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O T T A W A November 9th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1530.

Interim Report of An Investigation into Failures of SAE 9255 Canadian Dry Pin Track Pins for the Grizzly Tank.

(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

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Origin of Material:

This is an interim report covering the work done on the SAE 9255 pins for the GRIZZLY tank during the period from November 1st to 8th, 1943.

Requests for this investigation, and materials submitted, are:

(1) O.T. 4088; Inspection Board of United Kingdom and Canada. Nine (9) broken pieces and 1 unused pin received on November 1st.

(2) AEDB Lot No. 390, Req. 603; Department of Munitions and Supply. Two (2) broken pins submitted by Prof.

(Origin of Material, cont'd) -

J. U. MacEwan on November 1st, and 100 broken pins received on November 8th, from Montreal, Quebec.

(3) AEDB Lot No. 391, Req. 604; Department of Munitions and Supply. Fifty (50) unused pins received from Hull, on November 4th.

(4) AEDB Lot No. 392, Req. 605; Department of Munitions and Supply. Forty (40) pins unbroken, taken from a tank which had been in service for approximately 50 miles, received on November 4th from Montreal.

The results of the work carried out at the Cockshutt Plow plant, Brantford, Ontario, on November 5th and 6th, are also included in this report.

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Chemical Analysis:

Drillings were taken for chemical analysis from an unused pin submitted by Hull and from 2 broken pins obtained from Montreal.

	Hull Pins	Montreal Pins	
		Failed No. 1	Failed No. 2
	- Per cent -		
Carbon -	0.52	0.55	0.53
Manganese -	0.95	0.95	0.85
Silicon -	2.09	1.96	2.02
Sulphur -	0.022	0.016	0.020
Phosphorus -	-	-	0.011

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Hardness Tests on Failed Pins

Surface and core hardnesses were taken on a large number of broken pins. Table I lists the readings obtained, using the Rockwell 'C' scale.

(Continued on next page)

(Hardness Tests on Failed Pins, cont'd) -

TABLE I.

Pin No.	Surface hardness, Rockwell 'C'	Core hardness, Rockwell 'C'	Pin No.	Surface hardness, Rockwell 'C'	Core hardness, Rockwell 'C'
1	46-50	49-50	46	54-55	53-55
2	50-53	53-54	47	50-51	51
3	49-51	49-51	48	50-51	52
4	51-52	51-52	49	50	51-52
5	53	53	50	52-53	53-54
6	53-54	53	51	51-55	52
7	51-52	51-52	52	50-51	52
8	50-51	51	53	52-53	52-53
9	49-51	50-51	54	52-54	54
10	50-51	50	55	52-53	52
11	52	52-53	56	50-52	
12	50-51	47-48	57	52-53	
13	50-52	48-51	58	50-52	
14	52-53	51-53	59	51-53	
15	50-52	51-52	60	54-56	
16	50-52	49-51	61	54-56	
17	50	50	62	51-53	
18	51-52	51-52	63	54-55	
19	50-51	50-51	64	49-51	
20	50-52	49-52	65	50-52	
21	51-52	53-54	66	50-51	
22	52-53	51-52	67	50-52	
23	51	49-52	68	54-55	
24	51	50-51	69	50-52	
25	52	51-52	70	50-51	
26	51-52	52-53	71	50-52	
27	51-53	51-53	72	50-52	
28	50-51	50-51	73	50-51	
29	52-53	51-52	74	52-54	
30	51-52	52	75	53	
31	52-54	52-53	76	51	
32	50-52	50-51	77	52	
33	50-51	51	78	50-52	
34	52-54	53-55	79	53-54	
35	50-52	51-52	80	54	
36	50-51	50	81	53-54	
37	51-52	50-51	82	50-52	
38	47-50	51	83	52-54	
39	50-53	52-53	84	52-54	
40	50-51	51	85	51-53	
41	50-51	50-51	86	48-49	
42	50- 2	47-48	87	49-50	
43	43-46	47-48	88	51-52	
44	51-52	52	89	53-54	
45	55	52-53	90	52-53	

Note: Readings underlined where reading in case or core exceeds 52 Rockwell 'C'.

