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OTTAWA May 10th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1639.

Examination of Broken Snowmobile Bogie Suspension Brackets.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals.
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Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA May 10th, 1944.

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Examination of Broken Snowmobile Bogie Suspension Brackets.

Origin of Material:

On April 2nd, 1944, Mr. H. J. Stevenson, Assistant Director General, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, submitted two snowmobile bogie suspension brackets for examination. This request is covered by Requisition No. 641, AEDB Lot No. 533, Report No. 107 "D". The bogies had broken up badly in field testing, one at 1,760 miles and the other at an unknown mileage. Both bogies were fabricated by Farand & Delorme, Montreal, Quebec.

The plant of Farand & Delorme was visited from April 25th to 27th, 1944, to obtain information as to welding and stress-relieving practice. The following information was obtained:

It would appear that the bogies submitted for examination had not been stress-relieved prior to field testing. There are in stock sufficient bogies to equip approximately 150 vehicles. Some of these bogies have been stress-relieved

(Origin of Material, cont'd) -

at 700° F., some at 950° F., and some at 1150° F., all for varying periods of time. Those treated at the latter temperature were in accordance with the recommendations of this Department, except that instead of the recommended time of 1 hour the time temperature had been increased to 3 hours, following which the brackets had been cooled overnight in the furnace. The deviation from recommended procedure would be beneficial and no criticism is advanced on this score. Unfortunately, it appears to be exceedingly difficult to determine accurately which bogies have received the low temperature treatment and which the high temperature treatment.

The normal service life of the vehicle is expected to be from 4,000 to 5,000 miles and it is desired that the bogies have this service life. Field tests in the past, with weaker compression springs, have shown bogie service life to be in the neighbourhood of 4,000 miles. A recent design change introduced compression springs of double compression strength as compared to the former springs. Within Farand & Delorme it is believed that the higher compression spring strength is a prominent factor in the service failure of the bogies submitted for examination.

Object of Investigation:

1. To determine the cause of failure of the bogies.

2. To make recommendations to eliminate the cause of failure.

Procedure:

(1). Both bogies were photographed as received (see Figures 1 and 2). For purposes of identification, these will be referred to hereafter as Samples A and B, respectively. Both

(Procedure, cont'd) -

bogies were subsequently cleaned and subjected to a careful visual inspection.

(2). Chemical analysis samples were machined from various parts of the bogie which had fractured. The following table lists the part number, material specification on the blue print, and the chemical analysis obtained in these Laboratories:

Part No.	A38421	38418	38422	38433 N.D.	B38417
Specification	SAE 1020	SAE 1015 or 1020	SAE 1020	Mild Steel	SAE 1015 or 1020
		- Per cent -			
Carbon -	0.22	0.09	0.06	0.29	0.18
Phosphorus -	0.008	0.009	0.007	0.031	0.013
Sulphur -	0.026	0.024	0.030	0.049	0.028
Manganese -	0.40	0.44	0.30	0.57	0.51
Silicon -	0.08	0.005	0.005	0.01	0.13
Chromium -	None.	None.	None.	None.	None.
Nickel -	None.	None.	None.	None.	None.
Molybdenum -	Trace.	Trace.	Trace.	Trace.	Trace.

(3). Transverse sections of the main pipe frame of Sample B were deep-etched in 50 per cent HCl at 180° F. for 10 minutes. Figures 3 and 4 show the appearance of these sections after this treatment.

(4). Sections of all fractured parts were examined under the microscope. Figures 5, 6, 7 and 8 show respectively the structures of the pinion support tube fractured edge, the normal pinion support tube, the fractured edge and crack of the angle iron brace, and the normal angle iron brace. These are from Sample A.

Figures 9, 10 and 11 show respectively structures of the edges of the fractures of the two pipe frame members and the base plate material. These specimens are from Sample B.

