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O T T A W A June 28th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1672.

Examination of Grizzly Tank Idler Wheel.

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(Copy No. 10.)

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

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

OTTAWA June 28th, 1944.

REPORT

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Origin of Material:

On May 11th, 1944, under Analysis Requisition No. O.T. 4205, Mr. W. L. Auchincloss, Inspector of Tanks, for Director of Tanks and M.T., Inspection Board of United Kingdom and Canada, Ottawa, Ontario, submitted a cracked idler wheel for examination. This idler wheel was taken from Grizzly Tank No. 76 and had failed during a track test.

Also submitted was a drawing of the wheel (U. S. Ordnance Drawing No. D37910) which showed the construction of the wheel, the location of the welds, and the numbers of the various parts. The drawing does not show the specifications of materials of the parts. A request for material specifications

(Origin of Material, cont'd) -

produced the following information (letter dated May 22nd, File No. 4/10/D/Ram/8):

> Hub is to be made from a steel casting, either class 2 QQ-S/681 or class 4 A2 QQ-S/681, the latter if a centrifugal casting is not available. A previous examination of an idler wheel from Grizzly Tank No. 106, by Montreal Locomotive Works, revealed that the hub had been made by welding together two pieces of what was apparently machined steel tubing. No record of a deviation permit covering this could be found.
>
> Inner and outer discs are to be made from W.D. 1025 steel; the flange and rim, from Corten steel made by the U.S. Steel Corp.

The idler wheels are of American manufacture. No information is available as to the manufacturing procedure and the welding electrodes used.

Object of Investigation:

To determine the cause of cracking of the idler wheel.

Procedure:

1. The cracked wheel was subjected to careful visual examination. Figure 1 shows the general shape and construction of the wheel. Figures 2 and 3 are close-ups of the cracked rim weld and hub weld respectively.

2. The wheel was sectioned by flame-cutting and sawing. Samples were machined from each of the cracked welds and from the plug welds reinforcing the disc-to-rim weld. It was noted that the hub had been fabricated by welding two pieces together as found in the previous Montreal Locomotive Works examination. A sample of this weld was also removed for examination.

Figure 4 is the macro sample of the cracked fillet weld joining the centre disc to the rim. Figure 5 is a similar sample of the plug weld reinforcing this weld. Figure 6 shows a sample of the cracked fillet weld joining the disc centre to the hub. Figure 7 shows a sample of the weld joining the flange to the rim. Figure 8 is a sample of the weld joining the two halves of the hub.

(Continued on next page)

(Procedure, cont'd) -

3. The macro samples were next subjected to a microscopic examination. Figures 9 to 11 show the normal, transition and heat-affected zones, respectively, of the rim materials. Figures 12 to 14 are the structures of the same areas of the rim materials. Figures 15 to 17 are the structures of the same areas of the hub material. Figure 18 shows the structure typical of all welds except that joining the two halves of the hub. Figure 19 shows the structure of this latter weld.

Figure 20 shows a crack at the root of the weld joining the flange and rim. Figure 21 shows a crack at the edge of one of the plug welds.

4. Chemical analysis samples were machined from the rim and flange, the centre disc, and the two halves of the hub. The table below lists the analyses secured and, for the purpose of comparison, the specified analyses.

	RIM AND FLANGE: Analysis Secured	Corten	DISC CENTRE: Analysis Secured	WD 1025	HUB - Analysis Secured: A	B	QQ-S681 b Class 2	4A2
	- Per cent -							
Carbon	0.11	0.10	0.21	0.20-0.30	0.23	0.24	0.35	-
Phosphorus	0.088	0.10-0.20	0.017	0.045 max.	0.012	0.013	0.05	0.05
Sulphur	0.043	-	0.036	0.05 max.	0.045	0.050	0.06	0.05
Manganese	0.37	0.10-0.30	0.40	0.25-0.60	0.44	0.44	0.70	-
Silicon	0.67	0.50-1.00	Trace.	-	Trace.	Trace.	0.60	-
Chromium	0.53	0.50-1.50	0.015	-	N.D.	0.015	-	-
Nickel	N.D.	-	Trace.	-	N.D.	N.D.	0.50	-
Molybdenum	None	-	Trace.	-	Trace.	Trace.	-	-
Copper	0.34-	0.30-0.50		-	0.03	0.05	0.50	-

(Continued on next page)

