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REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1526.

Examination of Five Types of Track Pins
of British Manufacture.

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(Copy No. 23.)

Abstract

This report describes an examination of five types of track pins of British manufacture for the Universal Carrier, the Crusader, the Matilda, the Valentine, and the Churchill tanks. The test results on the Universal Carrier pins are compared with Canadian specifications.

It was found that the British tend to produce a heavily cased pin with a very hard surface and a soft core. In the light of the theory held in this country, that the cased pins fail due to subsurface fatigue cracking, and in the light of recent field test results on British Universal Carrier pins it is felt that a heavy case and soft core is not the optimum pin condition.

Mention is made of laboratory and field tests on a homogeneously hardened pin which support the theory mentioned above and which indicate that the homogeneous pin has superior properties to the cased pin.

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

CANADA
DEPARTMENT OF MINES AND RESOURCES
Mines and Geology Branch

OTTAWA November 8th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1526.

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Origin of Material and Object of Investigation:

On February 2nd, 1943, Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, submitted Requisition No. 369, A.E.D.B., Lot Nos. 289, 290, 291, 292, 293. This requisition covered five types of track pins of British manufacture, supplied as follows.

Type of Pin	Steel Makers	Supplier
Universal Carrier	Manchester Steel Corp.	Stewart & Gray.
Mark II Infantry (Matilda)	Barrow Haematite.	Stewart & Gray.
Mark III Infantry (Valentine)		Guest, Keen & Nettleford, Ltd.
Mark IV (Churchill)	Barrow Haematite.	Stewart & Gray.
Mark VI Cruiser (Crusader)	Manchester Steel Corp.	

Twenty-two pins of each type were received by these Laboratories on July 12th, 1943.

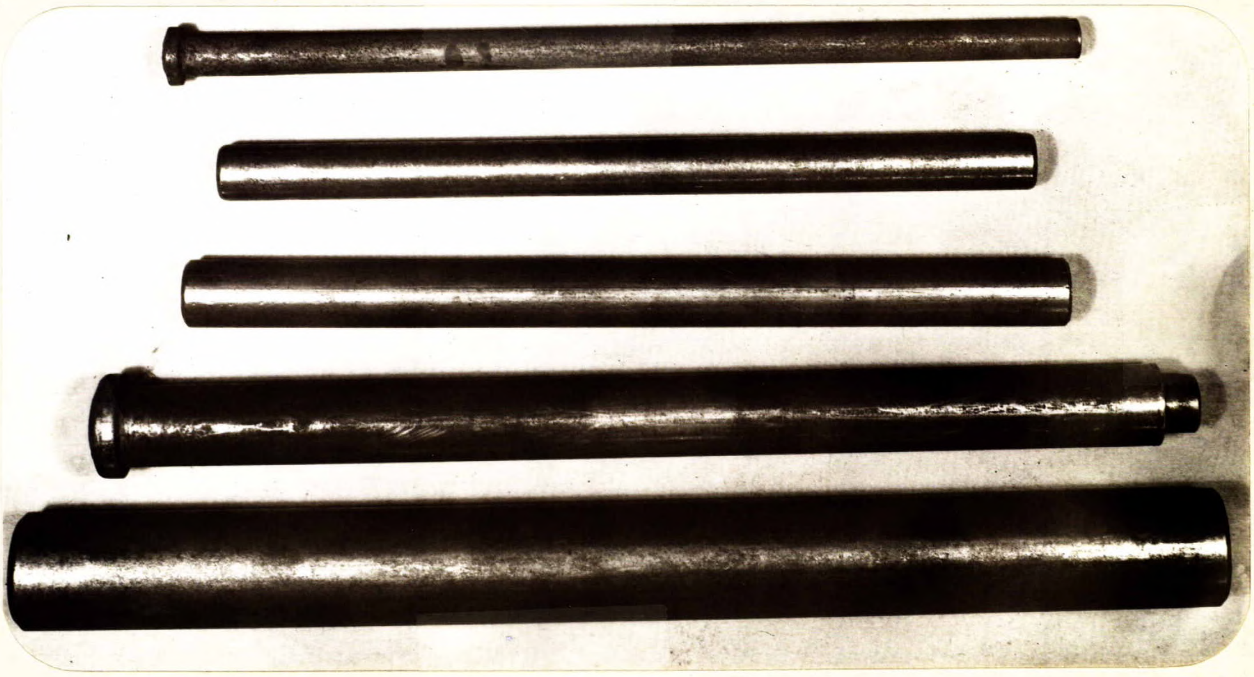
A complete metallurgical examination was requested with the object of using the data to prepare a track pin specification for pins larger than one-half inch and to check British carrier pin properties with those required by the Army Engineering Design Branch's Universal Carrier Pin specification (No. O.A.214).

