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OTTAWA July 17th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1679.

Examination of Welds of German Scout Car.

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(Copy No. 14.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Examination of Welds of German Scout Car.

Origin of Material:

On May 20th, 1944, a section of bulletproof plate bearing two parts of fillet-welded tapping blocks from a German scout car was submitted by the Division of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario. Requisition No. 648 (Lot No. 540, Report No. 13, Test No. 62) requested that a complete metallurgical examination be carried out on the plates and welds. The examination of the armour plate proper was reported in Investigation No. 1662, dated June 12th, 1944. The present report covers an examination of the welds.

Two samples of flame-cut plate were submitted. One plate was 0.085 inch thick and had a butt weld in the centre. In addition, nuts had been welded to the plate to prevent

(Origin of Material, cont'd) -

slippage of bolts carrying attachments. The second plate, 0.35 inch thick, had been flame-cut so that two parts of tapping blocks still remained attached by fillet welds approximately 1½ inches long.

No information was available as to time and place of capture or as to armour performance. It would appear that the thin plate had been supported approximately 2 inches inside the bulletproof plate and had probably been employed on the spaced armour principle.

Object of Investigation:

To examine the welds with a view to determining welding quality.

Procedure:

1. The samples were first visually examined. Figure 1 shows the bulletproof plate and the parts of tapping blocks with their attaching fillet welds. Figure 2 is from the thinner plate, showing the butt weld in the centre and the hexagonal nuts tack-welded to the plate. Figure 3 shows the opposite side of the thinner plate, showing the butt weld and various bolted attachments.

2. Macro sections of the welds in both plates were secured, mounted, and polished. Figure 4 is the macro section of the fillet weld joining the tapping block to the bulletproof plate. Figure 5 shows a transverse section of the butt weld of the thinner plate.

3. Both macro samples were repolished, etched, and subjected to a microscopic examination. Figure 6 shows the normal structure of the tapping block material and Figure 7 the structure of the heat-affected zone and fusion line. Figure 8 shows the normal structure of the bulletproof plate; Figure 9, the transition zone structure; and Figure 10, the structure of

(Procedure, cont'd) -

the heat-affected zone and fusion line. Figure 11 shows the structure of the weld metal.

4. A maximum of 2½ inches of fillet welds joining the tapping blocks to the bulletproof plate was available for all tests. After removing a macro sample, an attempt was made to secure sufficient weld metal for a chemical analysis. The table below lists the results secured:

Weld Metal Analysis

- Per cent -

Carbon	- 0.20	Nickel	- 5.36
Manganese	- 4.23	Molybdenum	- 0.18
Silicon	- 0.65		
Chromium	- 13.80		

5. Hardness tests were made on the fillet welds of the bulletproof plate, using a Vickers machine and a 10-kilogram load. The table below lists the results secured, each figure being the average of four readings, where a range is not given.

Area Tested	Vickers Hardness Number
Normal bulletproof plate -	473
Heat-affected zone, bulletproof plate -	613-772
Normal tapping block material -	135
Heat-affected zone, tapping block material -	168
Weld metal -	272-360

Discussion:

A visual examination of the samples indicated that all welds were made in a single pass. In the case of the butt weld in the thinner plate, a back-up bar was used but the bottom of the weld showed extensive lack of penetration and poor fusion. In many places fusion had been secured only in the upper 20 per cent of the sheet thickness. The tack welds joining the nuts to the back of this plate are obviously designed to facilitate assembly, in that the nuts themselves

(Discussion, cont'd) -

would be inaccessible in the vehicle. By this means the attachments can be bolted down securely and removed and replaced readily in service.

The fillet welds joining the tapping block to the bulletproof plate are of poor quality. Undercutting is extensive and severe. This indicates the use of inexperienced or indifferent welders and low inspection standards. The use of short fillet welds, rather than welding of the entire periphery of the tapping block, is interesting and may indicate an enforced economy of weld metal. On the other hand, the possibility exists that these welds may be sufficiently strong to secure a particular attachment.

The macro and micro examinations of the weld in the thinner plate indicated the use of a low-carbon ferritic electrode. A crack was found in the root of the weld which probably originated in adjacent areas of lack of penetration and/or poor fusion.