(Objec of Investigation, cont'd) -

5. Hardness tests, using a Vickers machine and a 10-kilogram load, were made on all welded joints. The table below lists the results secured, each figure being the average of four readings:

		Rim and Flange	Disc Centre	Hub
Normal material	-	186	232	145
Transition zone	-	198	199	171
Heat-affected zone	-	199	224	199
Normal weld metal	-	205	199	221

6. In view of the small differences of hardness in the above table a check was made on the response of the rim steel to the thermal cycle of welding. A string bead was laid down on the rim, using a 3/16-inch diameter electrode, 180 amps., 24 volts, with a welding speed of 6 inches per minute. The resulting bead was cross-sectioned and the hardness checked as above. The following table lists the results secured:

Area Tested		Vickers Hardness No.
Normal material	-	186
Transition zone	-	224
Heat-affected zone	-	285
Weld metal	-	272

Discussion:

A visual examination revealed that the disc-to-rim fillet weld had cracked around the complete periphery and that the disc-to-hub fillet weld on the opposite side (inside) of the wheel had also cracked around the complete periphery. An examination after sectioning showed that the fractured surfaces in both cases were very smooth and shiny, which is characteristic of fatigue failures of welds. It was also noted that by

(Discussion, cont'd) -

far the great majority of the plug welds reinforcing the disc-to-rim weld were not fused at all to the rim but consisted of blobs of metal which in some cases towards the centre did not even touch the rim material. In other cases the centre of the weld adhered to the rim in the form of an icicle and fused to the disc only in a thin film.

The macro-examination shows that all welds are single-pass and penetration is generally fair. The cracked welds show no sign of distorted metal along the fractured edges, a further indication of fatigue. The plug weld (Figure 5) examined is of the type referred to above in which only a small part is fused to the rim, the remainder not touching the rim material. The welds joining the two halves of the hub are manifestly of a different type from the other welds. These welds show a lower penetration and considerable porosity.

The microscopic examination reveals that the rim and hub are in the annealed condition and the centre disc shows the characteristic banded structure of hot-rolled steel. The transition zones and heat-affected zones of the disc centre and hub show nothing out of the ordinary. The same areas of the flange and rim show a typical transition-zone structure but an uncommon grain refining effect in the heat-affected zone. There is at least a possibility that the rim has been subjected to a heat-treating operation, probably by torch, to bring about the condition. A stringer bead laid down on this material in these Laboratories produced a heat-affected zone structure comparable to others shown in this report.

A microscopic examination of the weld metal indicates the use of the standard coated electrodes for all welds but that joining the two halves of the hub. Here the porosity and needles of nitrides indicate the use of a bare or lightly

(Discussion, cont'd) -

coated electrode.

Both the plug weld and rim-to-flange weld show small cracks. In the case of the plug weld, the crack originates in an area of lack of fusion at the root of the weld. In the rim-to-flange weld the crack has been caused by incomplete penetration at the root of the weld. Defects of this type act as severe stress raisers, with the result that the crack grows until it reaches the surface. The shiny surface of the fractured welds and the absence of distortion of the metal along the fractures point to failures as originating from this type of defect.

The chemical analyses show that the rim and flange materials, as well as the disc centre, are within the limits of the specifications. For all practical purposes the two halves of the hub are of identical analysis. Their composition is such that they will fit within the Class 4A2 analysis but not that of Class 2. It is noteworthy that these analyses reflect the present steelmaking practice of killing steel by additions of aluminium rather than ferrosilicon.

A microscopic examination of a longitudinal section of the hub reveals that both pieces are probably annealed steel castings. This opinion is based on the fact that all inclusions are of the round globular type characteristic of castings. If these hubs were made from machined steel tubing, as suggested, the inclusions would have been elongated by the drawing or piercing operation.

The unusually small differences of hardness between the normal metal and that affected by the thermal cycle of welding indicate that a stress-relieving treatment has been applied to the wheel after fabrication. The considerable differences in hardness in similar areas of a weld made in these Laboratories confirm this opinion. It should be noted that this weld was made on the lowest carbon material (rim)

(Discussion, cont'd) -

present in the assembly and that a similar weld on the disc or hub materials would have produced an increasing spread of hardness figures.

CONCLUSIONS:

1. The welding technique is open to improvement. The plug welds as seen and examined provide little, if any, reinforcement to the disc-to-rim weld.

