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OTTAWA September 18th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1495.

Examination of Three Welded Armour Plate Sections
(Sponson Plate to Side Plate).

(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 September 18th, 1943.

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1495.

Examination of Three Welded Armour Plate Sections (Sponson Plate to Side Plate).

Origin of Material and Object of Investigation:

On August 23rd, 1943, three sections of welded sponson plate to side plate were submitted to these Laboratories for examination. The accompanying Requisition No. 497, A.E.D.B. Lot No. 656, Report No. 13, from Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, gave the following information:

> Three specimens were welded and prepared by a representative of the Inspection Board of United Kingdom and Canada and forwarded to Chief, Ore Dressing and Metallurgical Laboratories, 552 Booth Street, Ottawa, by the Inspection Board of United Kingdom and Canada as per arrangements made with Division of Metallurgy, Army Engineering Design Branch. The three welded specimens are described as follows:
>
> 1. Cut specimen from a damaged part of Hull No. 62 which failed in the ballistic test. This specimen may be in two parts.
>
> 2. Cut specimen from a sub-assembly which withstood successfully the ballistic attack. This specimen may be in two parts.
>
> 3. Portion (intact) of a sub-assembly which withstood successfully the ballistic attack.

(Continued on next page)

(Origin of Material and Object of Investigation, cont'd) -

In Requisition No. 497, request was made for the following:

1. Examination of weld, depth and extent of penetration, hardness and extent of hardened zone, plate adjacent to hardened zone, and also body of plate.

2. Examination of welded portion of plate for inclusions and rolling defects.

3. Physical tests.

4. Microscopic examination for constituents, expecially ferrite.

5. Chemical analysis of portion of weld metal and plate.

The object of the investigation is to advance an explanation of the cause of failure in weld, adjacent zone or plate.

Macro-Examination:

Figure 1 is a photograph of the three specimens as received. The two first speciments were each in two pieces and Specimen No. 3 was in one piece. This photograph shows, also, where the sections for examination were cut.

The Unionmelt weld of Specimen No. 1 showed pronounced waving. Two types of fracture were distinguished. Figure 2 shows a section where failure occurred in the hand weld. The penetration of weld metal and extent of the heat-affected zones are also represented, by means of macro-etching in a solution of 10 per cent ammonium persulphate. (These conditions are shown in Figures 2 to 5 inclusive). The section shown in Figure 2 was taken from location D on Figure 1.

Figure 3 shows another type of fracture (observed

(Macro-Examination, cont'd) -

at C in Figure 1) in Specimen No. 1. This one occurred in the transition zone from the heat-affected to the normal plate metal, in the sponson plate. There was no indication of bullet proofing in this specimen, so that no conclusion could be drawn as to where the fracture originated.

The Unionmelt weld of Specimen No. 2 was much smoother externally than Specimen No. 1. Two types of fracture were observed here also. In the vertical section struck by the bullet, fracture occurred entirely in the weld metal itself. This position is represented at E in Figure 1. The other fracture ran practically through the weld metal and the sponson plate. This section (represented at B in Figure 1), and the section containing the first fracture, are shown in Figure 4, both being macro-etched in 10 per cent ammonium persulphate.

In Specimen No. 3, the Unionmelt weld also had a smooth exterior appearance. A section, taken at A in Figure 1, is shown in Figure 5. The abnormal extent of the width of the upper part of the weld metal, and its small depth, together with a stringer of unfused parent metal in the sponson plate, are the most striking features of this section.

Chemical Analysis:

A chemical analysis of each plate, as well as of the Unionmelt weld metal and the manual weld metal, was made for each specimen.

The results are tabulated as follows:

(Continued on next page)

(Chemical Analysis, cont'd) -

The Two Plates.

Element	Sponson Plates			Side Plates		
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
Carbon	0.30	0.27	0.27	0.26	0.28	0.30
Manganese	0.76	0.63	0.62	0.43	0.65	0.60
Silicon	0.44	0.50	0.52	0.24	0.31	0.31
Sulphur	0.022	0.016	0.014	0.022	0.012	0.022
Phosphorus	0.017	0.013	0.013	0.020	0.027	0.024
Chromium	1.29	0.90	0.90	2.02	2.04	1.93
Nickel	0.82	0.82	0.80	0.71	0.65	0.77
Molybdenum	0.18	0.16	0.15	0.23	0.20	0.32

The Two Weld Metals.

Element	Unionmelt Weld			Manual Weld		
	No. 1	No. 2	No. 3	No. 1	No. 2	No. 3
Carbon	0.23	0.23	0.23	0.13	0.11	0.11
Silicon	0.64	0.65	0.69	-	-	-
Manganese	4.40	4.25	4.22	3.90	1.70	1.71
Sulphur	0.020	0.012	0.019	-	-	-
Phosphorus	0.023	0.034	0.014	-	-	-
Chromium	8.25	7.56	7.64	15.22	14.39	14.88
Nickel	9.24	8.03	7.96	8.07	8.43	7.71
Molybdenum	0.10	0.12	0.14	-	-	-

Hardness Measurements:

On each sponson plate and side plate, a hardness survey was run from the fusion line perpendicularly to the tangent of the heat-affected zone.

The curves showing the variations of the Vickers hardness number (ordinates) with the distance from the fusion line (abscissae) are given in Charts Nos. 1, 2 and 3 (see Pages 4a, 4b, and 4c).

In the weld metal itself, hardness measurements were made on the Unionmelt bead as well as on each of the different beads of the hand weld. These latter beads are referred to as Nos. 1, 2 and 3, according to the order of deposition.

In Specimen No. 1, the hardness in the Unionmelt

(Charts Nos. 1, 2 and 3 follow,)
(on Pages 4a, 4b, and 4c.)
(Text continues on Page 5.)