Macro-Examination:

Figure 1 illustrates each type of pin. From top to bottom, they are:

Universal Carrier
Crusader
Matilda
Valentine
Churchill

Figure 1.



TYPES OF BRITISH TRACK PINS.

Table I lists the diameters and average weights of the various pins.

TABLE I.

Type of Pin		Diameter, inches	Average Weight
Universal Carrier	-	0.432-0.437	6 oz.
Crusader	-	0.620-0.630	8 oz.
Matilda	-	0.743-0.747	1 lb., 3½ oz.
Valentine	-	0.875-0.880	1 lb., 15 oz.
Churchill	-	1.246-1.250	4 lb., 4 oz.

Heat Treatment:

It was reported that the pins had been subjected to the following heat treatments:

Universal Carrier Pins -

25 minutes in Rapideep at 950° C.(1742° F.) and oil quenched. Reheated to 780° C.(1436° F.) and oil quenched.

Crusader Pins -

$2\frac{1}{2}$ hours in Rapideep at 950° C.(1742° F.) and oil quenched. Reheated to 830° C.(1526° F.) and oil quenched.

Matilda Pins -

Carburized in cyanide to obtain a case depth of 0.035 inch. Reheated in cyanide to 900° C.(1652° F.) and oil quenched. Reheated in cyanide to 800° C.(1472° F.) and water quenched.

Valentine Pins -

$1\frac{3}{4}$ hours at 950° C.(1742° F.) and oil quenched. Reheated to 880° C.(1616° F.) and water quenched. Reheated to 780° C.(1436° F.) and water quenched.

Churchill Pins -

The pins were carburized to give a total case depth of 0.045 to 0.050 inch, cooled in the box, and then reheated in a dry furnace to 860° C.(1580° F.) and water quenched.

Chemical Analyses:

Drillings were taken from the cores of one pin of each type and analysed chemically. The results are listed below in Table II.

TABLE II.

	Universal Carrier	Crusader	Matilda	Valentine	Churchill
	- (P e r		c e n t)		
Carbon	- 0.15	0.11	0.09	0.11	0.14
Manganese	- 0.47	0.41	0.34	0.27	0.65
Silicon	- 0.25	0.16	0.16	0.14	0.05
Sulphur	- 0.028	0.042	0.053	0.060	0.038
Phosphorus	- 0.011	0.032	0.036	0.030	0.027
Chromium	- 0.12	0.01	0.07	0.10	N.D.
Nickel	- 1.73	3.03	1.84	1.74	0.03
Molybdenum	- N.D.	Trace.	0.12	0.07	N.D.

(N.D. = Not detected).

PHYSICAL TESTS.

Tensile Tests:

The following table lists the tensile properties of the core materials, as determined by tests on one pin of each type:

TEST BAR	Ultimate strength, p.s.i.	0.2 per cent proof stress, p.s.i.	Elongation, per cent for 1-inch gauge length	Reduction of area, per cent
Universal Carrier, 0.252-in. diam. -	80,800	50,000	40	60
Crusader, 0.252-in. diam. -	98,000	64,400	27	58
Matilda, 0.252-in. diam. -	88,800	53,600	30	64
Valentine, 0.505-in. diam. -	85,500	51,000	30.5	63.5
Churchill, 0.505-in. diam. -	76,100	54,400*	29.5	69

* Yield strength, not 0.2 per cent proof stress.

