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September 14th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1710.

Examination of a C.D.P. Track Shoe and Pin from an
Experimental Lot Which Had Failed in Test.

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Origin of Material and Object of Investigation:

A steel track shoe and the corresponding C.D.P. pin were received on August 18th, 1944, from Prof. J. U. MacEwan, of the Division of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario. Requisition No. 666 (A.E.D.B. Lot No. 559, Report No. 22, Sec. B, Test No. 2), which accompanied the shoe and pin, requested:

1. Dimensions of shoe hinges and grouser.
2. Dimensions of pin.
3. Photographs of shoe and pin.
4. Metallurgical examination of shoe and pin.

The requisition stated that the shoe had been manufactured by Dominion Foundries and Steel Limited and had been in service for 1,888 miles before failing. The shoe was said to be B.T.S. No. 1 steel and was from an experimental, not a production, lot. The pin was from a production lot and was reportedly SAE 9255 steel.

TRACK SHOE.

Preliminary Examination:

The hinges on the three-hinge side of the shoe had all fractured (see Figure 1).

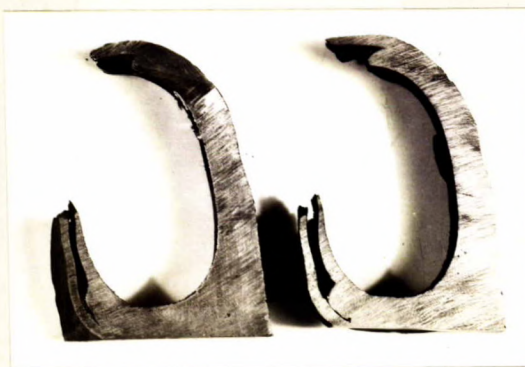
Figure 1.



VIEW OF FRACTURES.

Two of the hinges had pieces missing. One hinge had a serious shrink in the wall (see Figure 2).

Figure 2.



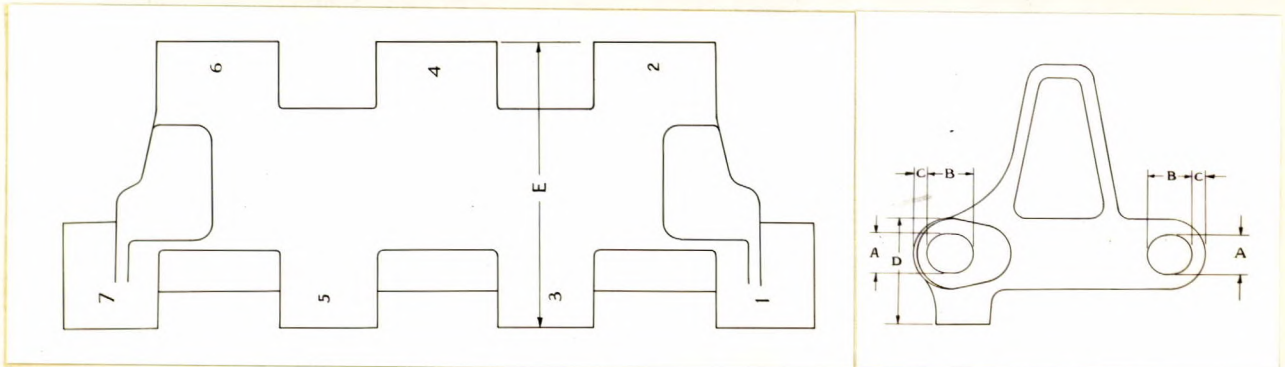
TWO SECTIONS FROM SAME HINGE.

An examination of the fractures indicated the occurrence of a cold shut in one hinge.

Measurements:

The high degree of distortion in the hinges made it impossible to measure any dimensions on the three-hinge side of the shoe. The hinges on the other side were measured, however, as was the grouser. The locations of these measurements are shown in Figure 3 and the results in Table I.

Figure 3.



LOCATIONS OF MEASUREMENTS.

TABLE I. - Results of Measurements.

Hinge No.	Location A	Location B	Location C	Location D
- Inches -				
1	0.885	0.910	0.287	2.005
3	0.875	0.908	0.275	2.040
5	0.865	0.915	0.270	2.040
7	0.875	0.905	0.290	2.040

Chemical Analysis:

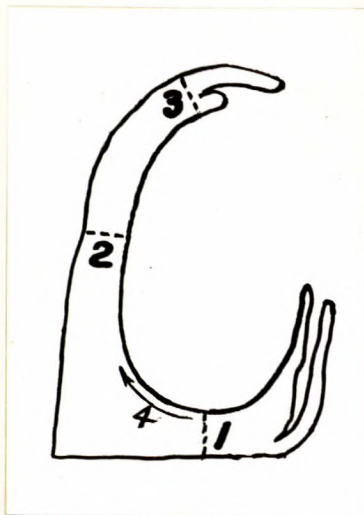
The chemical composition of the steel was as follows:

		<u>As Determined</u>	<u>B.T.S. No. 1</u>
		- Per Cent -	
Carbon	-	0.35	0.30-0.40
Manganese	-	0.78	1.35-1.55
Silicon	-	0.39	0.25-0.45
Phosphorus	-	0.027	0.06 max.
Sulphur	-	0.023	0.06 max.
Molybdenum	-	0.15	0.20-0.30
Copper	-	0.05	0.50-0.60 (optional)

Hardness Surveys:

Hardness surveys across the eye-hole wall were made at three places, in an attempt to discover any variations in hardness. A fourth survey was made around the eye-hole, starting at the bottom of the hinge. These readings were approximately 4 mm. apart. The locations of the surveys are shown in Figure 4 and the results in Table II.