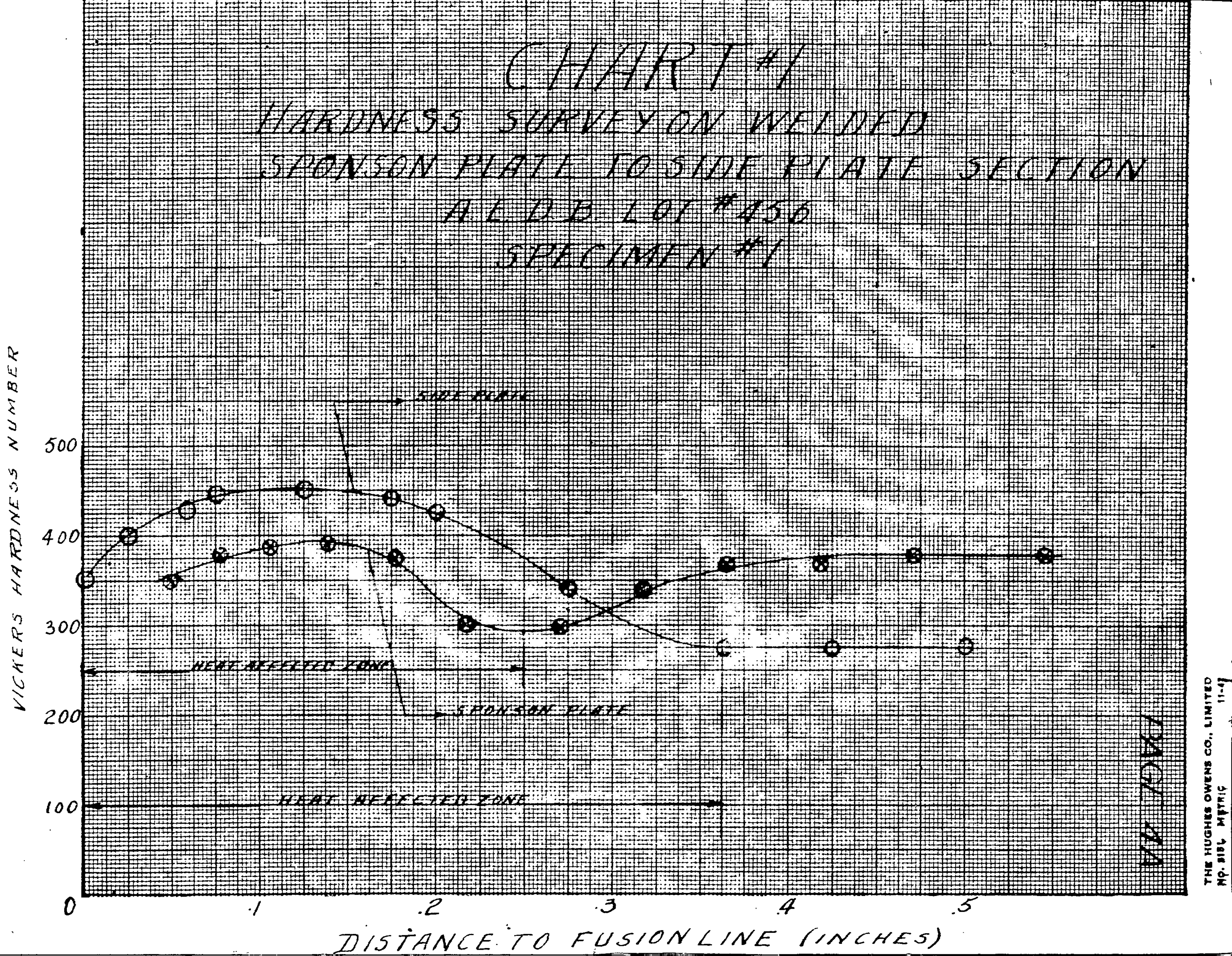


CHART #1
HARDNESS SURVEY ON WELDED
SPONSON PLATE TO SIDE PLATE SECTION
A.L.D.B. LOT #436
SPECIMEN #1
SIDE PLATE
HEAT AFFECTED ZONE
SPONSON PLATE
HEAT AFFECTED ZONE
VICKERS HARDNESS NUMBER
500
400
300
200
100
0
.1
.2
.3
.4
.5
DISTANCE TO FUSION LINE (INCHES)
PAGE 4A
THE HUGHES OWENS CO., LIMITED
NO. 3181 METRIC
11-4

