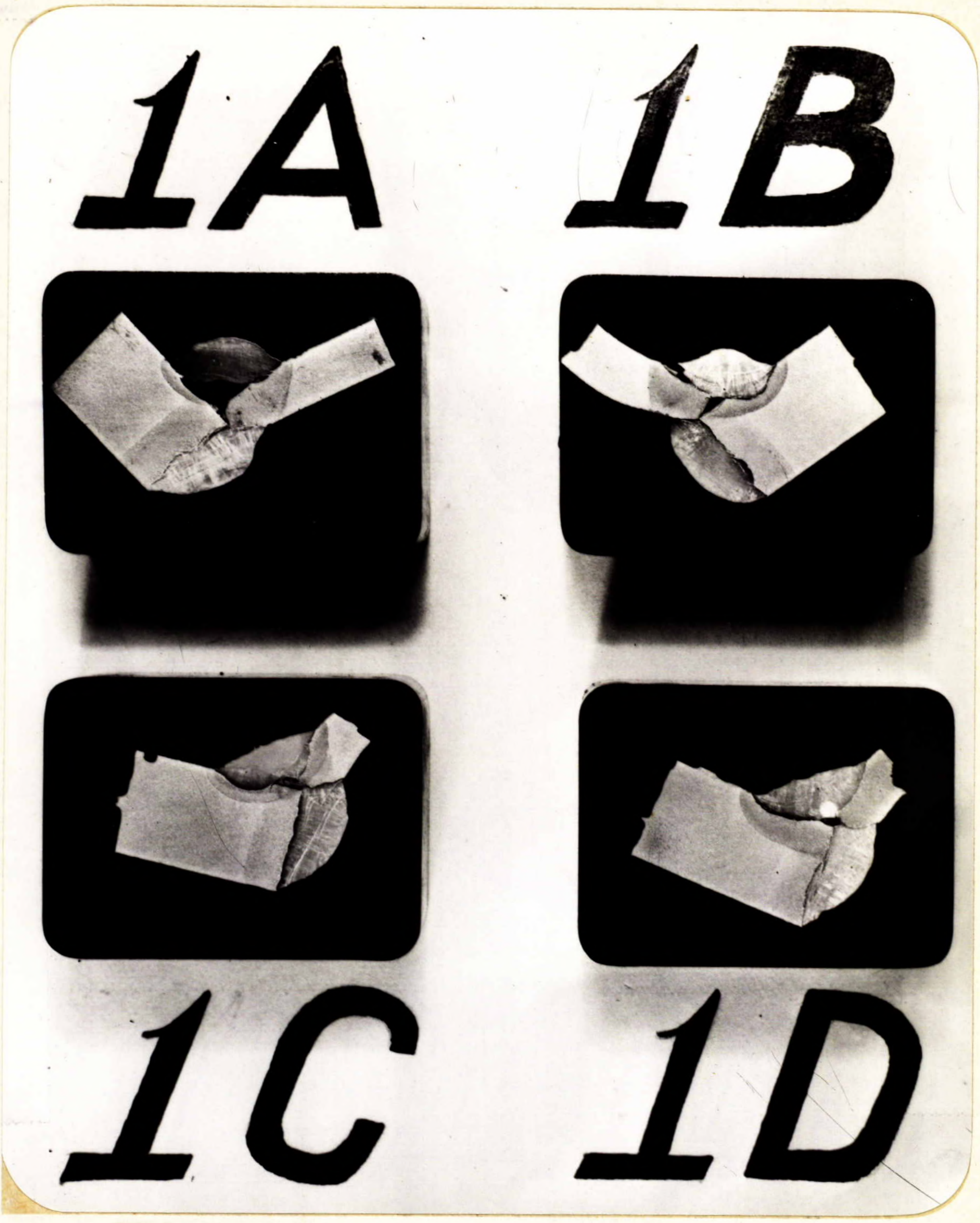
CLOSE-UP OF TYPICAL AREA OF BALLISTIC
FAILURE IN SECTION 1.

Figure 4.



CLOSE-UP OF TYPICAL AREA OF BALLISTIC
FAILURE IN SECTION 2.

Figure 5.

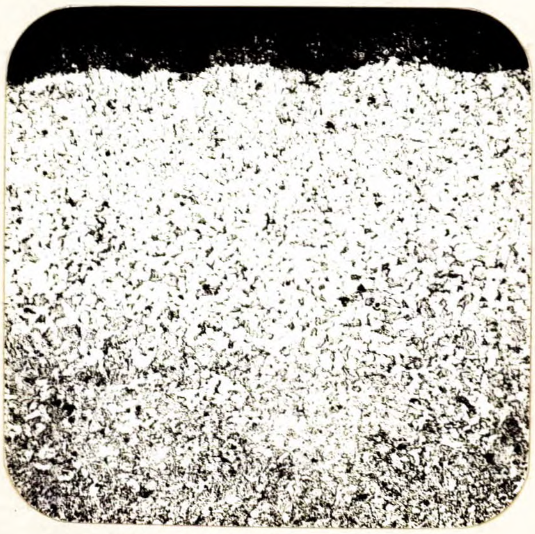


MACRO SAMPLES SHOWING TYPICAL WELDS.
ETCHED IN 1 PER CENT PICRIC ACID,
5 PER CENT HYDROCHLORIC ACID IN
ALCOHOL.

Figure 6.

500X. ETCHED IN 1% PICRIC ACID, 5% HYDROCHLORIC ACID IN ALCOHOL. STRUCTURE: FINE MARTENSITE WITH SOME RETAINED AUSTENITE (WHITE AREAS).

Figure 7



100X. ETCHED IN 20% NITAL. STRUCTURE OF 5-MM. PLATE FROM EDGE TOWARDS CENTRE. LAYER OF DECARBURIZED METAL APPROXIMATELY 0.017" IN DEPTH.

HJN:MMD.