(5). Hardness readings, using a Vickers machine and

(Procedure, cont'd) -

a 10-kilogram load, were taken on all fractured members. The following table shows the average of 4 readings in each case:

Sample A -		Vickers Hardness Numbers	
Normal angle	-	182	
Heat-affected zone of angle	-	283	
Normal pinion support tube	-	171	
Sample B -			
Normal pipe frame member	-	166)	Low-carbon tube.
Heat-affected zone of pipe	-	128)	
Normal pipe frame member	-	212)	High-carbon tube.
Heat-affected zone of pipe	-	197)	

(6). Transverse bend tests on sections of pipe frame members of Sample B indicate good ductility in both members.

Discussion:

A visual examination of Sample A reveals that both the angle iron brace and the pinion support tube fractured in the heat-affected zones of the welds. It would appear that the angle iron brace broke first and the additional load applied to the pinion support tube was too great for the latter. The chemical analysis and the micro-examination of both of these failed parts reveal that the angle iron brace is of a composition which must be welded with care if trouble is to be avoided. In this particular case a thin layer of weld metal has produced the conditions for high heat-affected-zone hardness. The microstructure in this area is coarse-grained, with ferrite grain boundaries. This condition, plus considerably higher hardness, results in both low impact resistance and low fatigue strength. The analysis and the micro-examination of the pinion support tube reveal no evidence of substandard material or of welding defects. This supports the belief that the failure in this

(Discussion, cont'd) -

member is due to prior failure of the brace.

A visual examination of Sample B reveals that the welding is, from the standpoint of welding defects, not responsible for this failure. Micro-examination revealed no evidence of faulty welding. It is most important, however, to note that the photomicrographs of specimens from both samples show little or no deformation at fractured edges. This is characteristic of materials which fail when under severe stress in three directions at right angles to one another. When these conditions prevail, local yielding to imposed additional stresses is impossible since the additional stresses are opposed by other high stresses. The result is a brittle type of failure. It would seem that at least one possible cause of failure of this particular bogie is either that it has not been stress-relieved after welding or that the stress relief has been at such a low temperature as to be ineffective. The ultimate result of this has been severe locked-up welding stresses in the bogie when it was subjected to field testing.

Chemical analysis of parts of Sample B indicate that there is cause for grave concern as to the quality of the material employed. It was found that the two most highly stressed parts of the assembly were of substandard materials (Parts Nos. 38422 and 38418). This being the case, another possibility of cause of failure is introduced. Materials of this composition cannot be expected to withstand the service stresses which the designer has recognized as needing higher strength material. It would seem that the system of acceptance of material on the basis of a chemical certification from the supplier is of questionable value. A review of this system with a view to closer control material composition is certainly

(Discussion, cont'd) -

warranted.

The increase of compression spring strength should result in reduced frequency of "bang through"; that is, impact producing complete compression and metal-to-metal transmission of shock. Metallurgically speaking, rapid loading of a part is not nearly so liable to produce failure as direct impact. It is considered that this design change should produce improvement of bogie life rather than reduce it.

The hardness readings are normal. The higher hardnesses encountered in the material remote from welds are attributable to the hardening effect of cold drawing. The hardnesses in the heat-affected zones of welds are lower than that of the normal material, demonstrating the elimination of the effect of cold-working and also that there is no detrimental response to the thermal cycle of welding.

The good ductility of the bend tests of the pipe frame members is additional evidence pointing to high locked-up welding stresses, since sectioning to remove the specimens entirely eliminates these stresses.

It is our understanding that a set of bogies, stress-relieved by the process recommended by these Laboratories, is now undergoing field trials. Should these bogies give satisfactory service, those bogies already fabricated should be accepted to avoid a production delay and the question of material composition should be waived in this particular instance. However, future production materials should be closely checked. This field trial will definitely indicate which of the two causes of failure is most important, <u>provided</u> that the bogies under test also contain substandard material.

CONCLUSIONS:

1. Welding is only indirectly responsible for the failure of these bogies. Sample A failure is due to the use of a high-carbon angle iron brace. This material must be handled with care in welding. First failure probably occurred in the heat-affected zone of the brace and the additional load thrown on the pinion support tube produced its failure.

2. There are two possible causes of failure of Sample B: (a) severe locked-up welding stresses which have not been eliminated by an effective stress-relieving treatment, and (b) the use of substandard materials in the most highly stressed members of the bogie.