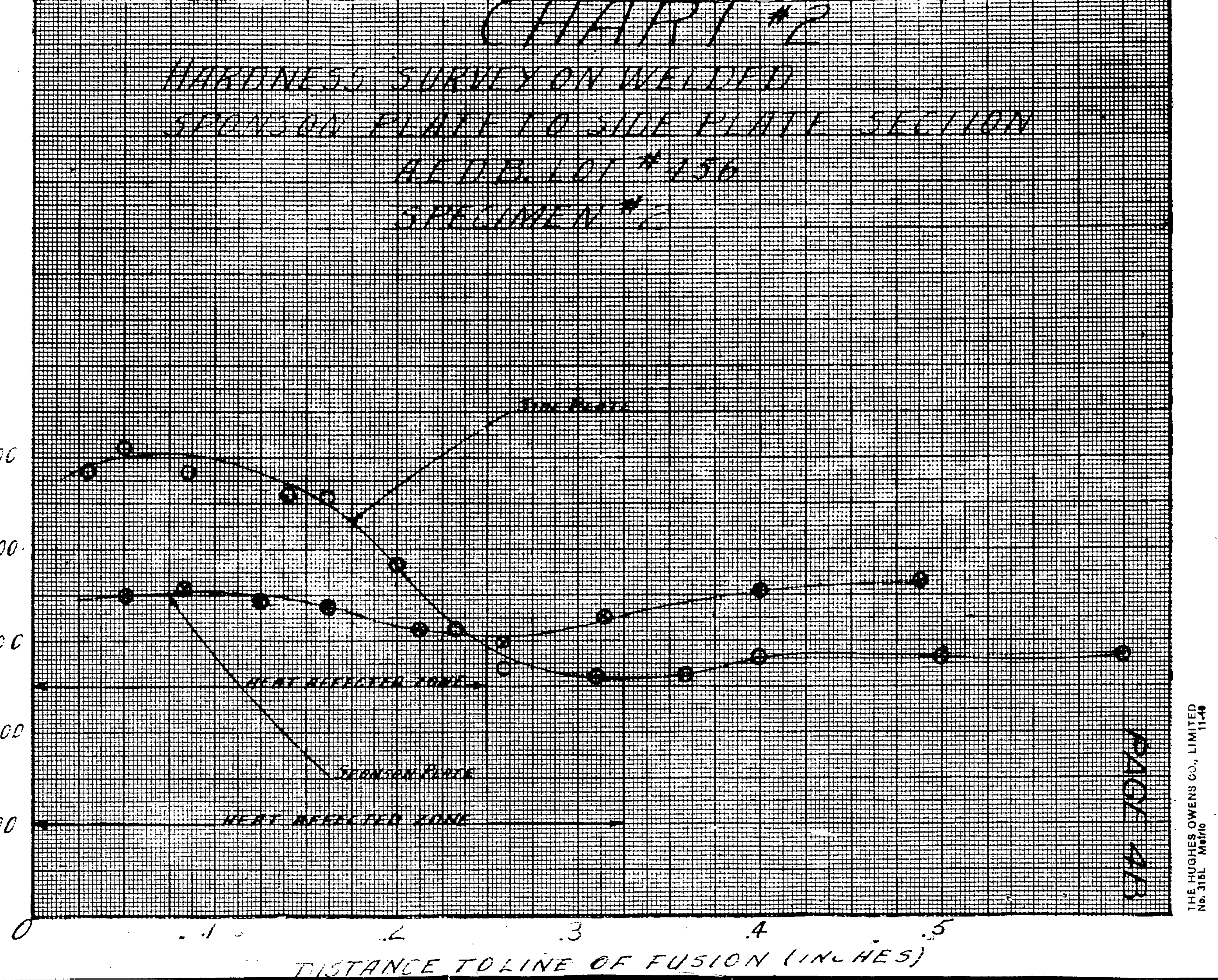


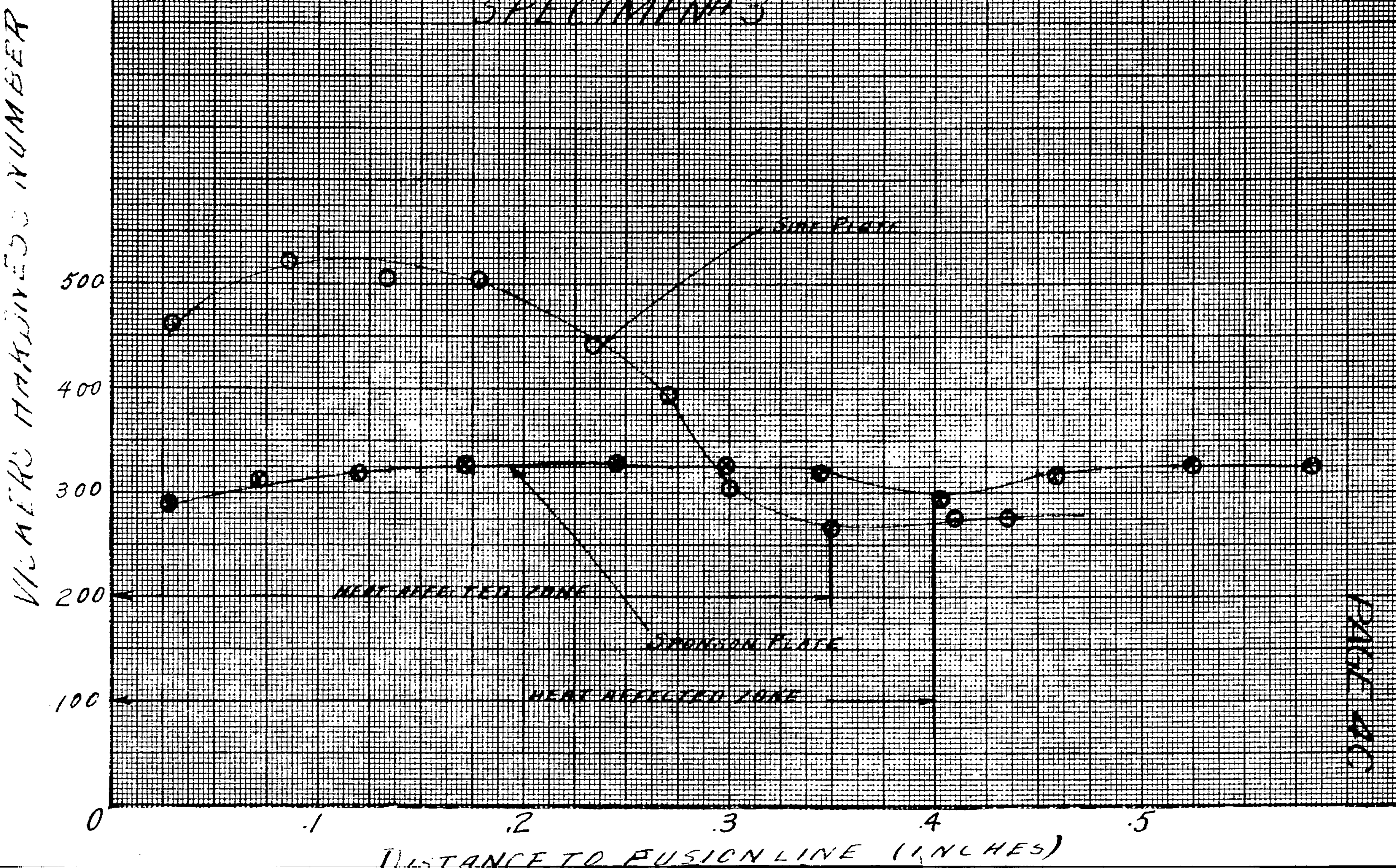
CHART #2
HARDNESS SURVEY ON WELDED
SPONSON PLATE TO SIDE PLATE SECTION
A.E.D.B. LOT #156
SPECIMEN #2
SIDE PLATE
SPONSON PLATE
HEAT AFFECTED ZONE
HEAT AFFECTED ZONE
VICKERS HARDNESS NUMBER
500
400
300
200
100
0
.1
.2
.3
.4
.5
DISTANCE TO LINE OF FUSION (INCHES)
PAGE 4B
THE HUGHES OWENS CO., LIMITED No. 315L Metric 11-40

CHART #3

HARDNESS SURVEY ON WELDED SPONSON PLATE TO SIDE PLATE SECTION

H.E.D.B. LOT #456

SPECIMEN #3



PAGE 4C

(Hardness Measurements, cont'd) -

bead near fracture was 301 V.H.N. However, the average hardness in this bead was 260 V.H.N. The manual weld beads were uniform in hardness, and measurements gave a result of 196 V.H.N. on the average.

In Specimen No. 2, a hardness of 358 was recorded near the fracture in the Unionmelt bead. The average hardness of the bead was 260 V.H.N. In this case, the hand beads were 212 V.H.N. on the average.

In Specimen No. 3, the Unionmelt bead was 260 V.H.N. in hardness, while Nos. 2 and 3 hand beads were 197 V.H.N. However, in the No. 1 hand bead the hardness was 464 V.H.N.

Magnetic Measurements:

Small cylindrical bars (1 inch high and $\frac{1}{4}$ inch in diameter) were machined from the Unionmelt bead and the manual bead in each of the specimens. Magnetic measurements were made on these bars on a deflectometer. This apparatus does not give measurements in standard units and is merely comparative.

The deflections observed were as follows:

			Unionmelt Bead	Manual Bead
Specimen	No. 1	-	0	0
"	No. 2	-	0.7	1.2
"	No. 3	-	0.9	0.3

Impact Measurements:

Since the chemical analyses and hardnesses of the sponson plates were different, impact measurements were made to check on the relative toughnesses. Since the thickness of the plate is only 3/8 inch, the bar for the Izod impact test could not be machined according to standard dimensions. Right-angle prisms with base dimensions of 3/8 inch and 7/16

(Impact Measurements, cont'd) -

inch were machined, the notch being made in the thicker section. The values obtained are not the actual impact strengths but are very close to the true figures.

The results were as follows:

Specimen		Foot-pounds
No. 1	-	11
No. 2	-	45
No. 3	-	14

The fractures of Specimens Nos. 1 and 3 were fibrous, while the fracture of Specimen No. 2 was uniformly fine-grained.

Micro-Examination:

Each section of the different specimens submitted was examined microscopically.

In each case a photomicrograph was taken, in the sponson plate and in the side plate, of each of the following zones:

(1) In the heat-affected zone (close to fusion line). See H.A.Z. (Column I).

(2) In the transition zone (from the heat-affected zone to the normal structure). See T.Z. (Column II).

(3) In the normal structure of the plate itself. See N.S. (Column III).

The following table shows each figure number as referred to:

PLATE	FIGURE		
Column No. -	I	II	III
Zones -	H.A.Z.	T.Z.	N.S.
Sponson Plate No. 1	6	7	8
Side " No. 1	15	16	17
Sponson " No. 2	9	10	11
Side " No. 2	18	19	20
Sponson " No. 3	12	13	14
Side " No. 3	21	22	23

For this examination, the specimens were hand-polished

(Micro-Examination, cont'd) -

and then etched in 4 per cent picral.

In the examination of the different beads of the weld metal itself, hand polishing was also adopted. The etching was done in a 5 per cent hydrochloric, 1 per cent picric alcoholic solution.

A. Specimen No. 1 -

Figure 24 shows a precipitation of carbides at the grain boundaries of the austenite in the Unionmelt bead. This type of microstructure was observed near the fracture in Section No. 1-D (c.f. Figure 1).

Figure 25 shows a precipitation of carbides on the slip planes of the austenite. This condition was present in the Unionmelt bead near the fusion line connecting with the side plate.

Figures 26, 27, and 28 all refer to a crack which was found to run all along the Unionmelt bead. Figure 26 shows the connection of this crack and the first deposited hand bead. Figure 27 shows a typical section of the crack where the shrinkage nature of the defect is evident. Figure 28 shows how this crack occurs only in the Unionmelt bead, at the surface formed by intersection of two sets of cleavage planes.

Figure 29 was taken at the fusion line of the weld metal. It shows a typical example of martensite in austenite. This condition was found in all the specimens at the same location, in the automatic as well as in the hand welds.

B. Specimen No. 2 -

Figure 30 shows the austenite and martensite structure near fracture. Figure 31 shows a typical example of cored austenite in the last deposited hand bead. This structure was

(Micro-Examination, cont'd) -

observed to have very close analogy with Nos. 1, 2 and 3 hand beads in Specimen No. 3.