The macro and micro examinations of the fillet welds on the bulletproof plate indicated the use of a low-carbon austenitic electrode. It will be noted, from Figure 4, that penetration of the weld metal into the armour plate is low, and this may be a characteristic of the electrode used, or it may be due to welding speed. A low penetration characteristic is useful in avoiding the dangers of dilution of the weld metal by armour plate material. The structures of the heat-affected zones and the normal materials show nothing unusual. A very definite possibility exists that these structures may be considerably modified by the heat of the flame-cutting process used to secure the samples.

The chemical analysis of the weld metal shows that there is a ratio greater than 2:1 between chromium and nickel and that a manganese modified type of rod has been used. The

(Discussion, cont'd) -

composition, as shown by the analysis, undoubtedly is affected by dilution by the metals being welded. The microscopic examination and hardness tests reveal that the deposited weld metal is partially austenitic and is very close to the border line separating the ferritic and austenitic conditions. The carbon content is higher than is usual but this may be the result of pickup from the armour plate. The very low molybdenum content might be expected to cause root cracking difficulties, although no root cracks were observed in the welds examined.

Although considerably lower in chromium and nickel contents than the electrodes used in this country, it would appear that the deposited metal has been satisfactory in its application to this particular tapping block. The macro sample indicated that the electrode has a low penetration characteristic, and it does not seem likely that dilution of a regular 18/8 type of electrode could have resulted in the analysis secured. However, the use of the same type of electrode, in deep grooves where dilution is a factor to be considered, could easily result in a hard, brittle ferritic deposit. The use of such an electrode in this country would be forbidden. The composition may indicate a growing scarcity of critical alloys and enforced economy of their use.

The hardness tests show unusually high hardnesses with regard to both armour plate and its heat-affected zone. The hardness of the normal bulletproof plate and its composition are such that it would not be considered a readily weldable armour plate in this country. The hardness of the heat-affected zone is in excess of that at which cracking troubles may be expected. There is reason to believe, in the light of experience obtained here, that the ballistic performance of the armour and its welds would fall considerably below our acceptance standards.

CONCLUSIONS:

1. All welds examined are made in a single pass.

2. Welds in thin plate are definitely defective, showing extensive lack of penetration and poor fusion.

3. Welds on bulletproof plate show considerable undercutting and would be unacceptable by our standards.

4. Welds on bulletproof plate have been made with the use of a manganese modified austenitic electrode. The composition of the deposited metal reveals lower chromium and nickel than would be considered suitable here.

5. The hardness of the bulletproof plate is considerably above that which is acceptable in this country. Its composition has resulted in high hardnesses in the heat-affected zones of welding, to a degree which Canadian experience indicates would result in poor ballistic performance.

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Figure 1.

FLAME-CUT BULLETPROOF PLATE
SAMPLE, 'AS RECEIVED'.