3. All fractured edges show little or no deformation, indicating brittle type of failure characteristic of severely stressed materials.

4. Good ductility results from bend tests made on pipe frame members further support the probability of locked-up stresses.

5. Increasing compression-spring strength should tend to increase bogie life by reducing the frequency of severe impact.

Recommendations:

1. The acceptance or rejection of the bogies now in stock should be decided by the results of the field tests of a set of stress-relieved bogies now under way. In the event that these bogies give normal service life the remaining bogies should be accepted and the question of material composition waived in this instance. In the event of early failure, there seems to be no alternative to rejection since non-destructive testing of individual bogie parts is impractical.

2. All angle braces should be joined to the bogies

(Recommendations, cont'd) -

by means of a double-pass weld. This will refine the grain and reduce the hardness of the heat-affected zone of this high-carbon material. Stress relief alone would reduce the hardness but would have no grain-refining effect.

3. The material specification for the angle iron brace (Part No. 38433 N.D.) should be changed from "mild steel" to an SAE specification. The terminology of "mild steel" is too indefinite and provides grounds for use of personal opinion as to suitability of material.

4. All bogies before being released to production should be subjected to a stress-relieving treatment at 1150-1200° F. for at least one hour, followed by a slow cool. Every effort should be made to segregate those bogies which have received this treatment from those receiving lower temperature treatment. The latter bogies should then be given the proper treatment.

5. The system of accepting material on the basis of a supplier's chemical certification appears to be of doubtful value. Every effort should be made to provide a closer check of the composition of incoming material.