C. Specimen No. 3 -

Figure 32 shows a typical example of austenite and martensite in the No. 1 hand bead. In the automatic bead few patches of martensite in austenite were found. This condition was shown in Figure ~~24~~ 33. A comment can be made at this point, namely, the quantity of martensite was found to check very closely with the magnetic measurements.

DISCUSSION OF RESULTS:

Specimens As Received, and Macro Sections -

Failure in Specimen No. 1, at first sight, can be attributed to defects in the weld metal or in the sponson plate itself.

Fracture in Specimen No. 2 originated in the weld metal, as shown in Figure 4 (Specimen No. 2-E).

The external appearance of the Unionmelt weld, as well as of the sections shown in Figures 2 to 5, has led to the following conclusions regarding the welding technique used (these observations are not given as definite defects, but to indicate the trends in procedure):

Specimens Nos. 1 and 2 likely were produced by (a) high welding speed, and (b) low energy input per linear inch (as shown by depth of ripples and weld contour).

Specimen No. 3 was welded with low welding speed and high energy input per linear inch (as shown by abnormal width of weld metal at the top and small depth of penetration.

As to the hand beads, the penetration and the disposition of the beads in Specimen No. 1 are very satisfactory. In

(Discussion of Results, cont'd) -

Specimens Nos. 2 and 3 the first bead shows excessive penetration, for the size of the bead, into the parent metal (side plate). This condition has brought about excessive dilution which, in turn, has resulted in a martensitic condition in the steel. This is confirmed by the hardness and magnetic response as well as the microscopic examination.

Chemical Analysis -

The chemical analyses of the side plates are normal and no explanation as to different behaviours can be found there.

The compositions of the sponson plates Nos. 2 and 3 are almost identical and are different from the No. 1 sponson plate only in the chromium and manganese contents. The higher chromium and manganese contents naturally increase the hardenability and lower the weldability, but no very important different behaviour can be expected since the differences are small.

The Unionmelt weld metal in Specimen No. 1 indicates less dilution than in Specimens Nos. 2 and 3. The critical dilution value seems to have been exceeded in these two last specimens and this would explain the martensite found in them.

The hand weld metal shows the same characteristic. More alloy is present in Nos. 2 and 3.

Magnetic Measurements -

The first comment applies to the method of sampling. In the present case, no attempt was made to have a sample which would reveal all traces of martensite in the whole section. Drillings taken all over the section of the weld metal would apparently give more general results, but the conversion of γ-iron to α-iron by excessive cold working would make this method of sampling quite faulty.

The method used herein provides a means of determining

(Discussion of Results, cont'd) -

only the martensite which happens to be within the bar taken for sample. However, the deflections are quite proportional to the amounts of martensite found in each case.

Hardness Surveys -

No special comments apply to the hardness surveys made on the plates. It is quite evident that the hardness increase is more pronounced in the side plate than in the sponson plate, but this is normal since the hardenability of the latter is greater and the mass effect greater. At the same time, it will be noticed that Sponson Plate No. 1 has a greater jump in hardness than Plates Nos. 2 and 3, and the same explanation covers this phenomenon.

It will be also observed that these hardness curves do not indicate any tendency to develop those root or toe cracks well known to the welding engineers. In fact, no defects of this type were found in the specimens submitted.

Impact Tests -

The impact results given here are quite significant, although the values are not real impact strength and represent only about 85 per cent of the true value.

However, it is remarked that these values are definitely too low in the case of Sponson Plates Nos. 1 and 3. Reference to Figures 7, 10 and 13 will bring out the correlation between banded structures and low impact value. This argument, moreover, is well supported by the three types of fracture. The fibrous fractures of Specimens Nos. 1 and 3 are well in accordance with the banding effect observed.

(Continued on next page)

(Discussion of Results, cont'd) -

Microscopic Examination -

The Sponson Plate.

The microscopic examination of the sponson plate has shown that the excessive heating has produced a large grain growth in the heat-affected zone. The structures shown in Figures 6, 9, and 12, of the coarse Widmanstatten type, are obtained by cooling at intermediate rates from high temperatures. Of course, these structures are definitely brittle. The width of the heat-affected zone containing this structure can be reduced by proper control of the energy input per linear inch of weld.

The transition zone shows a marked precipitation of ferrite. In Specimens Nos. 1 and 3 (Figures 7 and 13) the banding effect due to lack of homogeneity is well brought out. The detrimental effects on the toughness of the plate have already been noted. This heavy precipitation in this zone is one of the most important factors of the present problem. While it is accepted that ferrite must precipitate between the two criticals, the problem arises of whether it is possible to minimize the ferrite growth by shortening the time during which the steel is between the two criticals. This problem has not yet been solved and a study will be undertaken in these Laboratories of the influence, upon ferrite growth, of the time interval between the two criticals. As a matter of fact, higher alloy would appear to be less subject to the effect of ferrite growth but, on the other hand, one must always keep in mind the fact that increasing the alloy content would mean a higher hardenability and lower weldability.

The normal structures of the sponson plates are sorbitic and they do not show any marked differences.

Side Plates.

With regard to the side plates, the structures in the heat-affected zones are quite similar, so far as the areas near

(Discussion of Results, cont'd) -

Microscopic Examination, cont'd -

the fusion lines are concerned, to those of the sponson plate. However, they differ from the region of the transition zone. Higher hardness levels in heat-affected zones outside of the fusion zones correspond to structures ranging from martensite to bainite. No attempt was made to definitely identify different structures present. (An easier means of determining the danger of brittleness developed in welding is the hardness survey in the heat-affected zone.)

In the transition zone the ferrite precipitation is still characteristic; however, it is less dangerous than in the sponson plate, the zone being thinner and the section stressed during the ballistic test being of larger area. The normal structures of the plates which show tempered martensite are satisfactory and are similar.

Unionmelt Weld.

The Unionmelt bead in Specimen No. 1 was found to have two major defects. First, a crack was found to run all along the weld as received. This crack (Figure 28) existed prior to the laying down of the first hand bead (see Figure 26). The crack is of the common shrinkage type, as is well shown in Figure 27.

The other defect is the existence of carbides at the grain boundaries of the austenite (see Figure 24). This condition is known to have a detrimental effect on the strength and toughness of the material. The occurrence of carbides at the grain boundaries is due either to slow cooling or to the annealing effect given during the subsequent hand welding. In any case, it is proportional to the dilution resulting in increased precipitation of carbides.

No martensite was found in the weld except at the fusion line. Here, from a geometrical standpoint, the advantage of a V-shaped ending of section (as in Figure 5) over a straight

(Discussion of Results, cont'd) -

Microscopic Examination, cont'd -

ending (as in Figure 4) should be noted. Where a hard zone runs perpendicular to the sponson surface any impact will readily cause a failure through this zone. In the case of a hard zone following a V shape, failure on impact is much less probable. The carbide precipitation in the slip planes (see Figure 25) may be due to a drastic cooling caused by the chilling effect of the side plate.

In Specimen No. 2, martensite was found in the Unionmelt bead and near the fracture (see Figure 30); it is well known that this condition has an embrittling effect on the steel, and fracture might very well be attributed to this defect.

Martensite found in this type of welding is caused by dilution, which decreases the alloy content. Only a proper control of this dilution can make the steel retain its austenitic condition.

In Specimen No. 3, isolated patches of martensite were found in this bead (see Figure 32).

Manual Bead.