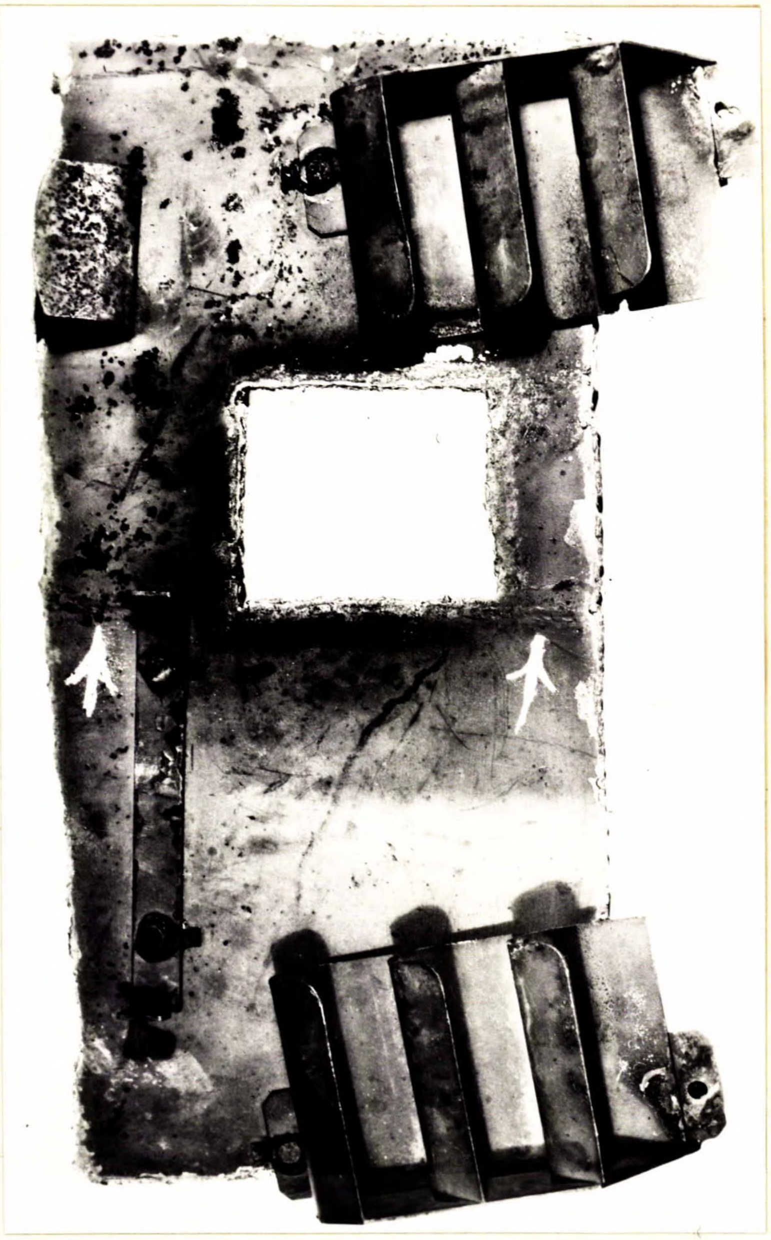
Arrows point to fillet welds joining tapping blocks to armour plate. Note proximity of flame-cut edge to welds examined.

Figure 2.

FLAME-CUT THIN PLATE
SAMPLE, 'AS RECEIVED'.

Arrows point to butt weld in centre. Note lack of penetration. Arrows also point to nuts tack-welded to plate.

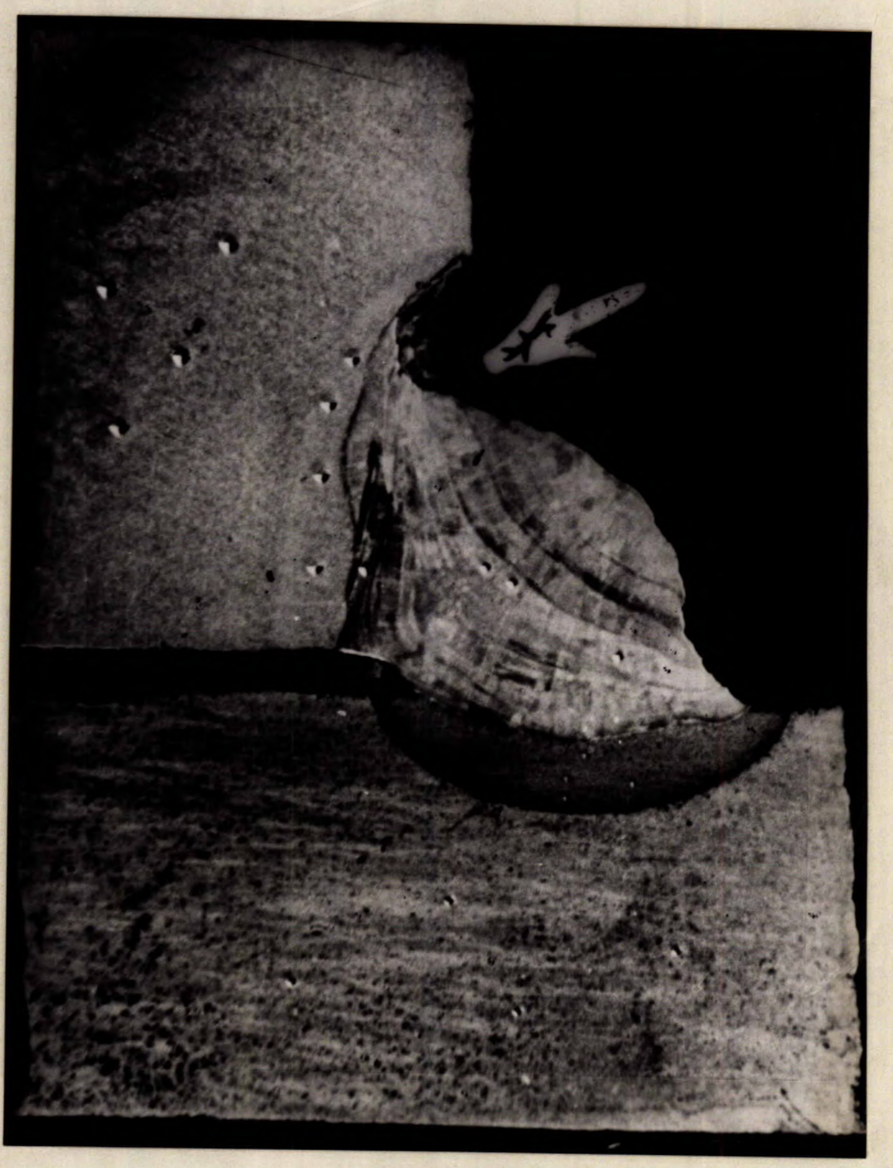
Figure 3.