Bend Tests:

Bend tests were carried out on pins of each type. The Universal Carrier pins and one Crusader pin were tested on the standard inspection bend test machine which applies the load manually, while all other pins were tested on the Amsler Universal testing machine which has a controlled rate of loading. All pins except the Churchill rested on 8-inch centres and were centrally loaded through a 12-inch-radius block. The Churchill pins rested on 12-inch centres and were loaded through a 12-inch-radius block. The results of these tests are given below, as well as the surface and core hardnesses and case depths.

It should be noted that the surface hardnesses of all pins were taken using the Rockwell 'A' or 'C' scale, and converted to V.P.N. using the Scott-Gray conversion chart. The core hardnesses of the Universal Carrier pins were taken using the Rockwell

(Bend Tests, cont'd) -

'B' scale and converted to V.P.N. using the conversion table given on Page 127 of the A.S.M. Handbook, 1939 Edition. The core hardnesses of all other pins were taken using the Vickers hardness tester with the 50-kilogram load, and converted to Rockwell 'B' by means of the same table.

Universal Carrier Pins -

Pin No	Surface Hardness: Rockwell 'A'	Surface Hardness: V.P.N.	Core Hardness: Rockwell 'B'	Core Hardness: V.P.N.	Case Depth, inches	Deflection at First Crack in Case, in inches
1	76-79-5	527-643	85-86	163-166	0.014	0.24
2	76.5-78	543-593	84-85.5	159-164	0.016	0.28
3	78-80	593-663	85-86	163-166	0.014	0.22
4	77-78.5	560-610	85-86.5	163-168	0.016	0.24
5	75.5-79	510-627	85-85.5	163-165	0.014	0.28
6	77-79.5	560-643	85-86	163-166	0.016	0.22
Average	77-79	549-630	85-86	163-166	0.015	0.246

Crusader Pins -

Pin No.	Surface Hardness: Rockwell 'A'	Surface Hardness: V.P.N.	Core Hardness: Rock. 'B'	Core Hardness: V.P.N.	Case Depth, inches	At First Crack: Load, lb.	At First Crack: Defl., in.	At Complete Failure: Load, lb.	At Complete Failure: Defl., in.
1*	82.5-84	760-830	96.5	220	0.039		0.15		
2	84-84.5	830-860	98	228		1,500	0.089	3,050	0.535
3	83.5-85	800-890	96	212	0.043	1,500	0.097	2,650	0.263
4	84-85	830-890	93	197	0.039	1,350	0.095	3,300	0.825
5	84-84.5	830-860	104	273		1,450	0.082	2,800	0.253
6	84-85.5	830-925	96	215	0.039	1,550	0.085	2,750	0.415
7	84-86	830-960	96.5	220	0.039	1,550	0.089	2,900	0.425
Average	84-85	830-890	97	223	0.040	1,485	0.088	2,910	0.453

* Note: Pin No. 1 was tested on the standard inspection bend test machine while Nos. 2 to 7 were tested on the Amsler Universal testing machine. The value obtained for the deflection at the first crack in the case of Pin No. 1 was not used in computing the average deflection.

(Continued on next page)

(Bend Tests, cont'd) -

Matilda Pins -

Pin No.	Surface Hardness: Rockwell 'C'	Surface Hardness: V.P.N.	Core Hardness: Rock. 'B'	Core Hardness: V.P.N.	Case Depth, inches	At First Crack: Load, lb.	At First Crack: Defl., in.	At Complete Failure: Load, lb.	At Complete Failure: Defl., in
1	64-65.5	795-835	93	196	0.039	3,900	0.210	4,600	0.830
2	62-65.5	750-835	90.5	185	0.037	3,800	0.172	5,275	1.200
3	65-67	820-885	93	198	-	3,500	0.127	4,950	0.505
4	65-67	820-885	90.5	186	0.035			5,750	0.870
5	65-67	820-885	96	217	0.045			5,400	0.670
6	66-67	855-885	93	198	0.047			5,400	0.695
13	65-65.5	820-835				3,500	0.128	4,800	0.380
14	66-67	855-885				3,500	0.130	5,250	0.630
Average	65-66	820-855	93	197	0.041	3,640	0.153	5,180	0.747