In Specimen No. 1 no defects were found in the manual beads.

In Specimen No. 2, patches of martensite due to excessive dilution were found to be caused by excessive penetration. In such cases, when the bead is very small, penetration should be kept to a minimum. However, good penetration into the Unionmelt bead is not objectionable.

In Specimen No. 3, only one bead was found which was martensitic. This bead was the first hand bead deposited and had penetrated too much into the side plate metal in relation to its size.

The last hand bead deposited showed cored austenite (see Figure 31).

CONCLUSIONS:

1. No tendency to develop root cracks or toe cracks was found in the specimens submitted.

2. Sponson Plates Nos. 1 and 3 definitely were low in impact strength. There are indications that this is due to the lack of homogeneity.

3. Ferrite precipitation in the transition zone of the sponson plate was excessive in width and appreciably less in the side plate.

4. The Unionmelt bead of Specimen No. 1 (from Hull 62) contained a serious shrinkage crack.

5. The Unionmelt bead of Specimen No. 1 (from Hull 62) shows a carbide precipitation at the grain boundaries. This may be a contributing cause of failure. In this weld, martensite was found only at the fusion line.

6. In Specimen No. 2, martensite was found in the Unionmelt and manual beads. The cracks found apparently originated at these brittle martensitic areas.

7. In Specimen No. 3, isolated patches of martensite were found in the Unionmelt bead. In one particular hand bead, the structure was martensitic. This bead had penetrated too deeply into the side plate metal.

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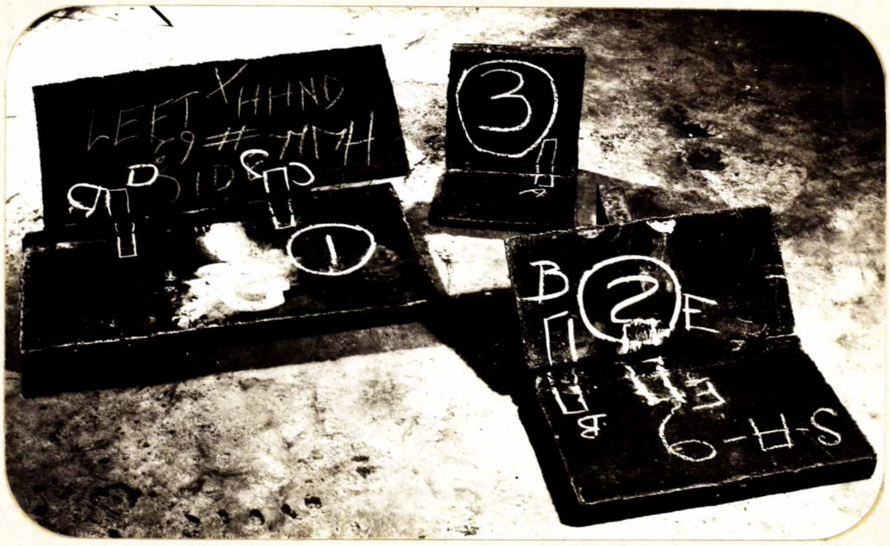
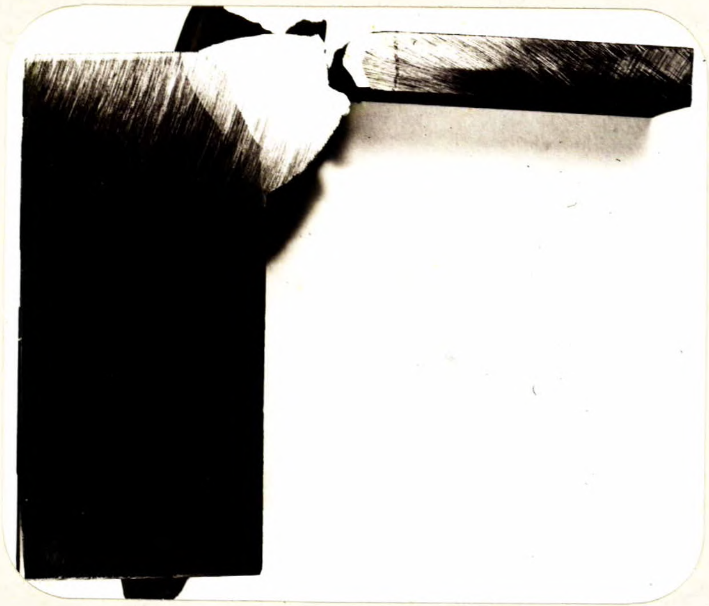
AD:GHB.

Figure 1.



SHOWING THE THREE WELDED SPECIMENS "AS RECEIVED" AND THE LOCATION OF SECTIONS TAKEN FOR EXAMINATION.

Figure 2.



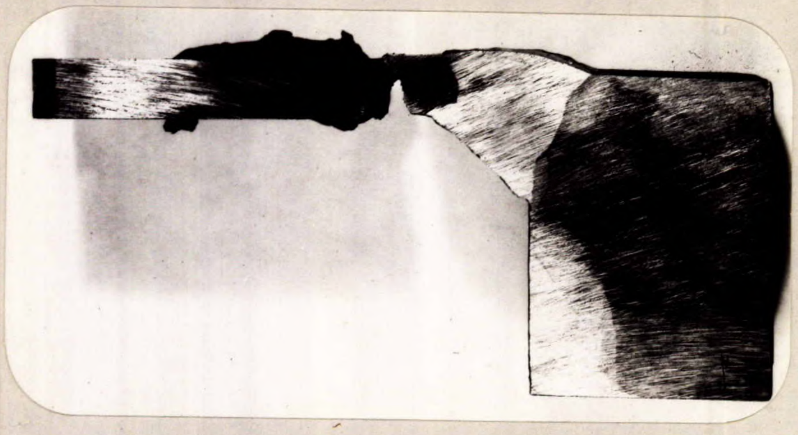
Etched in 10 per cent ammonium persulphate solution.

PHOTOGRAPH OF SPECIMEN NO. 1, SHOWING A FRACTURE IN THE WELD METAL, THE DEPTH OF PENETRATION, AND EXTENT OF HEAT-AFFECTED ZONE.

This is section marked "D" on Figure 1.

(Note: Figures 2 to 5 inclusive are approximately 4/5 actual size).

Figure 3.

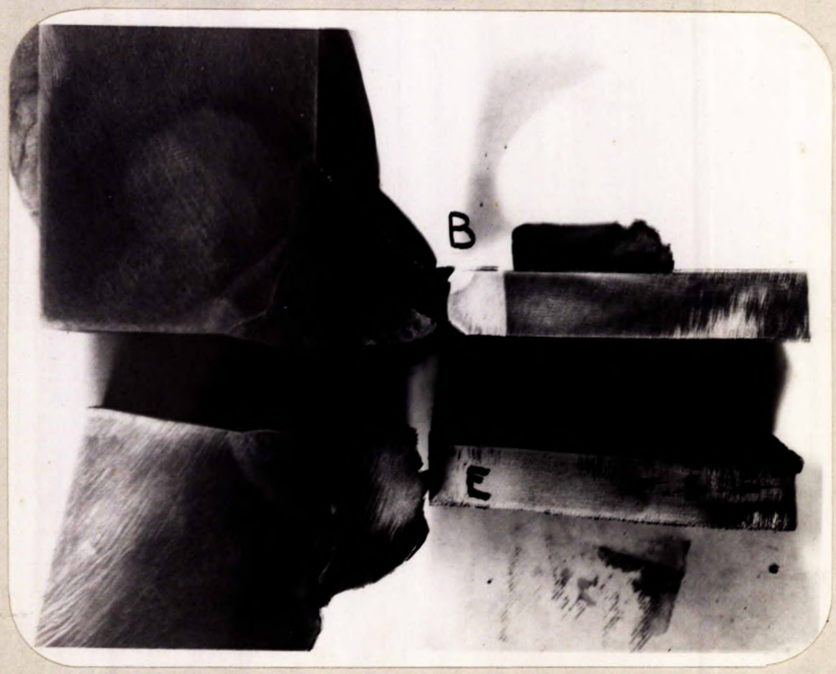


Etched in 10 per cent ammonium
persulphate solution.