2. The cracking of the welds is probably the result of fatigue accelerated by the stress-raising effect of small cracks at the roots of welds.

3. It would seem that the rim has been subjected to a heat treatment of some kind, subsequent to welding.

4. Heavily coated electrodes have been used for all welds except those joining the two halves of the hub. In this latter case, bare or lightly coated electrodes have been used.

5. The chemical analysis of the rim and flange and centre discs are within the specification limits. The hub material will fit within the 2 QQ-S/681 b Class 4A2 limits for castings, but not Class 2 limits.

6. The hub has been made from two pieces of annealed castings.

7. The entire assembly has been subjected to a stress-relieving treatment of the welding, as shown by the hardness tests.

Recommendations:

1. Every effort should be made to improve the welding technique used in making the plug welds.

2. Increased penetration at the roots of welds should be secured.

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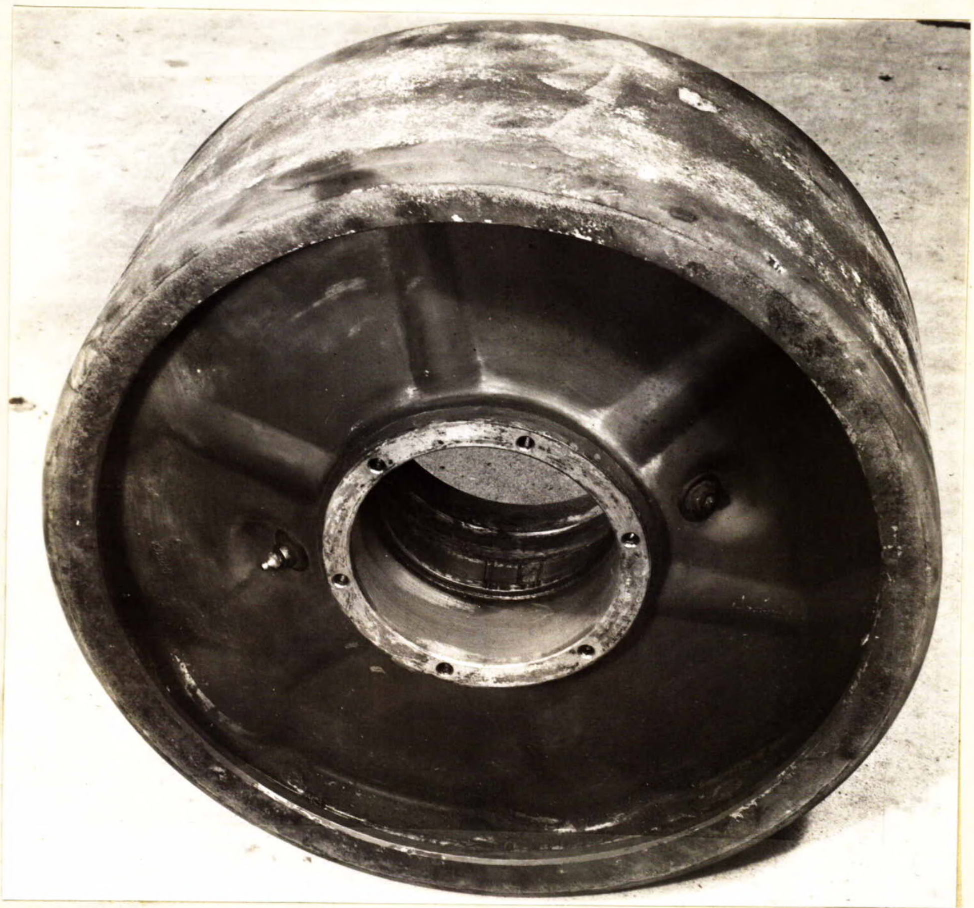
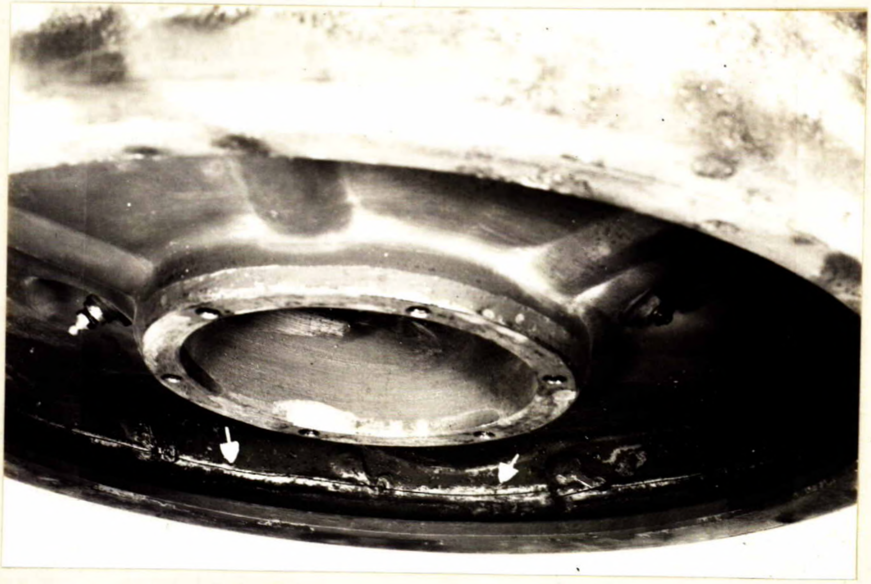
Figure 1.