36 pins have readings of 53 Rockwell 'C' on surface or core.

2 pins have all readings below 50 Rockwell 'C' for

(Hardness Tests on Failed Pins, cont'd) -

both core and surface.

TABLE IA. - Depth-Hardness Relationships.*

V.H.N.		Distance from surface, in inches
525	-	0.165
525	-	0.106
525	-	0.086
525	-	0.058
536	-	0.036
514	-	0.018
530	-	0.012
530	-	0.004
530	-	Surface.
508	-	0.255
508	-	0.197
514	-	0.169
514	-	0.100
503	-	0.075
488	-	0.050
519	-	0.018
536)	Surface	
536)		

* In the time available, it was only possible to check this relationship for two pins.

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Bend Tests on 7-Inch Centres:

Bend tests were carried out on 7-inch centres, using a 1-inch-radius block. The centres were reduced to allow bending of a section of a broken pin. Table II lists the results:

TABLE II. - 7-Inch Centres.

Pin	Load, pounds	Deflection, in inches	Surface hardness, Rockwell 'C'
Hull (unused)	24,250	0.584	-
Rivetted pin taken out prior to any service	24,900	1.42	-
Broken pin in service	22,000	0.589	-
" " " "	19,000	0.340	-
" " " "	17,000	0.325	50-51
" " " "	17,000	0.319	51-53
" " " "	23,800	0.877	51-53
" " " "	23,850	0.753	50-52

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Bend Tests on 5-Inch Centres, Broken Pins:

Broken pins were tested using 5-inch centres and 1-inch radius. The following results were obtained:

TABLE III.

Pin No.	Load, in pounds	Deflection, in inches	Surface hardness, R. 'C'	Core hardness, R. 'C'
1 -	26,500	0.260	50-53	53-54
2 -	26,000	0.390	49-51	49-51
3 -	24,600	0.265	51-52	51-52
4 -	26,500	0.328	53	53

Results from Unbroken Pins Taken from a Track Which Had a Number of Pin Failures:

Forty unbroken pins which had been removed from a track which had shown a number of pin failures up to approximately 60 miles were examined. Table IV gives the bend and impact test results. The bends were taken on the regular specified 12-inch centres and 12-inch-radius block. The impact tests were carried out on the standard test machine.

TABLE IV. - 12-Inch Radius and 12-Inch Centres.

Pin No.	Bend load, in pounds	Deflection, in inches	Impact, foot-pounds	Surface hardness, R. 'C'	Core hardness, R. 'C'
1	10,100	2.000	-	49-51	48-50
2	9,900	1.42	-	50-52	50-51
3	10,050	3.25	-	48-49	49-50
4	9,850	2.52	-	49-51	49-50
5*	8,000	0.570	-	49-51	49-51
6	10,000	1.035	-	50-52	51-53
7	9,500	0.897	-	50-51	51-52
8	10,200	1.679	-	50-51	48-51
9	9,400	1.12	-	49-50	49-51
10	10,050	1.69	-	50-51	48-51
11	10,050	1.92	-	52-53	50-52
12	9,900	2.65	-	49-51	48-50
13	10,150	2.800	-	50-51	50-51
14	10,350	2.630	-	52-53	49-51
15	10,350	1.430	-	50-51	50-52
16	10,350	1.895	-	50-52	50-51
17	9,550	1.066	-	50-51	49-51
18	10,200	2.000	-	50-52	50-52
19	9,380	1.250	-	49-51	50-51

(Continued on next page)

(Results from Unbroken Pins Taken from a Track Which Had a Number of Pin Failures, cont'd) -