SPECIMEN NO. 1.

Showing a fracture in the transition zone in sponson plate, the depth of penetration, and extent of heat-affected zone. (This is section marked "C" in Figure 1).

Figure 4.

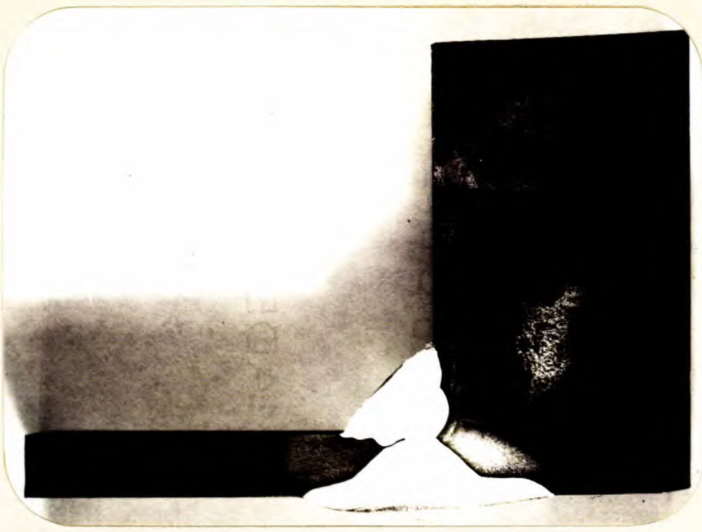


Etched in 10 per cent ammonium
persulphate solution.

SPECIMEN NO. 2.

Showing two fractures (1) in the weld metal (Section 2-E); (2) partly in the weld and in the sponson plate (Section 2-B). Shown also are depth of penetration and extent of heat-affected zone.

Figure 5.



Etched in 10 per cent ammonium persulphate solution.

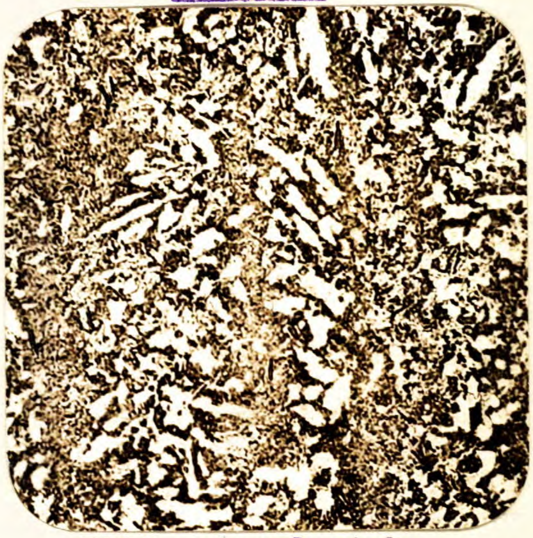
SPECIMEN No. 3.

Showing depth of penetration and extent of heat-affected zone.

Figure 6.

X500, picral etch.
HEAT-AFFECTED ZONE IN SPONSON PLATE NO. 1.

Figure 7.



X500, picral etch.
TRANSITION ZONE IN SPONSON PLATE NO. 1.

Figure 8.

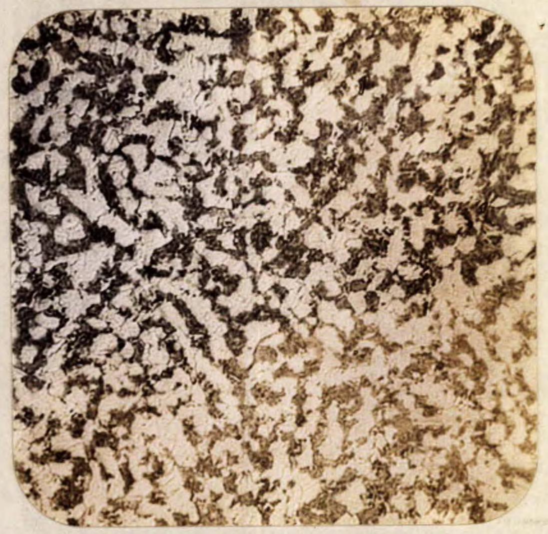
X500, picral etch.
NORMAL STRUCTURE IN SPONSON PLATE NO. 1.

Figure 9.

X500, picral etch.

HEAT-AFFECTED ZONE IN
SPONSON PLATE NO. 2.

Figure 10.



X500, picral etch.

TRANSITION ZONE IN
SPONSON PLATE NO. 2.

Figure 11.

X500, picral etch.

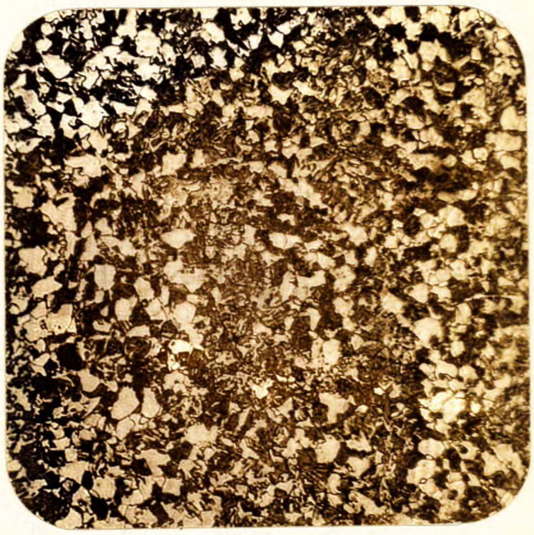
NORMAL STRUCTURE IN
SPONSON PLATE NO. 2.

Figure 12.

X500, picral etch.

HEAT-AFFECTED ZONE IN SPONSON PLATE NO. 3.

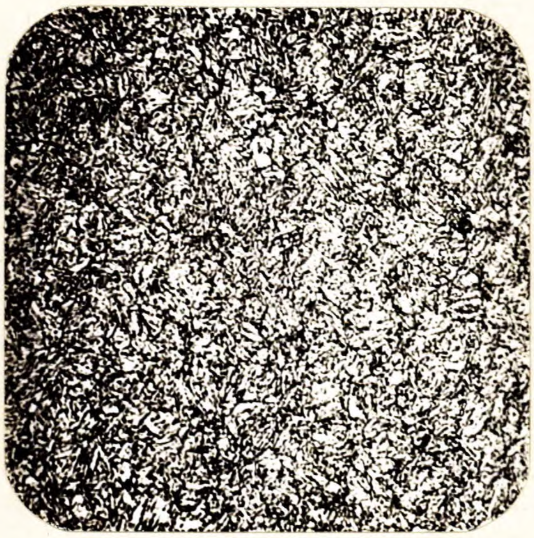
Figure 13.



X500, picral etch.

TRANSITION ZONE IN SPONSON PLATE NO. 3.

Figure 14.



X500, picral etch.