GENERAL SHAPE OF IDLER WHEEL - AS RECEIVED.

Figure 2.



CRACKED DISC-TO-RIM WELD.

Note that crack also runs through plug welds.

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Figure 3.

CRACKED DISC-TO-HUB WELD.

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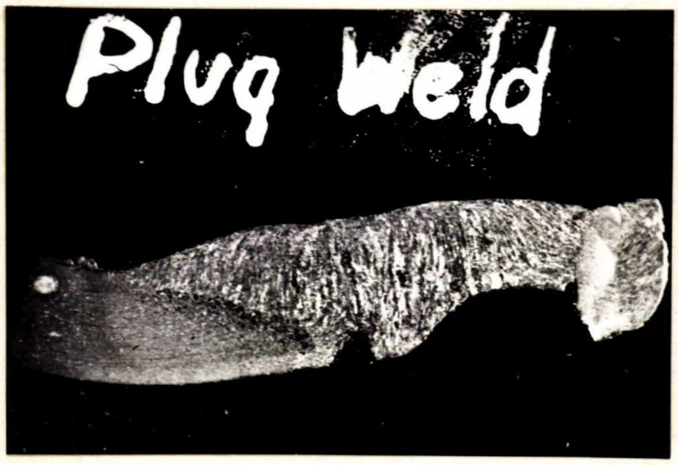
Figure 4.

MACRO SECTION OF DISC-TO-RIM WELD.

Note that crack runs through the root of the weld.

Figure 5.



TYPICAL SAMPLE OF PLUG WELD.

Note small area of fusion at left side. Centre and right side of weld do not touch the rim material.

Figure 6.

MACRO SECTION OF DISC-TO-HUB WELD.

Note that crack runs through the root of the weld.

Figure 7.

MACRO SECTION OF RIM-TO-FLANGE WELD.

Note small area of incomplete penetration at root of weld.

Figure 8.

WELDS JOINING TWO HALVES OF HUB.

Note considerable porosity.

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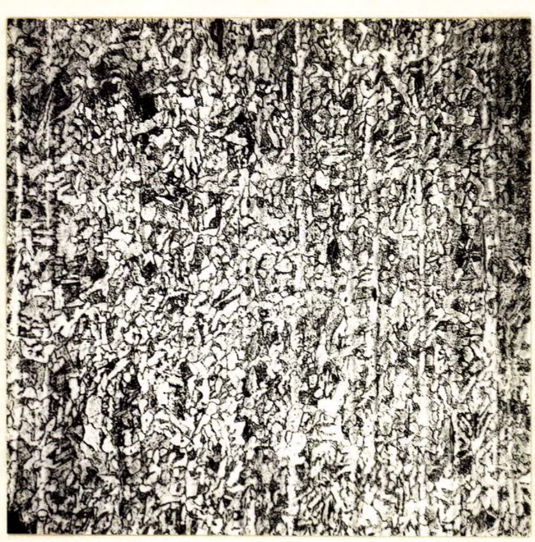
Figure 9.



X100, etched in 2 per cent nital.

STRUCTURE OF NORMAL DISC MATERIAL.

The typical banded structure of hot-rolled steel.

