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OTTAWA August 5th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1470.

Examination of Canadian Dry Pin Track which had been in service for 2,486 miles.

(Copy No. 13.)

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

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

(Mines and Geology Branch

O T T A W A August 5th, 1947.

R E P O R T

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Examination of Canadian Dry Pin Track
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Abstract

This report describes a thorough examination on a Canadian Dry Pin Track which had had 2,486 miles of service. It includes measurements made on the links and pins and metallographic examination made on the metal of the links and discussed the implications involved.

Origin of Material and Object of Investigation:

On July 16th, 1943, under Requisition No. 559, A.E.D.B. Lot No. 347 (Report No. 8 Sec. "A") and Requisition No. 560 A.E.D.B. Lot No. 348 (Report No. 8 Sec. "B"), Professor J. W. MacEwan, Consultant to Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, submitted twenty-one SAE 9255 homogeneous Canadian Dry Pin Track Pins, manufactured by Cockshutt Plow Company, Limited, Brantford, Ontario, and twenty-two austenitic

(Origin of Material and Object of Investigation) - manganese steel Canadian Dry Pin Track Links, manufactured by Hull Iron and Steel Foundries, Limited, Hull, Quebec.

It was reported that the links and pins had had approximately 2,486 miles of service at the Ottawa Proving Grounds. Up to 2300 miles no cracked shoes had been observed, but at 2,420 miles 16 links showed cracks in one or two of the centre hinges of the four hinge side. No pin failures occurred during the entire test. An examination of the links and pins was requested to determine the wear and deterioration.

TRACK LINKS

Macro-Examination:

The twenty-two shoes were received in three lots, ten shoes with no obvious cracks, eight shoes with cracks in the two centre hinges of the four-hinge side, and four shoes with a crack in one of the centre hinges of the four-hinge side.

Of the ten shoes with no obvious cracks, the first shoe had cracks starting on both the centre hinges; the second shoe had cracks starting on all four of the hinges. Four were found to have small cracks on the inside edge of one of the centre hinges. Seven of these shoes had the left guiding lug bent over slightly (the shoe is placed with the two lugs up and the four hinge side away from the observer, on examination), and one had the right guiding lug bent over.

Of the eight shoes with cracks in the two centre hinges of the four hinge side, five had both the centre hinges cracked completely through while the remaining three had one of the centre hinges cracked completely through and the other cracked almost through. Three of these shoes are illustrated in Figure 1. Seven of the shoes showed cracks on the inside edge of the two outer

(Figure 1 appears on Page 4).

(Macro-Examination, cont'd) -

hinges on the four-hinge side and four showed cracks on the outside edges of the outer hinges on the three-hinge side. One of these cracks is illustrated in Figure 2. Two of the shoes had the left guiding lug bent over and one the right. This latter shoe is illustrated in Figure 3. In none of the cases where one of the guiding lugs was bent over was there any indication of torn metal.

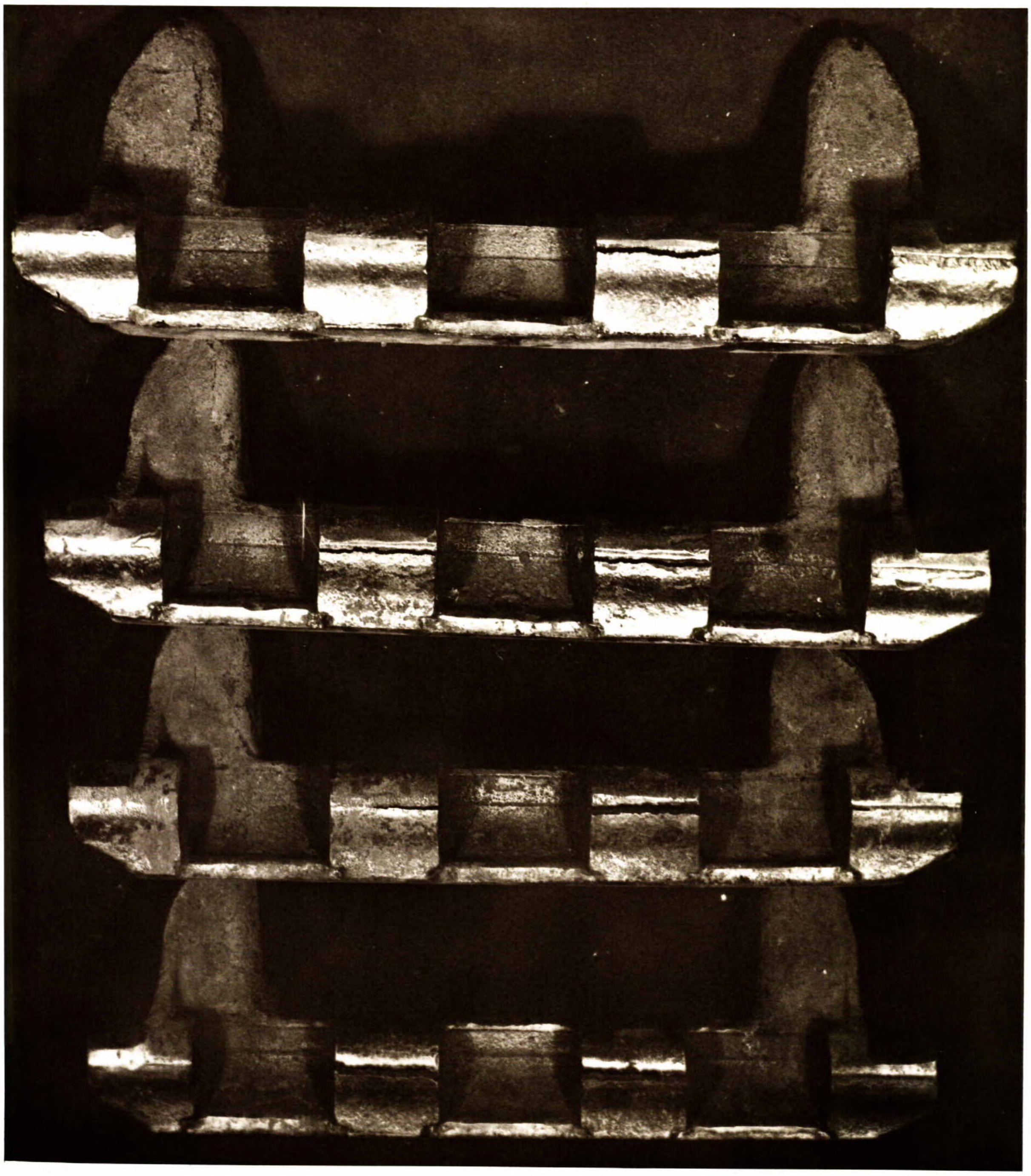
Of the four shoes with a crack in one of the centre hinges on the four-hinge side, all four had one of the centre hinges cracked completely through, while on the other centre hinges cracks had started. One of the shoes is shown in Figure 1. Two of the shoes exhibited cracks on one of the outer hinges on the four-hinge side.