OPPOSITE SIDE OF THIN PLATE
SHOWN IN FIGURE 2.

Arrows point to butt weld in centre.

Figure 4.

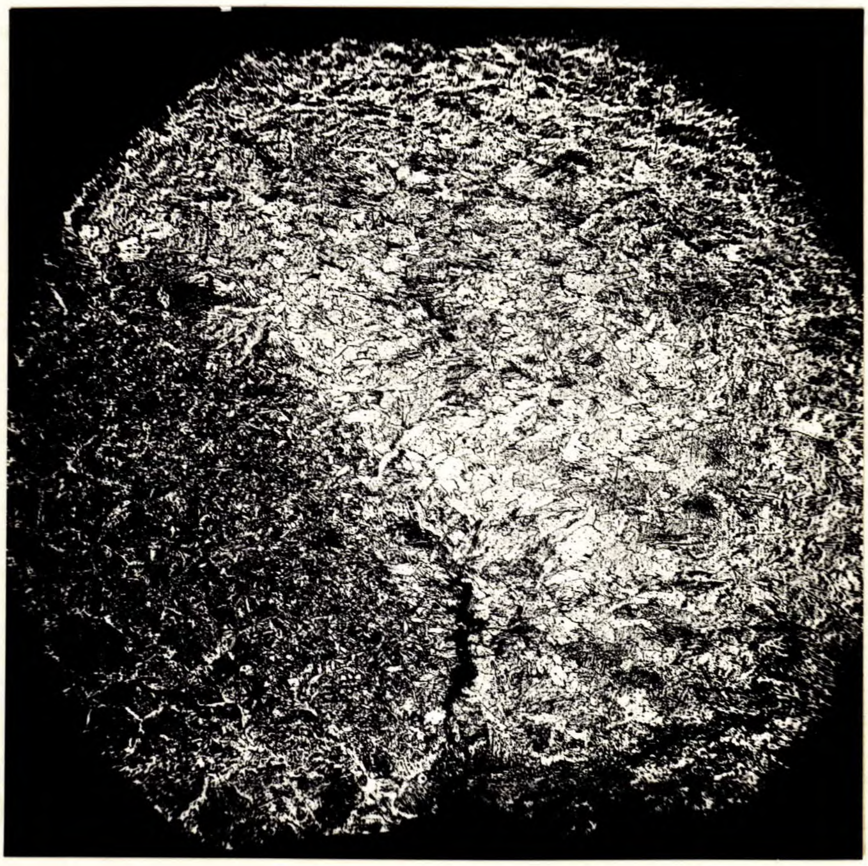


X3, etched in 1 per cent HCl and
4 per cent picric acid in alcohol.