Valentine Pins -

Pin No.	(Rock. 'A')	V.P.N.	Rock. 'B'	V.P.N.	Case Depth, inches	First Crack Load, lb.	First Crack Defl., in.	Failure Load, lb.	Failure Defl., in
1	84-85	830-890	90.5	185	0.026	5,000	0.13	9,600	1.8
2	84-85	830-890	87	169	0.028	4,600	0.12	9,950	1.15
3	84-85	830-890	93	196		4,800	0.08	10,000	0.80
4	85	890	95	206	0.026	5,200	0.12	10,650	1.20
5	85	890	92	193	0.028	5,000	0.20	9,750	0.75
6	84-85	830-890	91	187	0.030	5,500	0.16	10,225	1.70
Average	84-85	830-890	91	189	0.028	5,015	0.135	10,030	1.23

Churchill Pins -

Pin No.	(Rock. 'C')	V.P.N.	Rock. 'B'	V.P.N.	Case Depth, inches	First Crack Load, lb.	First Crack Defl., in.	Failure Load, lb.	Failure Defl., in
1	66-69	855-960	84.5	161		8,600	0.150	10,700	0.246
2	64-69	795-960	91	186	0.069	8,300	0.140	10,750	0.232
3	63-67	770-885	92.5	195		8,800	0.167	10,100	0.225
4	66-67.5	855-900	86	165	0.071	8,800	0.156	12,700	0.435
5	62-67.5	750-900	89	178	0.063	9,000	0.177		
6	66-67.5	855-900	92.5	194	0.061	9,150	0.157	10,400	0.198
Average	64.5-68	810-920	90	180	0.066	8,775	0.158	10,930	0.267

Drop Impact Tests:

Pins of each type were subjected to drop impact tests by allowing a weight to fall on them from various heights. During the tests the pins were supported on 8-inch centres. The results of these tests, as well as the surface and core hardnesses and case depths of the pins, are recorded below. The same remarks apply to the conversion of the values obtained

(Drop Impact Tests, cont'd) -

for surface and core hardness as were mentioned under the bend tests.

Universal Carrier Pins -

Pin No.	Surface Hardness Rockwell 'A'	Surface Hardness V.P.N.	Core Hardness Rockwell 'B'	Core Hardness V.P.N.	Case Depth, inches	Intensity of Impact, foot-pounds	Remarks
7	80-81	663-697	87.5-88	170-174		45	Passed.
8	76-78.5	527-610	84	159	0.014	45	Passed.
9	77-80	560-663	85-87	163-170	0.012	45	Passed.
10	73.5-76.5	458-543	84-85.5	159-164	0.012	45	Passed.
11	75-80.5	495-680	86.5-87.5	162-172	0.012	45	Passed.
12	77-78.5	560-610	86	166	0.012	45	Passed.
Average	76-79	527-627	85-87	163-170	0.012		

Crusader Pins -

Pin No.	Surface Hardness Rockwell 'A'	Surface Hardness V.P.N.	Core Hardness Rockwell 'B'	Core Hardness V.P.N.	Case Depth, inches	Intensity of Impact, foot-pounds	Remarks
11	84.5	860	97	223	0.031	45	Passed.
8	84	830	94	202	0.035	100	Passed.
9	84-85	830-890	99.5	238	0.039	150	Failed.
10	84-84.5	830-860	95.5	210	0.039	150	Passed.
13	85-85.5	890-925	96	215	0.039	150	Passed.
14	84-85	830-890	98	228	0.035	150	Failed.
15	84-85	830-890	98.5	231	0.037	150	Passed.
16	84-85	830-890	96.5	219	0.039	150	Failed.
17	84-85.5	830-925	97	222	0.039	150	Failed.
18	84-84.5	830-860	100	243	0.039	150	Failed.
12	83.5-85	800-890	104	270	0.037	250	Failed.
Average	84-85	830-890	97.5	227	0.037		