Measurements of the Shoes:

The eyeholes of the shoes were measured with inside callipers to determine if there had been any stretch or wear. Measurements were taken at right angles and parallel to the axis of the guiding lug. The manner of taking the measurements is shown in Figure 4 and the method of numbering the hinges for reference purposes in Figure 5. Table I records the results of the measurements.

(Figure I appears on Page 4.)
(" 2 " " " 5.)
(" 3 " " " 6.)
(Figures 4 and 5 appear on Page 7.)
(Table I is shown on Page 8.)

Figure 1.



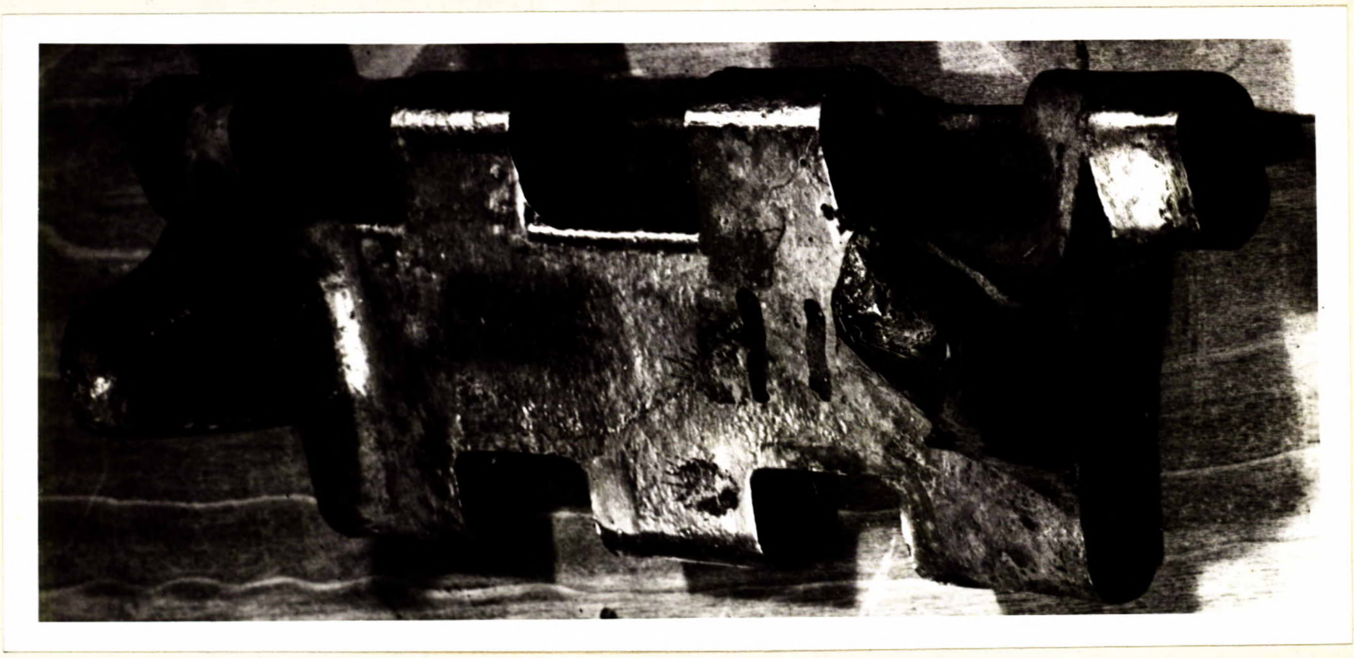
LINKS AS RECEIVED.