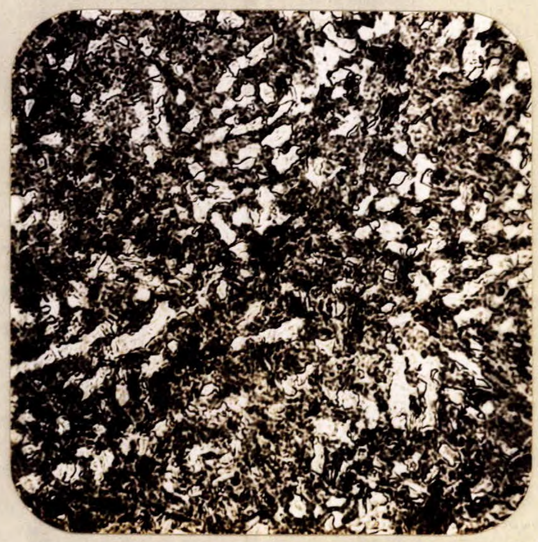
NORMAL STRUCTURE IN SPONSON PLATE NO. 3.

Figure 15.

X500, picral etch.

HEAT-AFFECTED ZONE IN
SIDE PLATE NO. 1.

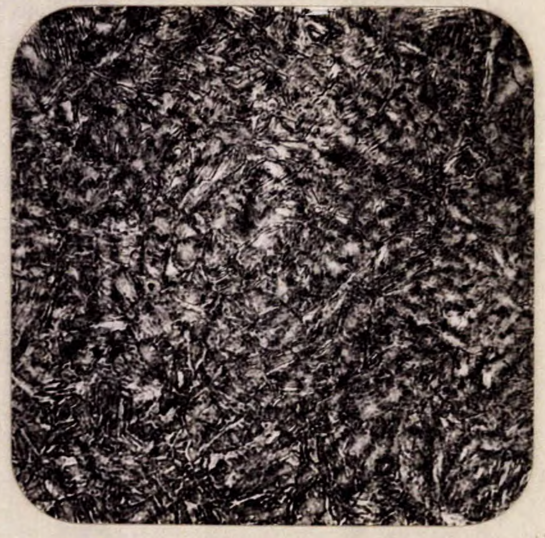
Figure 16.



X500, picral etch.

TRANSITION ZONE IN
SIDE PLATE NO. 1.

Figure 17.



X500, picral etch.

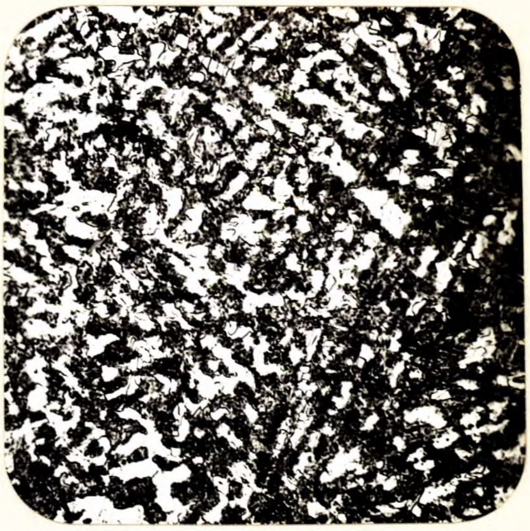
NORMAL STRUCTURE IN
SIDE PLATE NO. 1.

Figure 18.

X500, picral etch.

HEAT-AFFECTED ZONE IN
SIDE PLATE NO. 2.

Figure 19.



X500, picral etch.

TRANSITION ZONE IN
SIDE PLATE NO. 2.

Figure 20.

X500, picral etch.

NORMAL STRUCTURE IN
SIDE PLATE NO. 2.

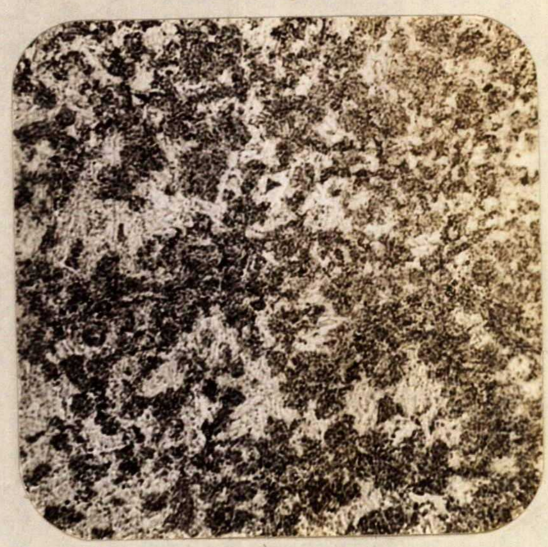
Figure 21.

X500, picral etch.

HEAT-AFFECTED ZONE IN
SIDE PLATE NO. 3.

—

Figure 22.

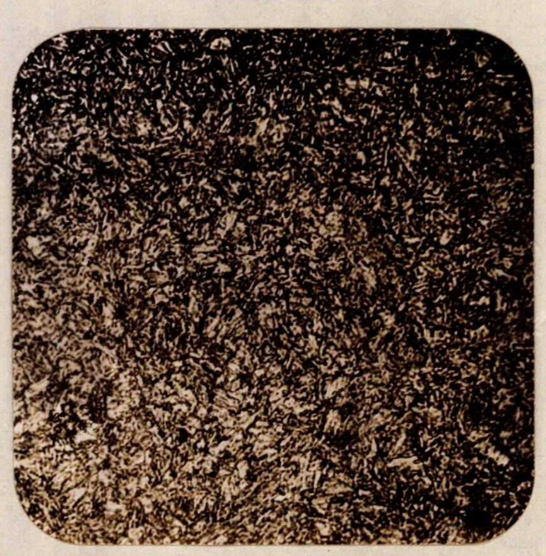


X500, picral etch.

TRANSITION ZONE IN
SIDE PLATE NO. 3.

—

Figure 23.

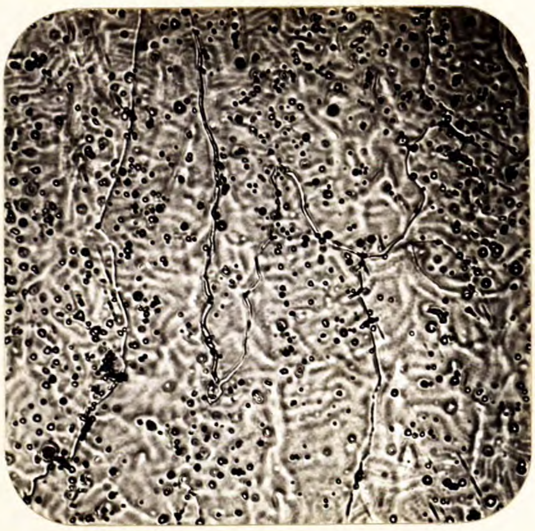


X500, picral etch.

NORMAL STRUCTURE IN
SIDE PLATE NO. 3.

—

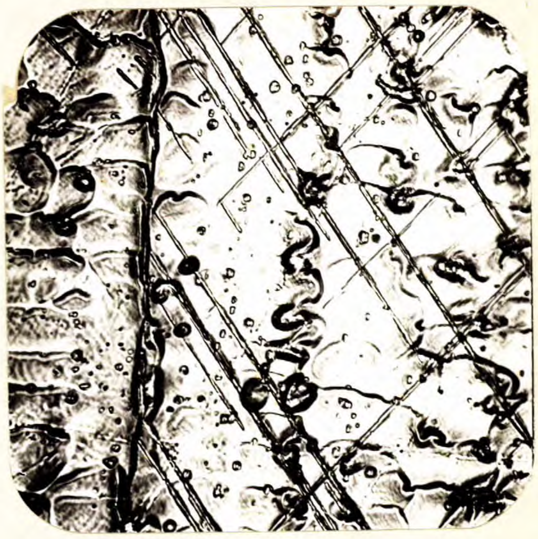
Figure 24.