TABLE IV. - 12-Inch Radius and 12-Inch Centres, cont'd. -

Pin No.	Bend load, in pounds	Deflection, in inches	Impact, foot-pounds	Surface hardness, R. 'C'	Core hardness, R. 'C'
20	-	-	3x400	50-52	49-50
21	-	-	3x400	52-53	52-53
22	-	-	3x400	51-53	51-52
23	-	-	3x400	50-51	50-51
24	-	-	3x400	50-52	49-50
25	-	-	3x400	50-52	48-50
26	-	-	3x400	49-51	48-51
27	-	-	3x400	52-54	52-53
28	-	-	3x400	50-52	51-52
29	-	-	3x400	49-51	48-51
30	-	-	3x400	50-51	49-51
31	-	-	3x400	50-52	50-51
32	-	-	3x400	50-51	49-51
33	-	-	3x400	50-51	49-50
34	-	-	1x400F	55-56	54-55
35	-	-	3x400	50-52	49-51
36	-	-	3x400	49-51	48-51
37	-	-	3x400	50-51	49-51
38	-	-	3x400	50-52	50-52
39	-	-	3x400	50-51	49-51

• Below specification bend figure, 0.7 inch.
Readings underlined where hardness in case or core exceeds R. 'C' 52.
Seven pins have readings of 53 R. 'C' or more on case or core.
No pin has all readings below 50 R. 'C'.

Results from Unused Pins Obtained from Hull Iron and Steel Foundries Limited.:

Fifty pins were obtained at random from the stock pile at the Hull Iron and Steel Foundries Limited. These pins had not been rivetted into track. Incidentally, a few tests made on rivetted pins taken from unused track gave similar results. Impact and bend tests were made under the standard specified conditions (namely, 12-inch radius and 12-inch centres for the bend test and impacts, on the standard testing machine). Table V lists the results:

(Continued on next page)

(Results from Unused Pins Obtained from Hull Iron and Steel Foundries Limited, cont'd) -

TABLE V. - 12-Inch Radius and 12-Inch Centres.

Pin No.	Impact, foot-pounds	Bend load, in pounds	Deflection, in inches	Surface hardness, R. 'C'	Core hardness, R. 'C'
1	-	10,000	1.722	51-52	50-51
2	-	9,900	1.675	45-47	45-48
3	-	8,900	0.720	49-51.5	49-51
4	-	10,150	1.758	47-50	48-50
5*	-	8,050	0.485	53-54	53-55
6	3x400	"	"	49-51	48-52
7	3x400F	"	"	52-53	52-53
8	3x400	"	"	51-52	51-52
9	3x400	"	"	47-48	48-50
10	3x400	"	"	47-49	47-50
11	3x400	"	"	50-52	51-52
12	3x400	"	"	50-52	50-52
13	3x400	"	"	48-49	46-49
14	3x400	"	"	48-49	49-51
15	3x400	"	"	50-52	50-52
16	-	9,450	1.042	49-50	49-51
17	-	10,400	1.750	50-52	50-52
18	-	10,400	1.300	48-52	52-53
19	-	10,100	2.412	50-51	51
20	-	9,550	0.946	50-51	49-50
21	-	10,550	1.464	50-52	50-53
22	-	10,400	1.692	47-50	48-50
23	-	10,700	1.200	50-51	51-53
24*	-	7,000	0.403	54-56	53-55
25	-	9,750	2.325	48-50	48-50
26	-	10,500	1.854	49-51	49-52
27	-	10,200	2.135	49-51	49-52
28	-	10,550	1.170	53-54	49-52
29	-	9,800	1.300	48-51	49-51
30	3x400	"	"	50-52	46-49
31	3x400	"	"	49-50	50-51
32	3x400	"	"	53-54	52-53
33	3x400	"	"	48	48-50
34	3x400	"	"	49-50	52-53
35	3x400	"	"	50-53	52-54
36	2x400F	"	"	52-53	50-51
37	2x400F	"	"	51-52	50-52
38	3x400	"	"	48-50	50-53
39	3x400	"	"	50-51	51-52
40	3x400	"	"	48-49	49-51
41	3x400F	"	"	50-51	50-51
42	2x400F	"	"	52	51-52
43	2x400F	"	"	51-52	52-53
44	3x400	"	"	47-49	48-49
45	3x400	"	"	50-52	51-52
46	3x400	"	"	48-50	49-52
47	3x400	"	"	49-50	49-52
48	3x400	"	"	52-54	47-50
49	3x400	"	"	42-48	48-49
50	3x400	"	"	50-51	49-51
51	3x400	"	"	50-51	49-51

* Figures are below specifications for bend.