Matilda Pins -

Pin No.	Surface Hardness (Rock. 'C')	Surface Hardness V.P.N.	Core Hardness Rockwell 'B'	Core Hardness V.P.N.	Case Depth, inches	Intensity of Impact, foot-pounds	Remarks
7	64-66.5	795-870	96	211	0.041	150	Passed.
8	65-67	820-885	102	255	0.045	250	Passed.
9	62-66.5	750-870	92	193	0.051	250	Passed.
10	64-67.5	795-900	92	191	0.051	300	Passed.
11	66-66.5	855-870	95.5	210		300	Failed.
12	63.5-66.5	780-870	89.5	180		300	Passed.
Average	64-66.5	795-870	95	207	0.047		

(Continued on next page)

(Drop Impact Tests, cont'd) -

Valentine Pins -

Pin No.	Surface Hardness: Rock. 'A'	V.P.N.	Core Hardness: Rock. 'B'	V.P.N.	Case Depth, inches	Intensity of Impact, foot-pounds	No. of Blows	Remarks
7	83-85	780-890	94	201	0.030	350	1	Passed.
						400	1	Passed.
8	84	825	90	182	0.028	350	1	Passed.
						400	1	Passed.
9	83-85	780-890	88.5	176	0.028	400	2	Passed.
10	83-85	780-890	94	201	0.030	400	2	Failed on second blow.
11	83-85	780-890	91.5	190	0.035	400	3	Failed on third blow.
12	83-85	780-890	90	182		350	1	Passed.
						400	1	Passed.
Average	83-85	780-890	91	189	0.030			

Churchill Pins -

Pin No.	Surface Hardness: Rockwell 'C'	V.P.N.	Core Hardness: Rock. 'B'	V.P.N.	Case Depth, inches	Intensity of Impact, foot-pounds	Remarks
7	66-67.5	855-900	86	166	0.051	350	Failed.
8	60-66.5	705-870	86.5	168	0.061	300	Failed.
9	66.5-67.5	870-900	85	162	0.059	400	Failed.
10	65-68.5	820-940	90	183	0.069	250	Failed.
11	64.5-67	810-885	83	157	0.061	200	Failed.
12	65-67	820-885	96	214	0.059	150	Passed.
13	66-67	855-885	96	213	0.061	150	Passed.
14	63-66.5	770-870	83	157	0.051	200	Passed.
15	65-67	820-885	86	165	0.069	200	Passed.
Average	65-67	820-885	88.5	176	0.060		

Average Values of Bend and Impact Properties:

For convenience, the following tables, showing the properties of the pins, are included.

(Continued on next page)

(Average Values of Bend and Impact Properties, cont'd) -

Average Bend Test Results -

Type of Pin	Surface Hardness Rockwell 'A' or 'C'	Surface Hardness V.P.N.	Core Hardness Rock. 'B'	Core Hardness V.P.N.	Case Depth, in.	At First Crack Load, lb.	At First Crack Defl., in.	At complete Failure Load, lb.	At complete Failure Defl., in
Universal:									
Carrier	77-79 R. 'A'	549-630	85-86	163-166	0.015		0.246		
Crusader	84-85 R. 'A'	830-890	97	223	0.040	1,485	0.088	2,910	0.453
Matilda	65-66 R. 'C'	820-855	93	197	0.041	3,640	0.153	5,180	0.747
Valentine	84-85 R. 'C'	830-890	91	189	0.028	5,015	0.135	10,030	1.23
Churchill	64.5-68 R.'C'	810-920	90	180	0.066	8,775	0.158	10,930	0.267