Note cracks on two centre hinges.

Figure 2.

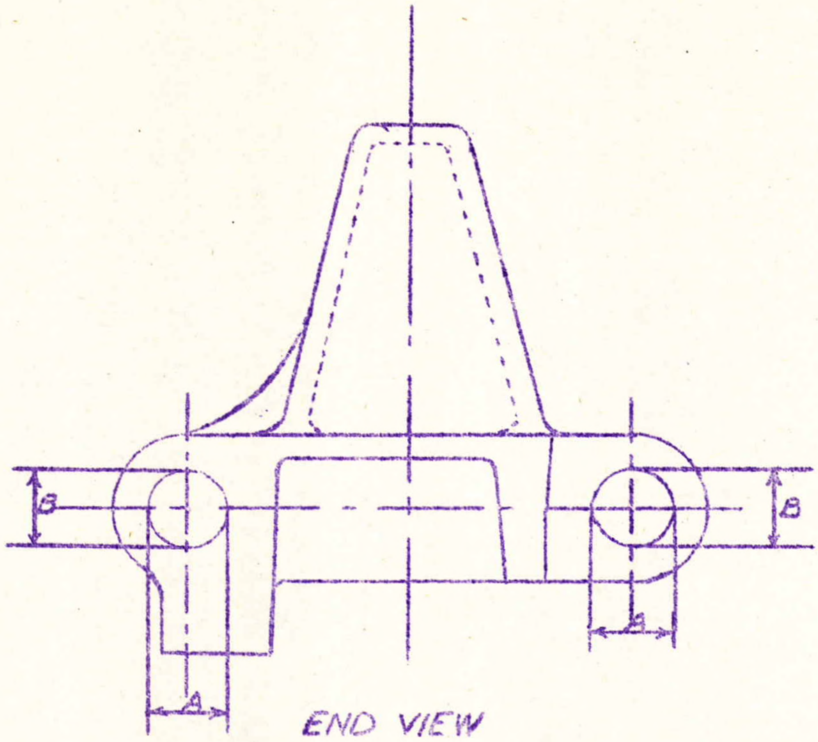
CRACK IN OUTER HINGE OF THREE-HINGE SIDE.

Figure 3.



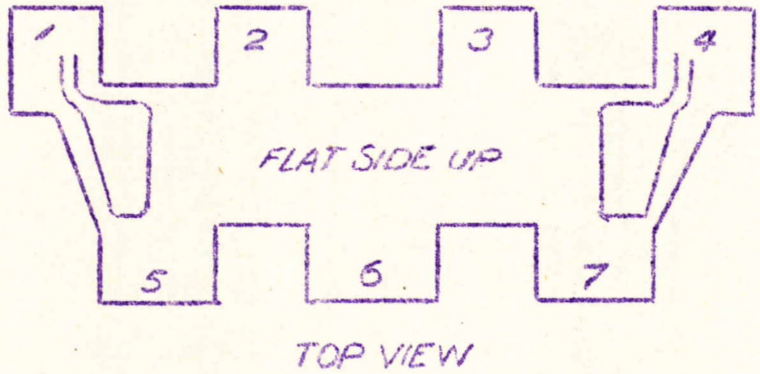
RIGHT GUIDING LUG BENT.

Figure 4.



MEASUREMENTS ON LINK.

Figure 5.



NUMBERING OF HINGES.

TABLE I.[1]