MACRO SECTION OF FILLET WELD JOINING TAPPING BLOCK TO ARMOUR PLATE.

Arrow points to severe undercut partly filled with slag. Note low penetration and narrow heat-affected zone.

Figure 5.

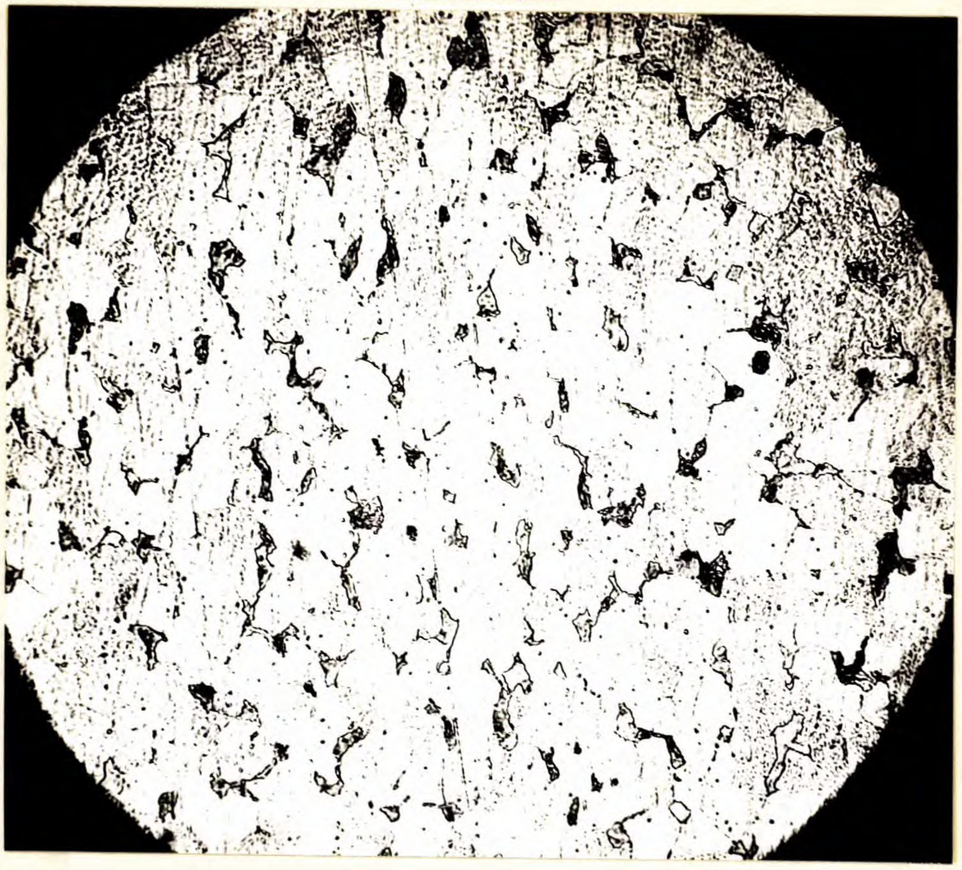


X47, etched in 1 per cent HCl and
4 per cent picric acid in alcohol.

MACRO SECTION OF BUTT WELD IN THIN PLATE.

Note crack at root of weld, probably originating in adjacent areas of lack of penetration and/or poor fusion. Low-carbon welded metal.

Figure 6.



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

NORMAL STRUCTURE OF TAPPING BLOCK MATERIAL.