Average Drop Impact Test Results -

Type of Pin	Surface Hardness Rockwell 'A' or 'C'	Surface Hardness V.P.N.	Core Hardness Rockwell 'B'	Core Hardness V.P.N.	Case Depth, inches	Maximum Impact Passed, foot-pounds
Universal:						
Carrier	76-79 R. 'A'	527-627	85-87	163-170	0.012	45
Crusader	84-85 R. 'A'	830-890	97.5	227	0.037	150
Matilda	64-66.5R 'C'	795-870	95	207	0.047	300
Valentine	83-85 R. 'A'	780-890	91	189	0.030	400
Churchill	65-67 R. 'C'	820-885	88.5	176	0.060	200

-

Izod Impacts:

Standard 0.450-diameter round impact bars each with three notches 0.13 inch deep and having an included angle of 45°, were cut from the cores of two Churchill pins and two Valentine pins. The average results of impact tests in an Izod impact machine on each triple-notch specimen are as follows:

Churchill	Pin No. 1	-	48.5 foot-pounds.
	Pin No. 2	-	92 "
Valentine	Pin No. 1	-	87 "
	Pin No. 2	-	79 "

-

Case Depths:

The case depth was measured on pins of each type by cutting a transverse section from the pin, etching it in nital, and measuring, with the Brinell microscope, the case depth from the surface to the first point of colour change.

(Continued on next page)

(Case Depths, cont'd) -

The following results were obtained:

Type of Pin		Case Depth, in inches
Universal Carrier	-	0.012-0.016
Crusader	-	0.031-0.043
Matilda	-	0.035-0.051
Valentine	-	0.026-0.035
Churchill	-	0.051-0.071

Depth-Hardness Relationship:

Hardness readings were taken across the faces of polished transverse sections of each type of pin, using the Vickers hardness machine and the 10-kilogram load. Table III lists the results obtained at various distances from the surface. Figure 2 shows the results plotted for a typical pin of each type.

(Figure 2 is on Page 11,)
(Table III on Page 12.)

(Depth-Hardness Relationship, cont'd) -

Figure 2.

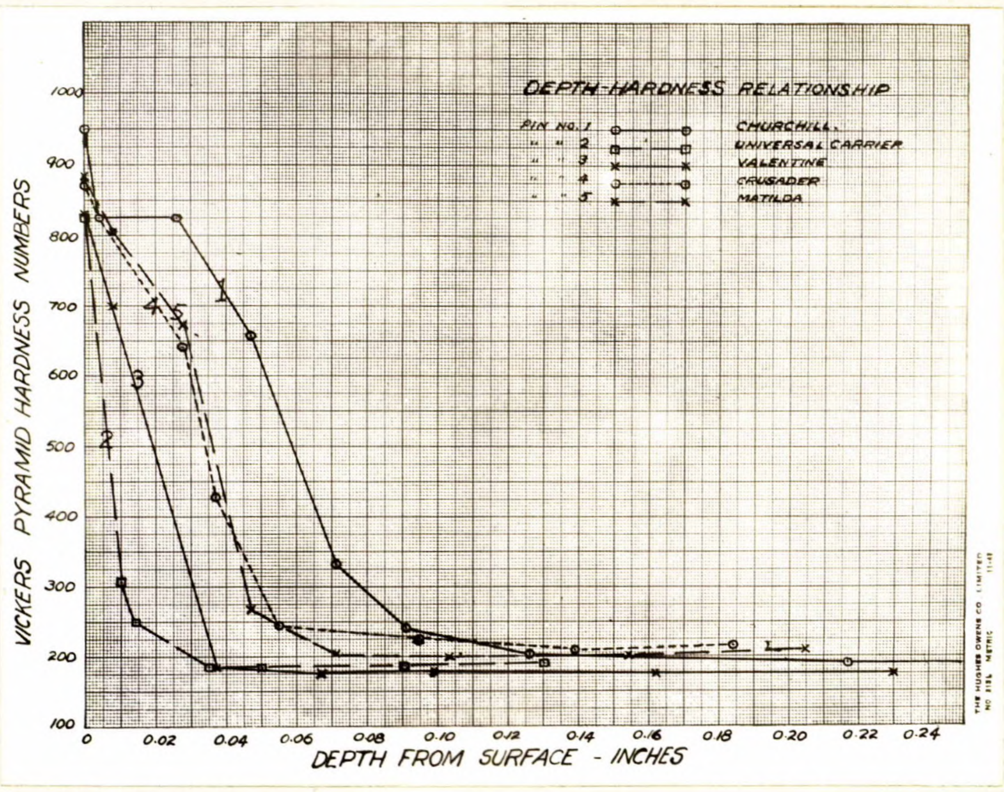


CHART SHOWING DEPTH-HARDNESS RELATIONSHIP
OF EACH TYPE OF PIN.