Shoe No.	Measurement, direction of	1	2	3	4	5	6	7
		EYEHOLE NUMBER						
1	A[2]	0.92-0.96	1.00[4]	1.00-0.99	0.95-0.93	0.98	0.98	0.98
	B[3]	0.87	0.90	0.89	0.87	0.88	0.88	0.88-0.91
2	A	0.92-0.95	0.99[4]	0.99	0.96-0.92	0.96	0.97	0.97
	B	0.87	0.89	0.87	0.87	0.88-0.86	0.87	0.87-0.91
4	A	0.92-0.98	0.99-1.02[4]	0.99	0.99-0.92	0.98	0.98	0.98
	B	0.85-0.89	0.89	0.88	0.88	0.92-0.89	0.89	0.87-0.90
5	A	0.95-0.97	1.00[4]	1.00[4]	0.97-0.95	0.97	0.97	0.97
	B	0.88	0.89	0.88	0.88-0.87	0.86-0.85	0.87	0.89
6	A	0.92-0.95	0.98-1.00[4]	1.00	0.95-0.91	0.95	0.95	0.95
	B	0.88-0.89	0.89-0.91	0.90-0.88	0.87	0.87	0.88	0.88-0.90
9	A	0.92-0.97	1.01[4]	1.03	0.98-0.92	0.96	0.96	0.96-0.99
	B	0.86	0.89	0.88	0.86	0.87	0.87	0.87
10	A	0.93-0.98	1.00[4]	1.00[4]	0.97-0.92	0.98	0.98	0.98-0.99
	B	0.87	0.88	0.88	0.88-0.87	0.88	0.86	0.88-0.89
12	A	0.92-0.97	1.02[4]	1.04-1.02	0.98-0.93	0.99	0.99	0.99
	B	0.88	0.91	0.89-0.88	0.87	0.89	0.89	0.89-0.91
13	A	0.89-0.94	0.94	0.94	0.94-0.91	0.93	0.93	0.93
	B	0.85	0.87	0.87	0.86	0.87-0.86	0.86	0.86-0.89
14	A	0.91-0.92	0.93	0.93	0.92-0.91	0.93	0.93	0.93
	B	0.85	0.86	0.86	0.85	0.86	0.85	0.85-0.89
15	A	0.93-0.95	0.97	0.97	0.94-0.91	0.96	0.96	0.96
	B	0.88	0.88	0.88	0.88	0.87	0.87	0.89-0.91
16	A	0.91-0.95	0.96	0.96	0.94-0.92	0.93	0.95	0.94-0.95
	B	0.86	0.87-0.86	0.87	0.86	0.87	0.87	0.87
17	A	0.92-0.97	0.97-0.99	0.99-0.98	0.97-0.92	0.98-0.96	0.96	0.96
	B	0.87-0.89	0.89-0.88	0.89	0.89-0.88	0.88	0.88	0.88
18	A	0.93-0.96	0.96-0.97	0.97	0.95-0.91	0.96-0.95	0.95	0.95-0.96
	B	0.88-0.89	0.89	0.88	0.88-0.87	0.89	0.89	0.89
19	A	0.93	0.96-0.97	0.98	0.95-0.91	0.94	0.94	0.94-0.97
	B	0.88	0.89	0.88	0.88	0.88-0.87	0.88	0.88
20	A	0.93	0.94	0.96-0.95	0.94-0.90	0.95	0.95	0.95
	B	0.84-0.86	0.87	0.88-0.88	0.86	0.87-0.86	0.86	0.88
21	A	0.91-0.94	0.95	0.95	0.93-0.90	0.94	0.94	0.95
	B	0.86	0.87	0.86	0.86	0.88	0.87	0.89-0.90
22	A	0.92-0.94	0.97	0.97	0.95-0.92	0.94	0.94	0.94
		0.88	0.88	0.88	0.88	0.88	0.88	0.88

(1) Original diameter of eyehole from Drawing No. F1489 (ED) was 0.831 inch.

(2) A - Perpendicular to axis of the grinding lug.

(3) B - Parallel to axis of the grinding lug.

(4) Indicates a hinge which is cracked so badly that accurate measurement is impossible.

-

Weight of Shoes:

The shoes were weighed and Table II shows the results:

TABLE II.

Shoe No.		Weight, pounds	Shoe No.		Weight, pounds
1	-	$18\frac{3}{4}$	14	-	20
2	-	18	15	-	$19\frac{1}{4}$
4	-	$18\frac{1}{2}$	16	-	18
5	-	$18\frac{3}{4}$	17	-	$18\frac{3}{4}$
6	-	18	18	-	$19\frac{1}{2}$
9	-	$18\frac{3}{4}$	19	-	$18\frac{1}{2}$
10	-	$18\frac{1}{4}$	20	-	$18\frac{1}{4}$
12	-	18	21	-	$18\frac{3}{4}$
13	-	$19\frac{1}{2}$	22	-	$19\frac{1}{2}$

Hardness of the Wearing Surfaces:

Sections were cut from three eyeholes and hardness readings were taken on the wearing surface, using the Vickers machine and the 5-kilogram load. Eight readings were taken on each eyehole and the mean values of these readings are recorded below:

Number	V.P.N.
1	466
2	510
3	489

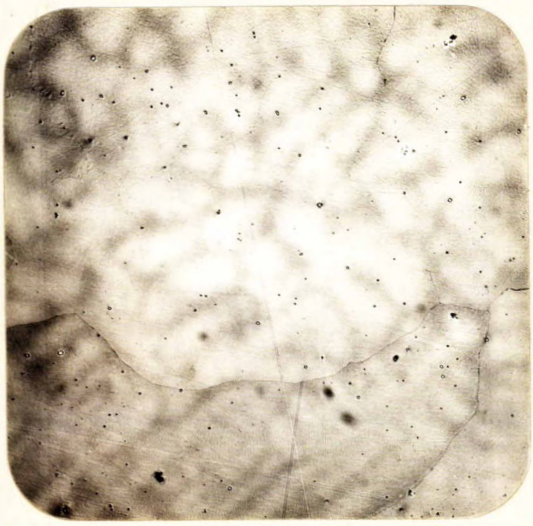
On the flat surfaces of three links, which are in contact with the bogie wheels, hardness readings were taken using a Brinell machine with a 3000-kilogram load. The results appear below:

Shoe No.	B.H.N.
6	315
13	340
17	350

Micro-Examination:

Micro specimens were cut from one of the hinges and from a thick section, polished, etched in 2 per cent nital and examined under the microscope. Figure 6 shows the structure near the break in the hinge.