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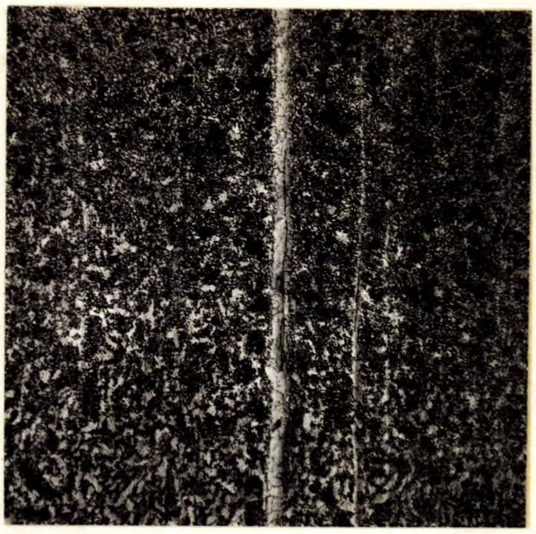
Figure 10.



X100, etched in 2 per cent nital.

STRUCTURE OF TRANSITION ZONE OF DISC MATERIAL.

Note banding around sulphide inclusions. Spheroidized pearlite in ferrite.

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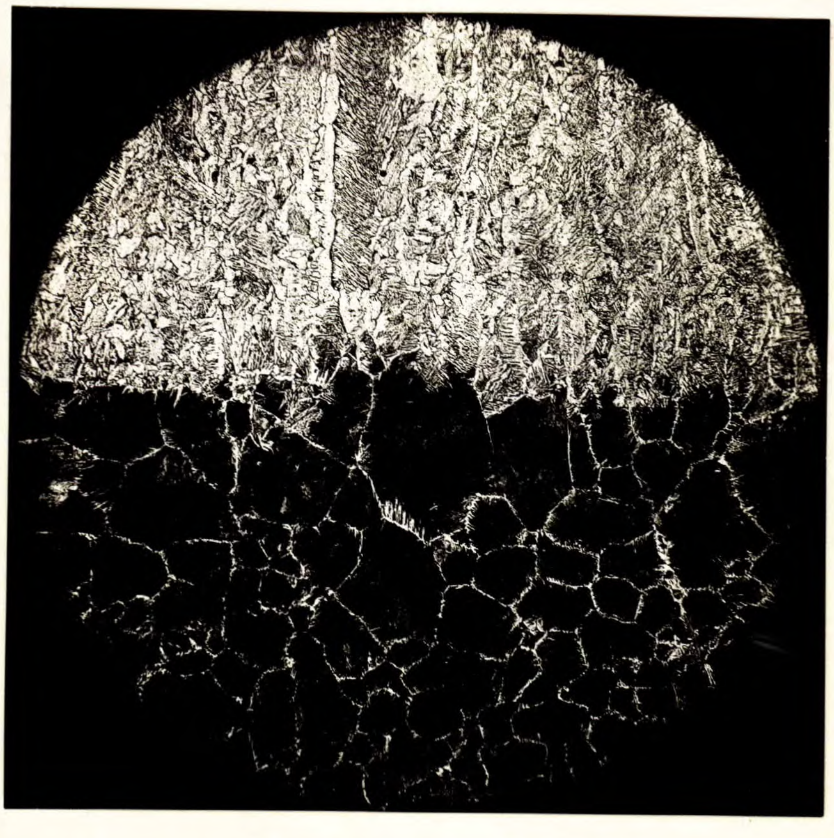
Figure 11.



X100, etched in 2 per cent nital.

STRUCTURE OF HEAT-AFFECTED ZONE AND FUSION LINE OF DISC MATERIAL.

Coarse-grained pearlite with ferrite at grain boundaries.