-

(Depth-Hardness Relationship, cont'd) -

TABLE III.

Type of Pin	Pin No.	Surface	VICKERS HARDNESS NUMBER (10-kilogram weight) At depths, in inches, from the surface 0.005	0.01	0.02	0.04	0.06	0.08	0.10	0.20
Universal Carrier	1	907	700	503	335	183	183	183	183	
"	9	824	575	307	230	185	185	186	187	
Crusader	4	752	805	777	675	345	230	215	210	207
"	5	830	815	777	695	452	325	290	299	285
"	8	870	819	780	700	395	242	238	225	215
"	12	877	874	870	690	360	260	265	270	305
Matilda	2	673	700	724	568	255	220	196	193	187
"	5	883	830	792	725	425	233	201	200	208
"	11	835	835	785	590	375	275	206	203	206
"	12	867	827	780	660	410	201	194	193	189
Valentine	3	802	575	495	380	225	186	185	184	186
"	6	835	635	598	523	275	210	204	201	199
"	7	830	745	660	485	182	176	176	178	175
"	11	722	815	742	600	300	227	216	210	192
Churchill	2	947	824	824	824	715	485	293	232	192
	3	950	913	890	867	760	485	241	225	198
	11	947	885	825	797	730	505	273	240	190
	14	935	905	875	705	370	210	187	180	160

Grain Size:

The McQuaid-Ehn grain sizes of the steels used were found to be as follows:

Universal Carrier	-	5
Crusader	-	4-5
Matilda	-	5
Valentine	-	4-5
Churchill	-	4-5.

Micro-Examination:

Transverse sections were cut from two pins of each type and polished for metallographic examination. Examination of the unetched specimens under the microscope showed that the pins had been made from clean bar stock. The samples were then etched in 2 per cent nital and examined again under the microscope. Figures 3, 4, 5, 6, and 7, at 500 magnification, show

(Micro-Examination, cont'd) -

typical core structures of each type of pin, while Figures 8, 9, 10, 11, and 12, at 1000 magnification, show typical case structures.

DISCUSSION:

Before proceeding with the discussion of the experimental work it should be remarked that Canadian experience has shown that 95 per cent of pin failures are due to fatigue. In the absence of fatigue machines, bend and impact tests were used since service data indicated a close relationship between these pin properties and performance.

In some instances good bend properties are required of the pins. For example, it has been reported that the design of the track link for the Cromwell tank is such that a large bending moment is imposed on the pins. The cased pins cannot take the bend without cracking and hence homogeneous pins, which have better bend properties, must be used.

Churchill track pins of the homogeneous type have been received from England, indicating that this type of pin has at least some supporters in Great Britain. The pin examined, however, was heavily decarburized, which would be expected to lead to excessive wear.

UNIVERSAL CARRIER PINS -

The Army Engineering Design Branch specification (O.A. 214) covering Universal Carrier steel track pins is as follows:

Case Hardness:

The case hardness shall be of a minimum hardness of 650 V.P.N., or 80 Rockwell 'A'.

(Continued on next page)

(Discussion, cont'd) -
Universal Carrier Pins, cont'd -

Depth of Case:

The depth of case of pins one-half inch in diameter or less shall be between 0.012-0.020 inch in thickness. The depth of case should be measured from the surface of the pin to the first point of colour change after the pin has been etched and should not include the transition zone.

Core Hardness:

The core hardness shall be within the limits of 24-32 Rockwell 'C' or 250-315 V.P.N. for pins of one-half inch diameter or less.