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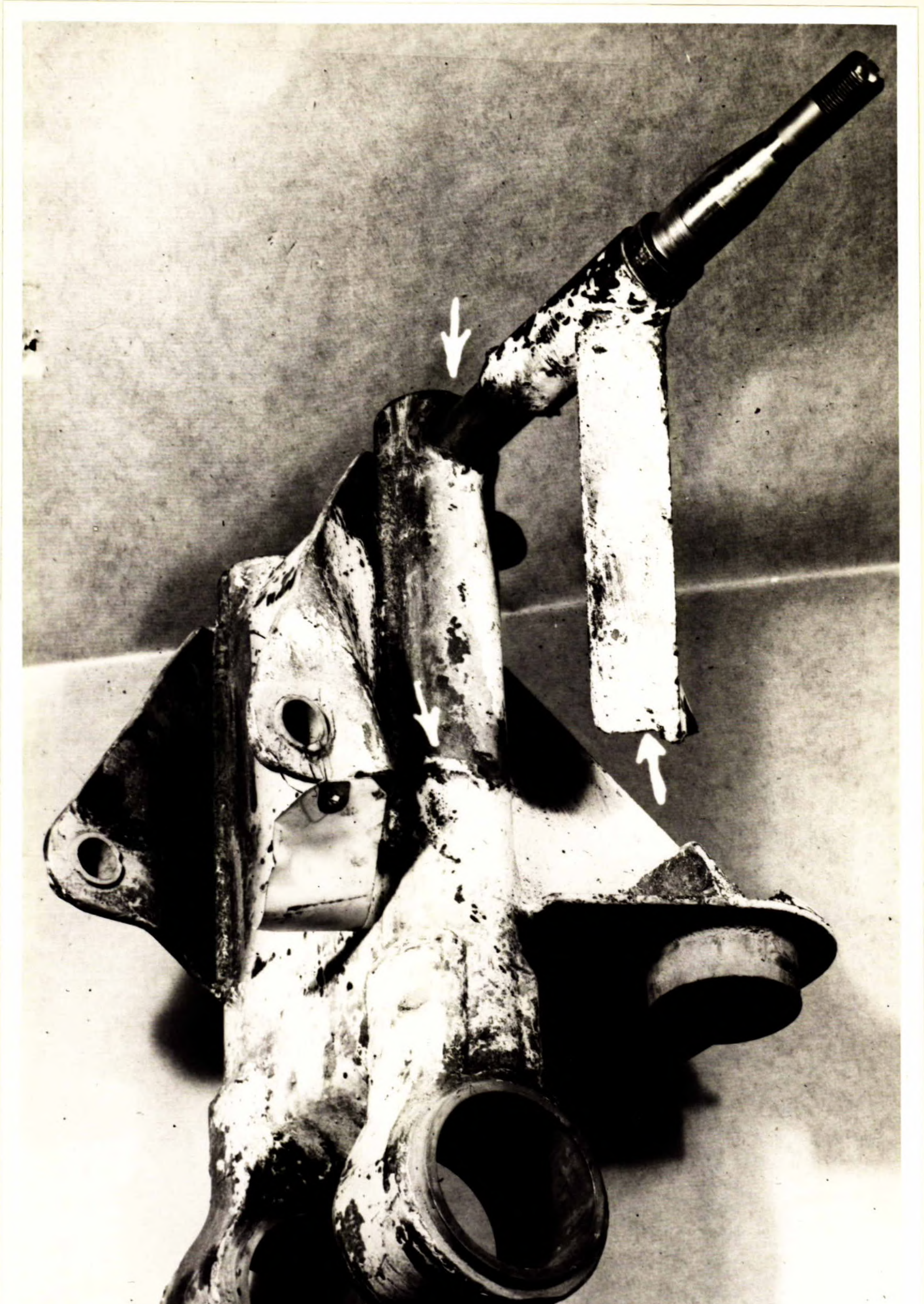
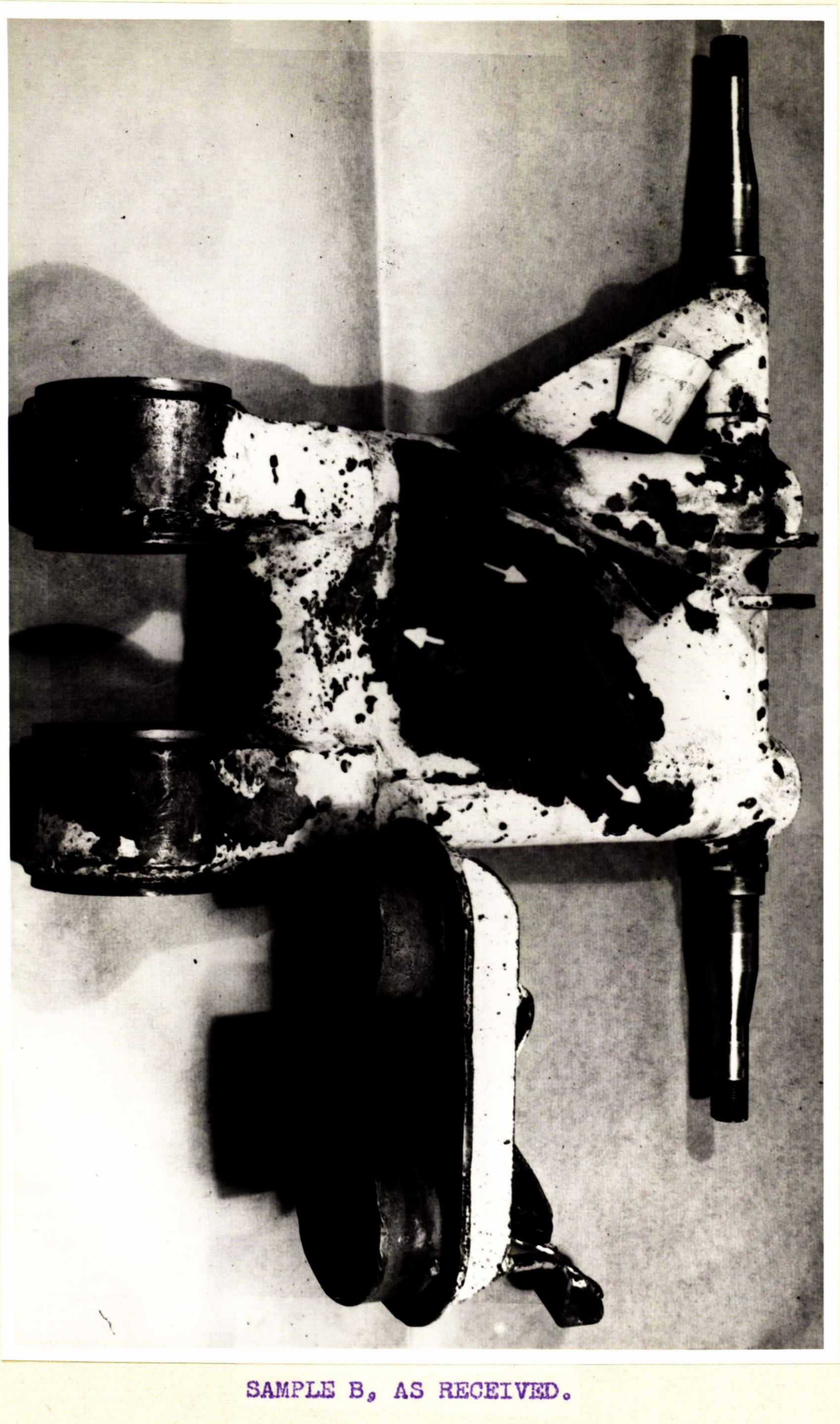
Figure 1.