X500, etch in 5% HCl, 1% picral solution.

SHOWING CARBIDES AT THE GRAIN BOUNDARIES OF GRAIN BOUNDARIES OF THE AUSTENITE IN SPECIMEN NO. 1 (UNIONMELT).

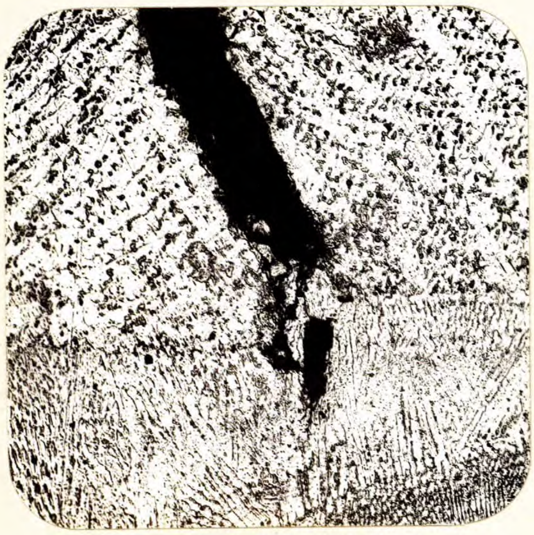
Figure 25.



X500, etch in 5% HCl, 1% picral solution.

SHOWING CARBIDE PRECIPITATION AT THE SLIP PLANES OF THE AUSTENITE IN SPECIMEN NO. 1 (UNIONMELT).

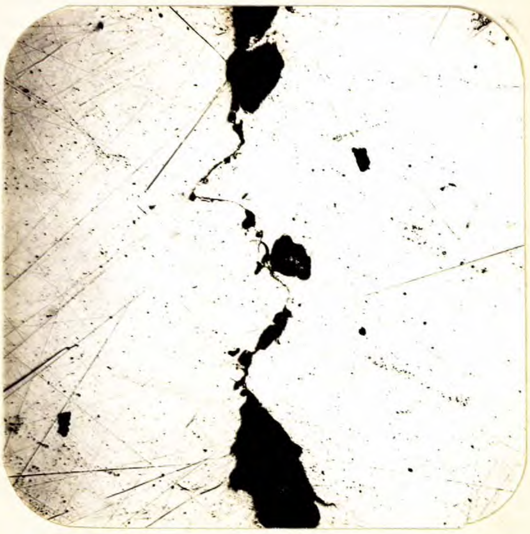
Figure 26.



X250, etch in 5% HCl, 1% picral solution.

SHOWING THE CONNECTION BETWEEN THE CRACK IN UNIONMELT AND THE FIRST DEPOSITED HAND BEAD IN SPECIMEN NO. 1.

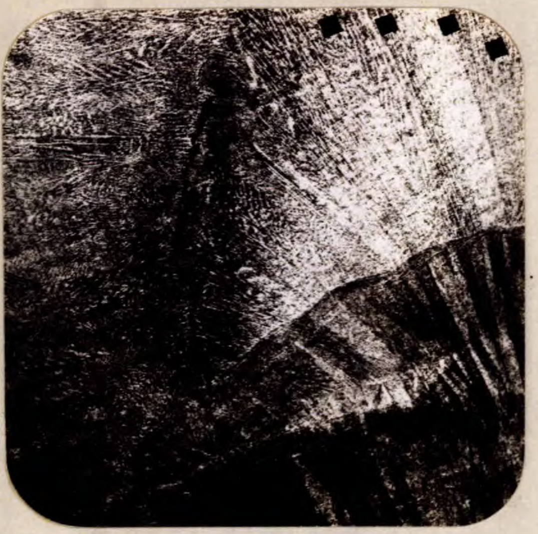
Figure 27.



X100, unetched.

SHOWING THE SHRINKAGE NATURE OF THE CRACK IN SPECIMEN NO. 1 (UNIONMELT).

Figure 28.



X75, etch in a saturated solution of ferrichloride in hydrochloric acid.

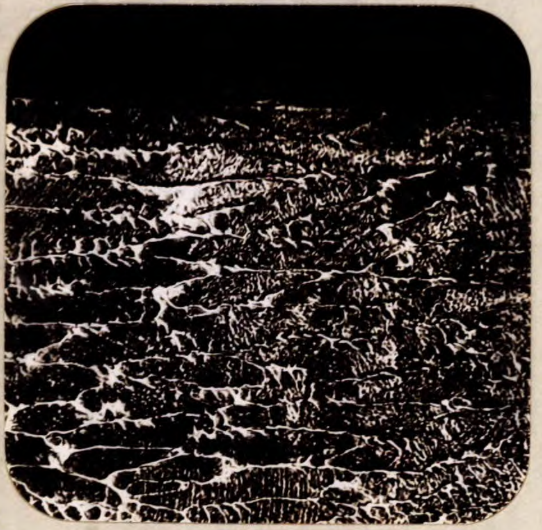
SHOWING THE GENERAL APPEARANCE OF THE CRACK IN SPECIMEN NO. 1.

Figure 29.

X500, etch in 5% HCl, 1% picral solution.

SHOWING THE MARTENSITE IN THE AUSTENITIC MATRIX AT THE FUSION LINE IN SPECIMEN NO. 1.

Figure 30.



X250, etch in 5% HCl, 1% picral solution.

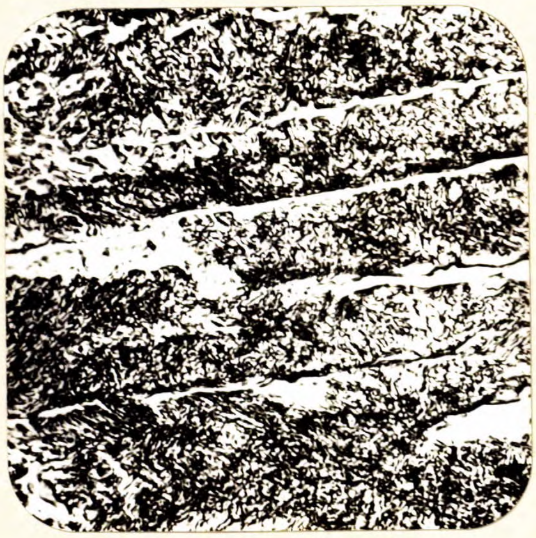
SHOWING THE MARTENSITIC AND AUSTENITIC STRUCTURE AT FRACTURE IN SPECIMEN NO. 2 (UNIONMELT).

Figure 31.

X500, etch in 5% HCl, 1% picral solution.

SHOWING THE CORED AUSTENITE IN THE LAST-DEPOSITED HAND BEAD IN SPECIMEN NO. 2.

Figure 32.



X1000, etch in 5% HCl, 1% picral solution.

SHOWING THE MARTENSITE IN AUSTENITE IN THE FIRST HAND BEAD OF SPECIMEN NO. 3.

Figure 33.

X500, etch in 5% HCl, 1% picral solution.

SHOWING AN EXAMPLE OF A PATCH OF MARTENSITE IN AUSTENITE IN SPECIMEN NO. 3 (UNIONMELT).

AD:GHB.