Figure 6.



X100, nital etch.

STRUCTURE OF LINK.

Note absence of free carbides and large grain size.

Pull Tests:

One shoe (No. 12) was taken and subjected to a pull test, together with a good shoe, in the Amsler Universal testing machine. This shoe had both centre hinges on the four-hinge side cracked completely through, cracks on the inside edges of the two outer hinges of the four hinge side, and cracks on the outer edges of the three-hinge side. Figure 7 shows this shoe attached to the good shoe after it had been pulled. Note bend on pin.

At a load of 78,000 pounds the two centre hinges opened up and the load fell off. (Satisfactory uncracked shoes withstood a pull of 195,000 pound without cracking.

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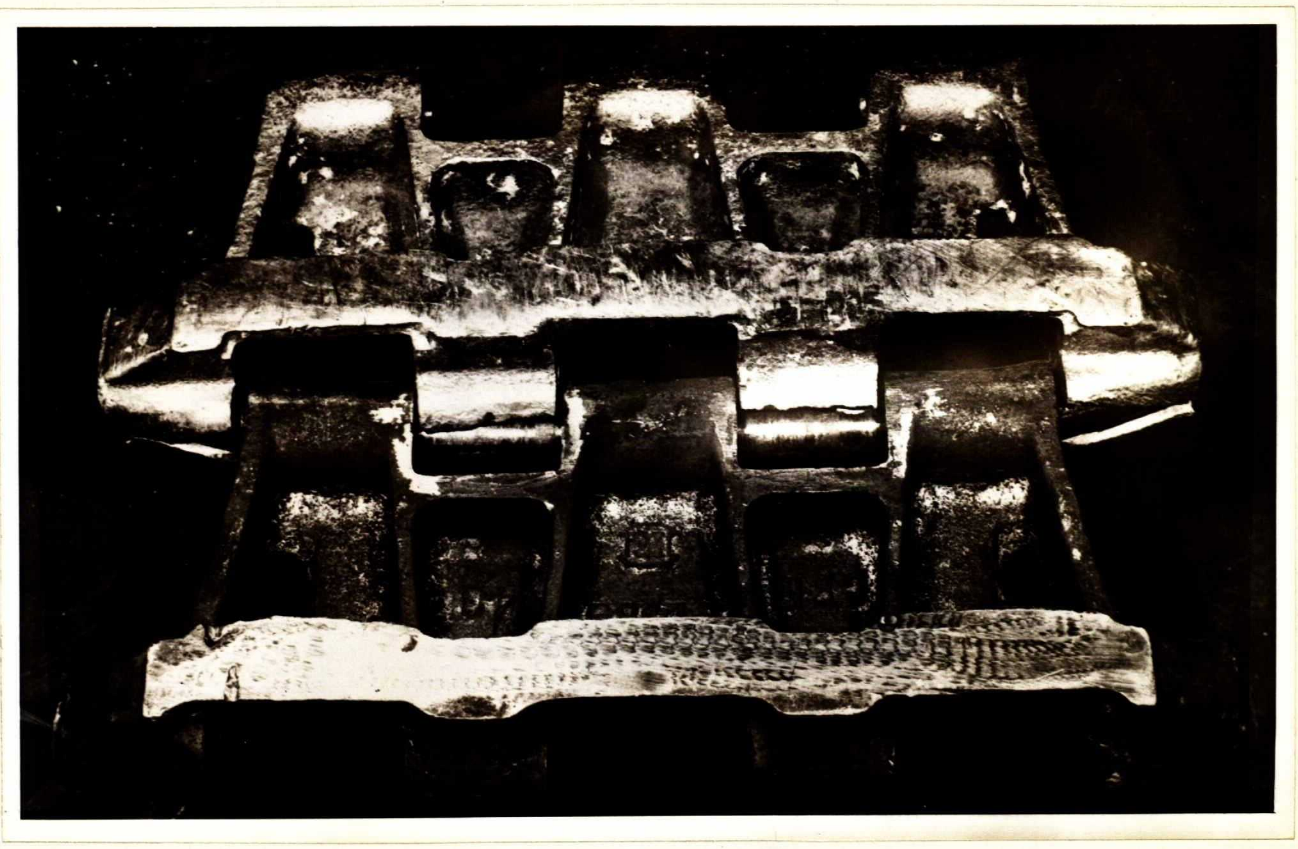
(Pull Tests, cont'd) -

Figure 7.



PULLED LINKS.