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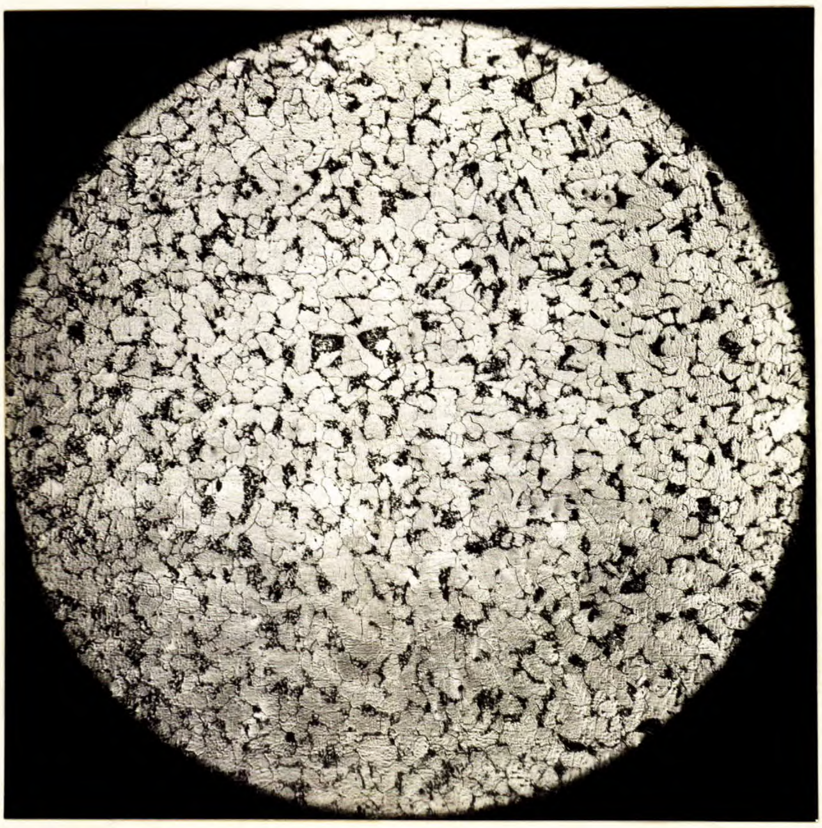
Figure 12.

X100, etched in 2 per cent nital.

STRUCTURE OF NORMAL RIM MATERIAL.

Annealed condition - pearlite
in a matrix of ferrite.

Figure 13.

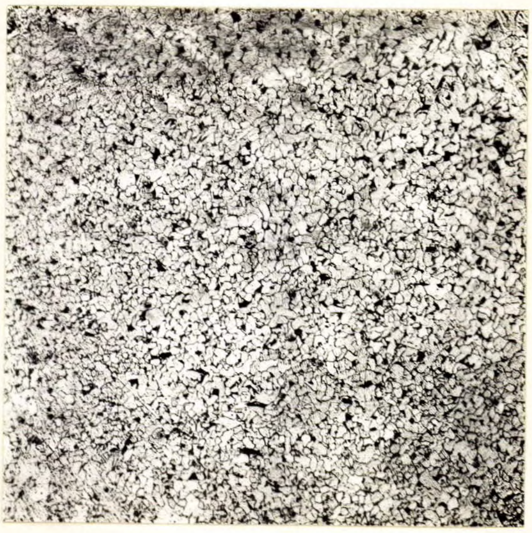


X100, etched in 2 per cent nital.

STRUCTURE OF TRANSITION ZONE OF RIM MATERIAL.

Spheroidized pearlite in a matrix of ferrite.

Figure 14.



X100, etched in 2 per cent nital.

STRUCTURE OF HEAT-AFFECTED ZONE OF RIM MATERIAL.

Note fine grain. Compare with Figure 12.
Pearlite in a matrix of ferrite.

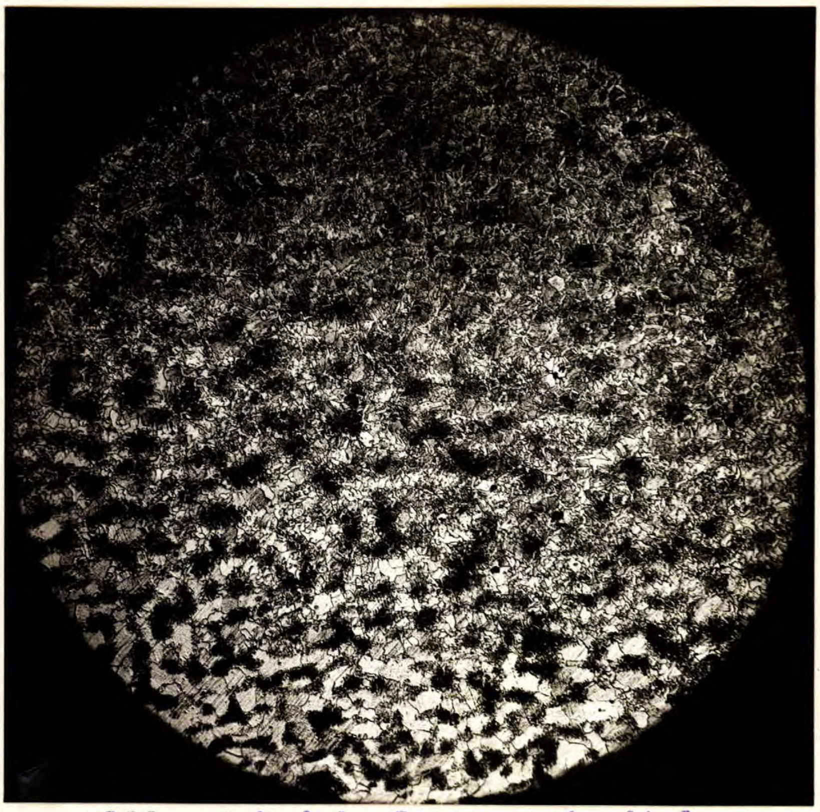
Figure 15.