Readings are underlined where hardness in case or core exceeds Rockwell 'C' 52. Fourteen (14) pins have readings of 53 R. 'C' or over on case or core. Three have all readings below R.'C' 50.

Tests Carried Out at Cockshutt Plow Company, Brantford:

On November 5th and 6th the writer visited the Cockshutt Plow Co. plant to investigate the process. Previous experience with pins which had not been centreless-ground had shown that treatment in high cyanide concentration may produce embrittlement in these SAE 9255 steel pins. With the centreless-ground pin a short-cycle heat treatment in low cyanide salt was decided on.

It was felt that the effect of low and high cyanide at this short time cycle (22 minutes) should be determined since pins within the specified hardness range were failing, and it was thought that cyanide concentration might be the cause of these failures. 300 pins of the same heat of steel, Atlas Heat 2808, were treated as follows:

150 heated in 24.4 per cent cyanide for 20 minutes at 1575° F., oil quenched, and drawn at 800° F. for one hour.

150 heated in 10.7 per cent cyanide for 20 minutes at 1575° F., oil quenched, and drawn at 800° F. for one hour.

All conditions were kept constant, the only variable being the cyanide concentration. The results were:

(Continued on next page)

(Tests Carried out at Cockshutt Plow Co., Brantford, cont'd) -

"HIGH CYANIDE" PINS.

HARDNESS (V.H.N.)

After Quench -
(12 pins at random from 150)

62.5, 63, 62, 63
61.5, 62.5, 63, 64
62, 62.5, 62, 60.5
63.5, 63, 63, 62
63, 61, 62.5, 63
63, 61.5, 63
62.5, 62.5, 60.5, 63
63.5, 61, 63, 62
63.5, 62.5, 63, 63
61.5, 62.5, 63, 61.5
62.5, 62.5, 63, 64
63.5, 63, 63, 62.5, 63.5

After Draw at 800° F. for 1 hour -
(6 pins at random from 150)

49, 50, 49, 49.5
48.5, 48, 48, 49
48.5, 49, 50, 49
49, 48, 49, 49
49.5, 49, 49
49, 48.5, 49.5, 49

IMPACT TESTS

Pin No.	Blow	Results
1	400 ft-lb.	Broke on first blow.
2	400 "	" " " "
3	350 "	" " second "
4	350 "	" " first "
5	350 "	" " second "
6	350 "	" " first "

"LOW CYANIDE" PINS.

HARDNESS (V.H.N.)

After Quench -
(10 pins at random from 150)

63, 63, 62.5, 63
62.5, 63, 60, 63
63, 63, 63.5, 63
62, 63, 63.5
63, 63, 63.5
63, 63.5, 63.5
63, 63, 63
61, 62.5, 62.5
63, 63.5, 62.5
63, 63, 63

After Draw at 800° F. for 1 hour -
(5 pins at random from 150)

49, 49, 48.5, 48.5
49, 48.5, 49.5, 48.5
50, 49, 50, 50
49, 48, 48.5, 49
50, 50, 50, 50
49.5, 49.5, 50, 50

IMPACT TESTS

Pin No.	Blow	Results
1	400 ft-lb.	Passed 3 blows.
2	400 "	Broke on third blow
3	400 "	" " " "
4	400 "	Passed 3 blows.
5	400 "	" 3 "
6	400 "	" 3 "

Forty pins of each type were sent to these Laboratories for further tests. Table VI lists the results obtained on these Cockshutt Plow pins:

(Continued on next page)

(Tests Carried out on Cockshutt Plow Pins at O.D.M.L.) -

TABLE VI.