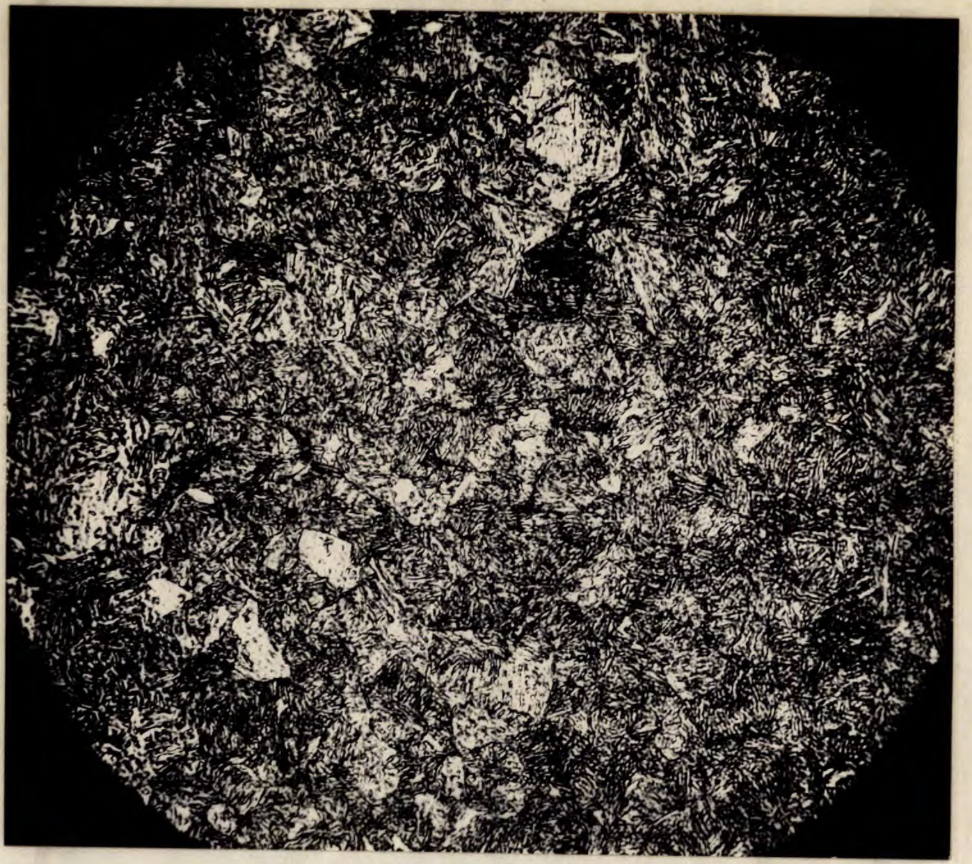
Pearlite in a matrix of ferrite.

Figure 7.

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

HEAT-AFFECTED ZONE (LOW-CARBON MARTENSITE)
AND FUSION LINE OF TAPPING BLOCK MATERIAL.

Figure 8.



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

NORMAL STRUCTURE OF BULLETPROOF PLATE.

Tempered martensite.

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Figure 9.

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

TRANSITION ZONE OF BULLETPROOF PLATE.

Note spheroidizing effect on carbides.

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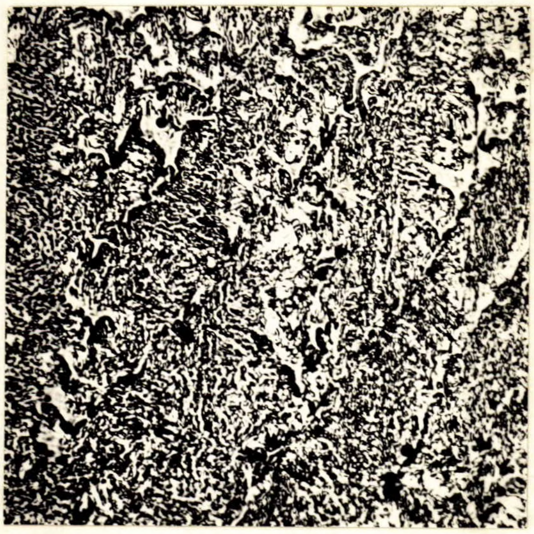
Figure 10.

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

STRUCTURE OF HEAT-AFFECTED ZONE (COARSE,
TEMPERED MARTENSITE) AND FUSION LINE
OF BULLETPROOF PLATE.

Figure 11.



X500, etched in 1 per cent HCl and
4 per cent picric acid.

STRUCTURE OF WELD METAL.

Hyper-eutectic cementite in a matrix of austenite.

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