X100, etched in 2 per cent nital.

STRUCTURE OF NORMAL HUB MATERIAL.

Annealed condition - pearlite
in a matrix of ferrite.

Figure 16.



X100, etched in 2 per cent nital.

STRUCTURE OF TRANSITION ZONE OF HUB MATERIAL.

Mostly spheroidized pearlite in a matrix of ferrite.

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Figure 17.

X100, etched in 2 per cent nital.

STRUCTURE OF HEAT-AFFECTED ZONE AND
FUSION LINE OF HUB MATERIAL.

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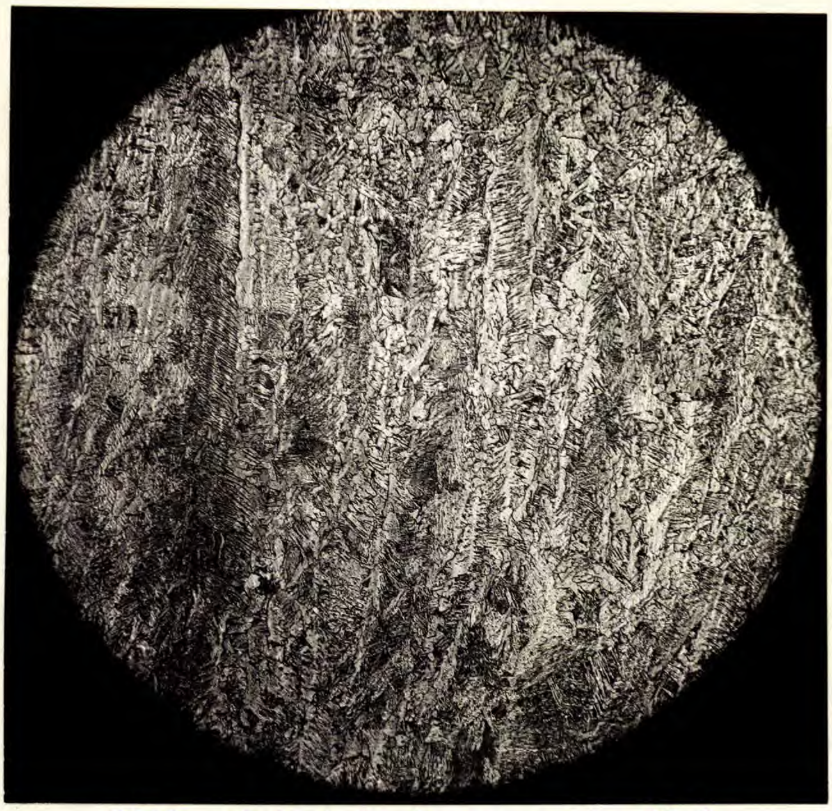
Figure 18.



X100, etched in 2 per cent nital.

STRUCTURE OF WELD METAL REPRESENTATIVE OF ALL WELDS OTHER THAN HUB WELDS.

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Figure 19.

X100, etched in 2 per cent nital.

STRUCTURE OF HUB WELD METAL.

Note black needles of nitrides, indicating use of bare or lightly covered electrodes.