Note bend on pin.

TRACK PINS.

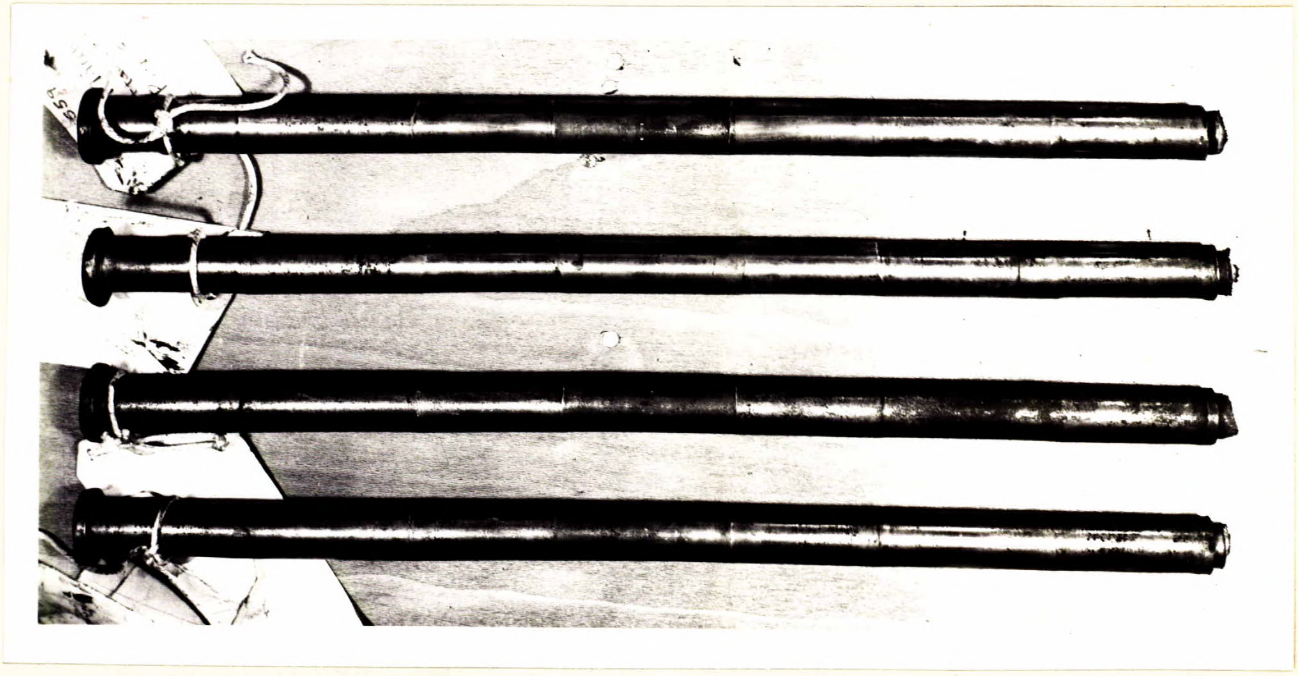
Macro-Examination:

Two of the twenty-one pins exhibited slight crankshaft effect while the remaining nineteen pins were worn evenly all around. Figure 8 shows four representative pins.

(Continued on next page)

(Macro-Examination, cont'd) -

Figure 8.



PINS AS RECEIVED.

The pins were all magnafluxed and examined for any cracks but none were found.

Measurement Wear:

Figure 9 shows the manner in which the measurements were taken on the pins.

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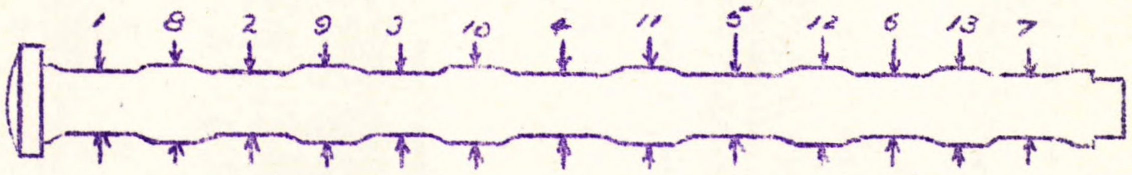
(Measurement Wear, cont'd) -.

Figure 9.



MEASUREMENTS ON PIN.

An example of the measurements on one pin and the method of calculating the wear follows:

	NUMBER OF READING						
	1	2	3	4	5	6	7
Minimum diameters -	0.800	0.796	0.792	0.794	0.796	0.798	0.801
	8	9	10	11	12	13	
Maximum diameters -	0.810	0.805	0.803	0.805	0.804	0.808	

Mean minimum diameter = 0.797 inch.
Mean maximum diameter = 0.806 inch.
Maximum wear = 0.810-0.797= 0.013 inch.
Mean wear = 0.806-0.797= 0.009 inch.

Maximum wear was found by subtracting the mean minimum diameter from the largest maximum diameter. The mean wear was found by subtracting the two mean values of maximum and minimum diameters. Although wear would be expected to be fairly light on portions of the pins that did not bear the load, calculated values for wear are probably slightly less than actual values.