Figure 4.



LOCATIONS OF SURVEYS.

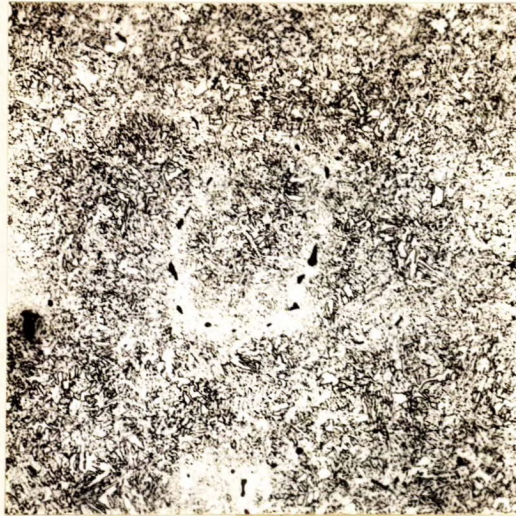
TABLE II. - Results of Hardness Surveys.

<u>Survey No.</u>	<u>Distance from inside edge, inches</u>	<u>Vickers Pyramid number</u>	<u>Survey No. 4. (V.P.N.)</u> <u>(Readings approx. 4 mm. apart, starting from bottom of hinge)</u>
<u>1</u>	0.2	206	199
	1.0	197	202
	1.9	199	199
	2.8	201	199
	3.7	205	198
	4.2	209	201
			228
<u>2</u>	0.4	260	225
	1.0	264	225
	1.7	247	270
	2.5	224	253
	3.0	202	235
	3.9	242	228
	4.4	238	199
	5.0	236	224
<u>3</u>	0.2	227	
	0.9	224	
	1.5	225	
	2.0	227	
	2.9	216	
	3.8	221	
	4.1	209	
	4.9	206	

Micro-Examination:

The microstructure was tempered martensite with the inclusions segregated around the grain boundaries (see Figure 5).

Figure 5.



X250, nital etch.

TEMPERED MARTENSITE.

Note inclusions in grain boundaries.

TRACK PIN.

Preliminary Examination:

The track pin was deeply worn and also slightly bent (see Figure 6).

Figure 6.



PIN AS RECEIVED.

Measurements:

The smallest diameter of the pin was measured three times in each of the seven worn sections (Figure 6). These are listed below, starting from the headed end of the pin:

Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
			- inches -			
0.756	0.752	0.756	0.757	0.752	0.762	0.780
0.761	0.745	0.750	0.759	0.752	0.756	0.775
0.768	0.749	0.757	0.759	0.758	0.762	0.770

Chemical Analysis:

The analysis of the pin was as follows:

	As Determined	NE 9255
	- Per Cent -	
Carbon	- 0.58	0.50-0.60
Manganese	- 0.93	0.75-1.00
Silicon	- 2.07	1.80-2.20
Phosphorus	- 0.025	0.040 max.
Sulphur	- 0.020	0.040 max.
Molybdenum	- 0.01	-

Hardness Determinations:

Surface hardness was taken three times on each of the seven worn sections with the Rockwell hardness tester. Results are shown below.

Section 1	Section 2	Section 3	Section 4	Section 5	Section 6	Section 7
			- Rockwell 'C' Hardness -			
30	35	39	42	43	35	40
32	34.5	39.5	39	40	35	37.5
23.5	38	42.5	40	44	39.5	38.5

Core hardness was taken on one transverse section cut from Section 4. Five readings were taken. The average was Rockwell 'C' 41.5. The specification called for Rockwell 'C' 45 ± 3 for both core and surface hardness.

Micro-Examination:

The structure was tempered martensite (see Figure 7).

Figure 7.



X1000, nital etch.

MICROSTRUCTURE OF PIN.

DISCUSSION:

The smooth surface of the fracture in one hinge indicated a cold shut. This and the very serious shrink in one other hinge are undoubtedly serious defects. Both defects indicate poor foundry practice. However, this should not be taken as an indictment of the producer, as it is understood the shoes in question were from a small experimental lot and that no other shoes have been made at this plant. There would, as yet, have been no opportunity of eliminating foundry troubles inevitably encountered in the commencement of production of a fairly complicated casting.

Both manganese and molybdenum were below the specified limits, the manganese being particularly low. In a production run this would point to poor control in the furnace. The probability is, however, that no particular care was paid to specification for the experimental run.

The low shoe hardness indicates that the shoe was drawn

(Discussion, cont'd) -

at a high temperature. The slight variation in hardness around the eye-hole wall was not sufficiently significant to be attributed to cold work. Severe bending of the wall might have caused the increased hardness in Survey No. 2.

The absence of ferrite in the microstructure indicates that quenching was satisfactory.

The eutectic inclusions present at the grain boundaries point to a high solubility of sulphides. The solubility of the sulphides is influenced by the oxide content of the steel, and thus a low oxide content is indicated. Either greater additions of aluminium, which would result in the formation of aluminium sulphides of lower solubility, or smaller additions, which would lower the solubility of the iron- and manganese-sulphides, might result in a more proper dispersion of non-metallics.

The pin had the specified composition but the hardness, particularly at the surface, was low. Low core hardness indicates low draw temperature, while the lower surface hardness is due to partial decarburization. This low hardness is responsible for the excessive wear.

CONCLUSIONS:

1. The shoe would be unsatisfactory both from the standpoint of composition and hardness if it was to be considered as representative of some production lot. However, as an experimental casting it may well have served the required purpose.
2. The pin is too soft and is partially decarburized.

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