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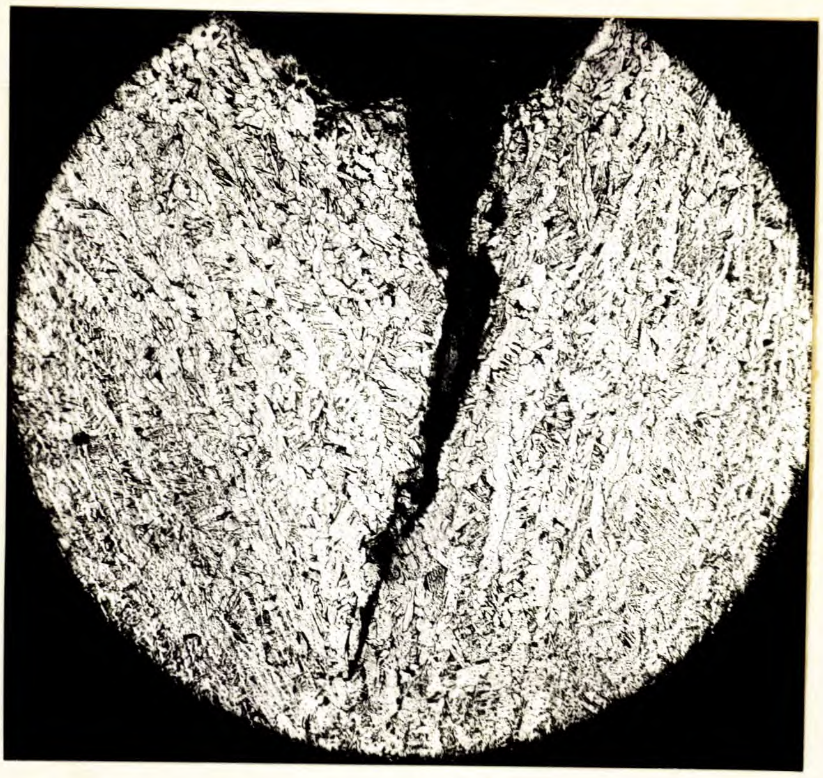
Figure 20.



X100, etched in 2 per cent nital.

CRACK AT ROOT OF RIM-TO-FLANGE WELD, ORIGINATING IN AN AREA OF INCOMPLETE PENETRATION.

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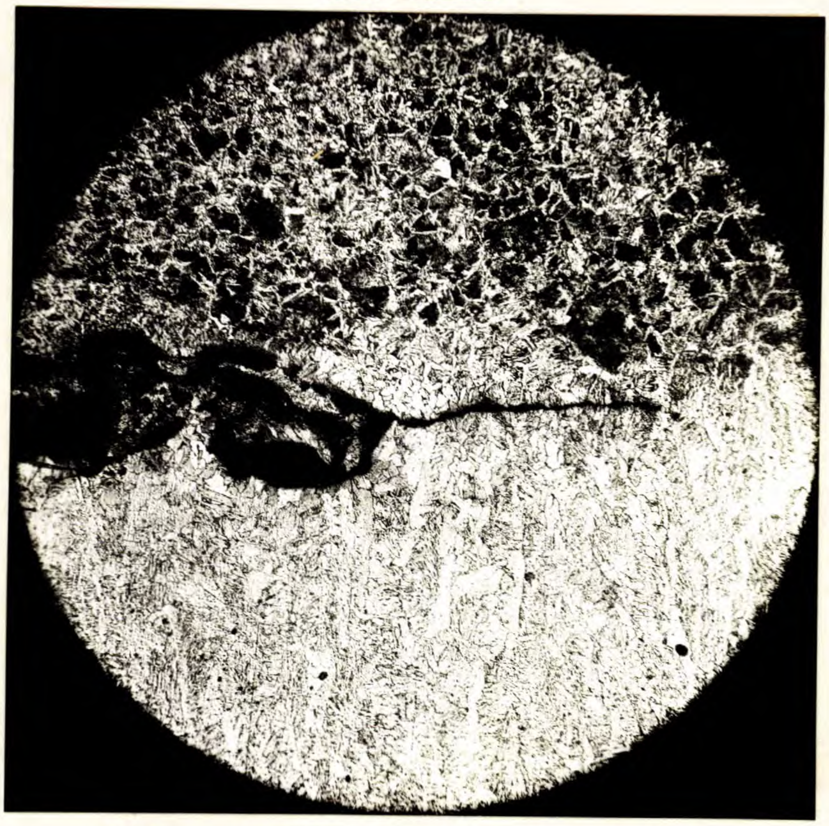
Figure 21.



X100, etched in 2 per cent nital.

CRACK CLOSE TO FUSION LINE OF A PLUG WELD.

Crack originating in an extensive area of lack of fusion.

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