(Continued on next page)

(Measurement Wear, cont'd) -

TABLE III.

Pin No.	Largest maximum diameter, inches	Mean maximum diameter, inches	Mean minimum diameter, inches	Maximum wear, in inches	Wear per 1,000 miles, inches	Mean wear, in inches	Wear per 1,000 miles, in inches
1	0.810	0.806	0.797	0.013	0.0054	0.009	0.0037
2	0.812	0.806	0.788	0.024	0.010	0.018	0.0075
3	0.811	0.808	0.793	0.018	0.0075	0.015	0.0062
4	0.817	0.810	0.796	0.021	0.0087	0.014	0.0058
5	0.810	0.805	0.785	0.025	0.0108	0.020	0.0083
6	0.810	0.804	0.793	0.017	0.0071	0.011	0.0046
7	0.812	0.810	0.790	0.022	0.0092	0.020	0.0083
8	0.813	0.810	0.795	0.018	0.0075	0.015	0.0062
9	0.811	0.805	0.792	0.019	0.0079	0.013	0.0054
10	0.811	0.809	0.793	0.018	0.0075	0.016	0.0067
11	0.810	0.805	0.793	0.017	0.0071	0.012	0.0050
12	0.810	0.807	0.787	0.023	0.0096	0.020	0.0083
13	0.812	0.809	0.791	0.021	0.0087	0.018	0.0075
14	0.815	0.810	0.799	0.016	0.0067	0.011	0.0046
15	0.815	0.810	0.787	0.028	0.0116	0.023	0.0096
16	0.815	0.812	0.792	0.023	0.0096	0.020	0.0083
17	0.812	0.806	0.796	0.016	0.0067	0.010	0.0042
18	0.812	0.805	0.791	0.021	0.0087	0.014	0.0058
20	0.810	0.807	0.792	0.018	0.0075	0.015	0.0062

Mean wear per 1,000 miles - 0.0064

On pins which exhibited the crankshaft effect, since the wear is uneven, it was calculated as twice the difference of the maximum and minimum diameters.

Pin No.	Largest maximum diameter, inches	Mean maximum diameter, inches	Mean minimum diameter, inches	Maximum wear, in inches	Wear per 1,000 miles, inches	Mean wear, in inches	Wear per 1,000 miles, in inches
19	0.816	0.813	0.795	0.042	0.0192	0.036	0.0150
21	0.814	0.812	0.785	0.058	0.0241	0.054	0.0225

(Continued on next page)

(Measurement Wear, cont'd) -

It was noted that, on thirteen out of twenty-one pins that minimum diameters occurred at a point about one- and-a-half inches from the headed end. This is illustrated by the following example:

	NUMBER OF READING						
	1	2	3	4	5	6	7
Minimum diameters -	0.769	0.797	0.797	0.798	0.796	0.794	0.786
	8	9	10	11	12	13	
Maximum diameters -	0.810	0.808	0.805	0.812	0.806	0.812	

Surface Hardness:

Hardness readings were taken around the middle of the pins using the Rockwell tester "C" scale.

TABLE IV.

Pin No.	Surface hardness.	Core hardness.	Pin No.	Surface hardness.	Core hardness.
1	48-52.5	47-49	12	49-51	46-47
2	48-50	48-50	13	45.5-50.5	
3	455-48		14	47-50.5	43-46
4	49-51.5	47	15	44.5-49	
5	46-52		16	45-51	45-47
6	51-53	48-49	17	48-49.5	43-45
7	49-51		18	47-49.5	44-46
8	45-49.5		19	44-47.5	
9	45-48	44-44.5	20	41-48.5	
10	48-50	48-48.5	21	46-48.5	
11	49-51	45-46.5			

Bend Tests:

Bend tests were carried out on an Amsler Universal machine, using a twelve inch-radius and supporting the pins on

(Continued on next page)

(Bend Tests, cont'd) -

twelve-inch centres. Table V records the results.

TABLE V.

Pin No.	Surface Hardness (Rockwell 'c')	Core Hardness (Rockwell 'c')	Load pounds.	Deflection in inches.
1	48-52.5	47-49	9150	1.070
4	49-51.5	47	10,500	2.28
6	51-53	48-49	8450	0.714
14	47-50.5	43-46	9500	1.36
16	44.5-51	45-47	9700	1.815
18	47-49.5	44-46	9000	2.6

Drop Impact Tests:

Drop impact tests were carried out by allowing a 50 pound weight to fall a distance of eight feet striking the pin. Thus the pin was subjected to a 400 foot pound blow. Table VI records the results.

TABLE VI.