LOW CYANIDE PINS (10.7%).

Pin No.	Impact	Bend load, pounds	Deflection, in inches	Surface hardness, R. 'C'	Core hardness R. 'C'	Remarks
1	3x400P:			51,50.5,51	50-51	
2		10,300	1.39	50-51	51-52	
3		10,150	3.45	50-51	50-51	Broken.
4		9,800	1.8	49.5,50,50	49-50	Not broken.
5	2x400P:			51,51,51.5	50-51	
6		9,600	1.8 Unbr.	46.5,46.5,47	45-47	Not broken.
7		10,000	2.000	50,50,50	48-50	
8		10,250	1.985	(52)	51-53	
9	3x400F:			49-51	50-51	
10		9,850	1.8 Unbr.	49-51	50	Unbroken.
11		12,500	2.00	49,51,50.5	49-51	
12		10,200	1.81	50,50,50.5	51	Broken.
13	3x400P:			49,49,50	48 51	
14	2x400F:			49,49.5,49.5	50-50	
15	3x400F:			51,50.5,51	50-51.5	
16	2x400F:			48.5,48.5,49	48-49	
17		9,900	1.59	50.5,50,50.5	51-52	Broke.
18		9,860	1.58	50,50,49.5	50-52	Broken.
19		10,450	2.17	51,51,51	50	Broken.

HIGH CYANIDE PINS (24%).

20	3x400P:			49-51	49-50	
21	1x350F:			51,51,51.5	50-52	
22		8,000	0.556	50,50,50	50-52	Broke.
23		9,300	0.830	50, 51.5,50.5	50-51.5	Broke.
24		9,100	0.763	51,51,51	50-51	Broke.
25		8,550	0.644	51.5,51,51	51-52	Broke.
26	1x350F:			52,52,52	53	
27	2x350F:			50.5,50.5,51	50-52	
28	1x350F:			50-51	50-51.5	
29		10,000	1.12	50.5,51,50.5	50-51	Broken.
30		9,950	1.31	50.5,50.5,51	51-52	
31		9,000	0.690	50,50.5,50	51-52	
32		9,560	0.910	51,51,51.5	51-52	
33	3x350P:			49.5,50,50.5	50-51	
34		9,450	0.791	51.5,51,52	51	
35		9,900	1.662	49.5,50,50.5	48-49	
36	3x350F:			51,51,51	52	
37	3x350F:			49.5,50,50.5	-	
38	1x350F:			51,51.5,51.5	50-51.5	
39	2x350F:			50,50,50.5	50-51	
40	2x350F:			51.5,51.5,52	52-53	

Two pins which had been treated as above but in a bath of 15 to 17 per cent cyanide, and having the same surface hardness, were impact-tested.

Pin No. 1 failed first blow at 350 ft-lb.
Pin No. 2 failed second blow at 350 ft-lb.

DISCUSSION:

The above is written as an interim report to meet the exigencies of the situation. As the work is still in progress no definite conclusions will be listed pending the completion of the final report. The test results available, however, at least indicate that treatment in high cyanide baths may severely lower the impact strength of the SAE 9255 steel pins. It also is of concern that a fair number of pins examined are over the specified Rockwell 'C' 51 hardness. Early test work demonstrated that this hardness limit cannot be exceeded without grave danger of embrittlement. It is of interest that the broken pins examined show a much higher percentage of high hardness pins than do unused or whole used pins.

In view of the danger of embrittlement associated with the casing of this medium carbon steel and its loss of toughness in high hardness ranges, it is felt that pin properties would most probably be improved by treatment in a lower-strength cyanide bath (or, better, in a neutral atmosphere) and by drawing at a temperature which would ensure that pins with hardness exceeding Rockwell 'C' 51 would not be encountered in regular production. This may mean a lowering of the average hardness to Rockwell 'C' 47 or 48.

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