SAMPLE A, AS RECEIVED.

Arrows point to fractured areas.



SAMPLE B, AS RECEIVED.

Arrows point to fractured area. Note severe tearing of base plate and pipe frame members.

Figure 3.

SAMPLE B. - SECTION OF ONE PIPE FRAME MEMBER AFTER DEEP ETCH IN 50 PER CENT HCl AT 180° F. FOR 10 MINUTES.

A fully killed steel.

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Figure 4.

SAMPLE B. - SECTION OF SECOND PIPE FRAME MEMBER AFTER DEEP ETCH.

A rimmed steel.

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Figure 5.

X100, etched in 2 per cent nital.

EDGE OF FRACTURE OF PINION SUPPORT TUBE OF SAMPLE A.

Pearlite in a matrix of ferrite. Note absence of distortion of structure at fractured edge.

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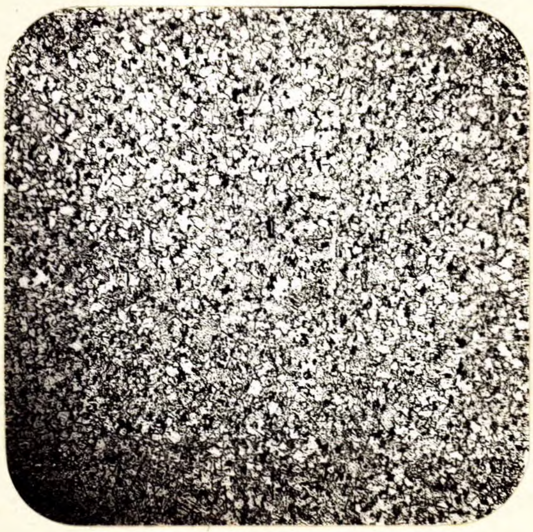
Figure 6.



X100, etched in 2 per cent nital.

STRUCTURE OF FRACTURED PINION SUPPORT TUBE OF SAMPLE A, REMOTE FROM FRACTURED AREA.

Pearlite in a matrix of ferrite. No perceptible difference from Figure 5.

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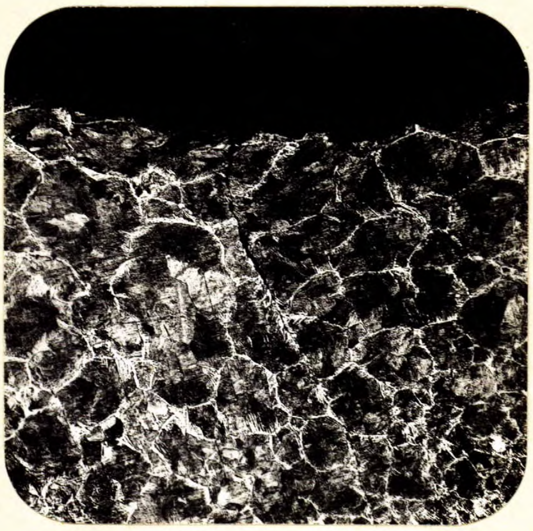
Figure 7.