Pin No.	Surface Hardness (Rockwell 'c')	Core Hardness (Rockwell 'c')	REMARKS
2	48-50	46-47	Passed.
9	45-48	44-44.5	"
10	48-50	48-48.5	"
11	49-51	45-46.5	"
12	49-51	46-47	"
17	48-49.5	43-45	"

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Discussion:

The macro examination of the links showed that the failures were located in the two centre hinges of the four-hinge sides. On examination of the links which had not failed completely, it was seen that the cracks tend to start on the inside edge of the two central hinges of the four-hinge side. It is therefore believed that, in service, these two hinges are subjected to a greater tension than the two outside ones.

This is further substantiated by the measurements on the eyeholes. Assuming the original diameter of the hole to be 0.831 inches, as given on Drawing No. F-1489 (AED), the measurements show that the holes have been elongated on the average of 0.13 inch and that the two centre hinges on the four-hinge side have been elongated more than those on the outside (about 0.05 more). Further, the two outside hinges show a tapering effect increasing in diameter from the outside to the inside, when measured in the direction perpendicular to the axis of the guiding lug. This tapering effect was also observed to a lesser extent on measuring parallel to the axis of the guiding lug. (Visual examination of good unused links subjected to pull tests showed that the two centre hinges on the four-hinge side stretched more than the two outside hinges.) The hinges on the three-hinge side stretched fairly evenly over their whole length. In some cases there was a slight tendency for a taper, the diameter increasing from the inside to the outside of the two outer hinges. This effect showed up more on measuring parallel to the axis of the guiding lug than perpendicular to it. Further, where any cracks occurred on the three-hinge side they occurred on the outer edge of the outer hinges. These factors point to a condition in which the outer parts of the three-hinge side are subjected to higher stresses than the central portions.

(Continued on next page)

(Discussion, cont'd) -

Some failures are due to cold shuts in the hinges. The ill effects of these casting defects are magnified by the stress distribution in the shoe and hence the shoe is weak where it should be strong. This might possibily be overcome by changing the method of gating. The metal, however, is of good quality as can be seen by the fact that, although the guiding lug illustrated in Figure 3 is badly bent over, there are no cracks or torn metal visible.

It is possible that the links have reached their fatigue limit. This is indicated by the large number of shoes which reportedly began showing cracks between 2,300 and 2,420 miles.

The hardness readings on the wearing surfaces show that the manganese steel has work-hardened satisfactorily and approaches the hardness of the pins. The readings taken on the flat surface show considerable work-hardening also.

Since the original weights of the shoes are not known, it is impossible to say positively if any weight has been lost during service but it seems probable that about three-quarters of a pound was lost.

The results of the pull test show that a shoe still has some strength, even though both centre hinges on the four hinge side may be cracked through. However, since no evidence is obtainable as to what stresses the shoe is subject to in service, it is impossible to state how much longer the shoe would be serviceable. The track definitely withstood a test over difficult terrain just before it was removed from service.

With the exception of two pins all the pins are worn evenly all around and no permanent deformation, due to bending, was observed. It was observed, however, that there was a tendency for the pins to wear faster at a point about one-and-a-half inches

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(Discussion, cont'd) -

from the headed end. In one case the diameter at this point was 0.035 inch less than the next smallest diameter and was 0.053 inch less than the largest diameter measured. This might indicate the presence of soft spots, caused by a retarding of the cooling rate at this point on quenching the pins.

The surface hardness of the pins is within the specified limits and in most cases was in the upper range of this limit. Thus the pins have not been heated up in service to a temperature exceeding the draw temperature (800° F.). The core hardnesses of the pins were slightly lower than the surface hardnesses. A slight increase in the difference between the two values may have been caused by work-hardening of the pin surface metal.

That the pins are still serviceable, is shown by the bend and drop impact tests. In the drop impact tests, all pins withstood a 400-foot-pound blow while the specification for new pins only requires them to withstand a 350-foot-pound blow. In the bend tests, all pins (except one) took a deflection of more than one inch and the one exception passed the 0.7-inch deflection required by specification. The failure of that pin to take a deflection of one inch may be attributed to its high surface hardness (51-53 Rockwell "c").

The average elongation of the eyeholes on the ten shoes which had no obvious cracks (shoes 13 to 22 inclusive) is 0.13 inch. That is a combined elongation and wear of 0.054 inch per thousand miles. The mean wear on the pins was found to be 0.0064 inch per thousand miles. This gives a ratio of wear for shoes to pins of 8.4 to 1. Probably the value is somewhat smaller due to the fact that pin wear is calculated and actual wear will be higher.

(continued on next page)

Conclusions:

1. Failure of the links occurs first in the two centre hinges of the four-hinge side, since these are the highest stressed portions of the casting.

2. Some of the failures were caused by cold shuts.

3. The metal is of good quality and no free carbides were observed.

4. The metal work-hardened considerably on the wearing surfaces, hardnesses varying from 466 to 510 V.P.N.

5. The pins wore evenly all around and were not permanently deformed by bending.

6. Soft spots on the pins caused greater wear in some portions than others.

7. The pins have not been heated excessively in service, as no noticeable softening effect occurred on the surface.

8. There were no fatigue cracks on the pins.

9. The ratio of wear on shoes to wear on pins is 8.4 to 1.

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JPO:GHB:FM.