X100, etched in 2 per cent nital.

EDGE OF FRACTURE OF ANGLE IRON
BRACE OF SAMPLE A.

Coarse-grained sorbite with ferrite at grain boundaries. Note crack following grain boundaries.

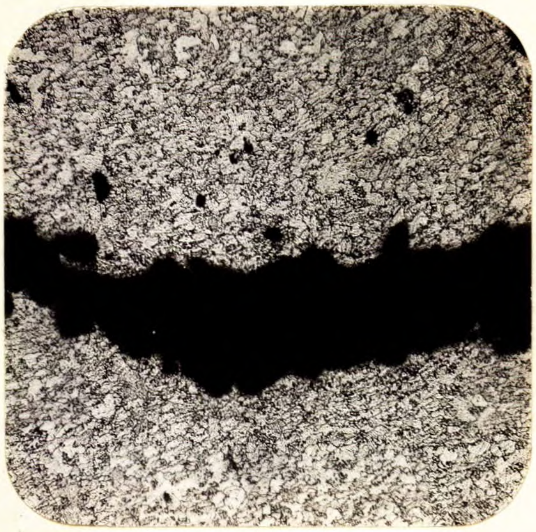
Figure 8.

X100, etched in 2 per cent nital.

NORMAL STRUCTURE OF ANGLE IRON
BRACE OF SAMPLE A.

Pearlite in a matrix of ferrite. Typical banded structure of hot rolled steel.

Figure 9.



X100, etched in 2 per cent nital.

SAME MATERIAL AS FIGURE 4. FRACTURE IN PIPE FRAME MEMBER OF SAMPLE B.

Mostly ferrite with some pearlite. Note absence of distortion along fractured edge.

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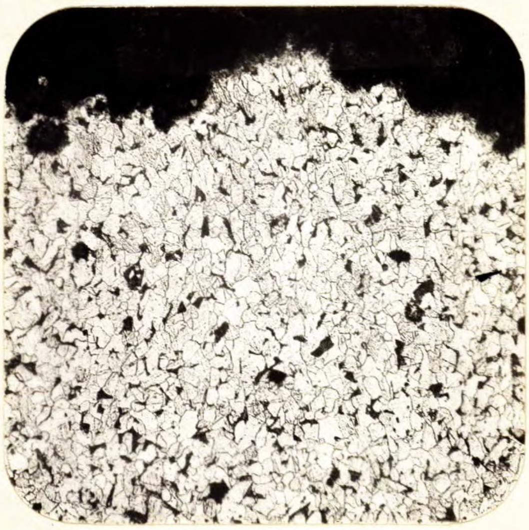
Figure 10.



X100, etched in 2 per cent nital.

SAME MATERIAL AS IN FIGURE 3. FRACTURE IN PIPE FRAME MEMBER OF SAMPLE B.

Pearlite in a matrix of ferrite. Note absence of distortion along fractured edge.

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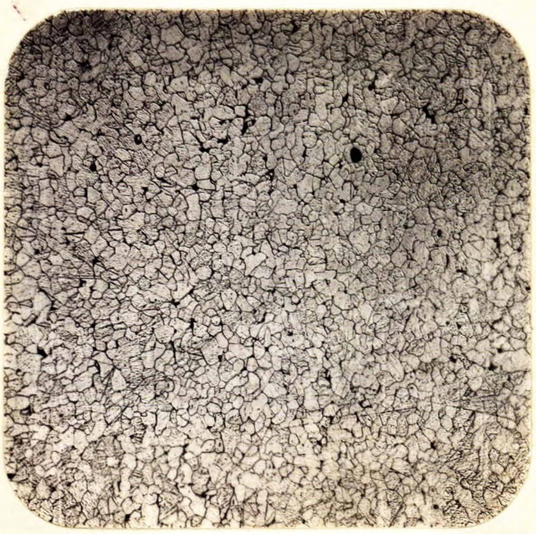
Figure 11.



X100, etched in 2 per cent nital.

STRUCTURE OF FRACTURED BASE PLATE MATERIAL OF SAMPLE B.

Typical low-carbon steel structure - nearly pure ferrite.

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