Angle of Bend:

Pins of 7/16-inch diameter shall give a minimum deflection of 0.25 inch without the case cracking, when freely supported between eight-inch centres and centrally loaded through a bending block with 12-inch-radius cylindrical face.

Impact Resistance:

Pins of 7/16-inch diameter, when freely supported between eight-inch centres, should withstand a blow of 45 foot-pounds. The case may crack but the pin should not break.

The chemical analysis of the Universal Carrier pin steel indicates that the steel is of the quality C.H.2.N. It is also similar to the specification for B.S.S. 5005/102.

The physical properties of the core appear to be normal for the type of steel and the treatment given.

Only two of the six pins tested took the 0.25-inch deflection called for in Specification O.A. 214 without the case cracking. All six pins tested passed the specified drop impact test, withstanding a blow of 45 foot-pounds.

The surface hardnesses, when measured on the Rockwell 'A' scale, were slightly below the 80 Rockwell 'A' specified but when measured with the Vickers hardness tester with the 10-kilogram load were well above 650 V.P.N. This may be explained by the fact that a 60-kilogram load is used with the Rockwell 'A' scale and hence the diamond would penetrate farther

(Discussion, cont'd) -
Universal Carrier Pins, cont'd -

than that of the Vickers machine. This difference would indicate a very hard, thin skin on the surface of the pins; the rapid decrease in hardness from the surface noted in the depth hardness surveys also points to the presence of this skin.

The core hardnesses were all below the 250 V.P.N. minimum specified. The theory has been put forward that cased pins fail due to fatigue cracks starting in the intermediate zone between the hard case and the soft core.

Fatigue is a direct function of the hardness. For parts subjected to alternating bending stresses (as in the track pin), the condition of the surface material would usually govern performance. Case-hardened pins have a harder surface than homogeneously hardened pins. It would consequently be expected that their fatigue life would exceed that of the homogeneous pin. However, the results of field tests indicate that the homogeneous pin has a longer service life (and hence fatigue life) than the cased pin. These results point to sub-surface failure of the cased pin at a point of lower hardness than the homogeneous pin surface hardness. If this theory is correct, the pins under examination would be more prone to failure of this type and hence tend to fail at an earlier mileage than a harder-cored pin. Recent field tests on British pins, carried out in Canada, give results that concur with this statement.

Recently, a homogeneously hardened pin has been produced in the United States under production conditions which gave excellent laboratory results, withstanding a drop impact blow of 400 foot-pounds and taking a bend of two inches without failing. This pin had a surface hardness of 48-54 Rockwell 'C', a core hardness of 52-56 Rockwell 'C', and was

(Discussion, cont'd) -
Universal Carrier Pins, cont'd -

produced by isothermal transformation. While field tests on this pin have not as yet been carried out, it is felt, in view of the excellent laboratory performance, that the results may well surpass those of any pin yet tested.

At the present time pins austempered by these Laboratories, as well as pins homogeneously hardened by a quench-and-draw treatment, have gone 4,350 miles with no failures. In spite of the higher hardness of the austempered pins the wear on the two types of pins was approximately equal. This would indicate that, while a very good pin is produced, there may be no special advantage obtained from the isothermal transformation heat treatment.

The case depth on the British pins was on the low side of the specification limits, being 0.012 to 0.016 inch. This would also be expected to promote subsurface failure. Thin-cased pins, however, have better impact properties.

The McQuaid-Ehn grain size of the steel used was found to be 5. While a grain size of 6 to 8 is preferable, 5 is allowable.

Microscopic examination shows the core (Figure 3) and the case (Figure 8) to have well refined structures, as is to be expected from the double-quench treatment these pins had received. The photomicrograph of the case shows that there is a thin skin at the surface of the pins in which the grain boundaries are surrounded by a black etching constituent. This would have an embrittling effect on the case and possibly was the cause of the failure of the pins in the bend test.

CRUSADER PINS -

The chemical analysis of the pin steel shows that the steel is probably of quality C.H.3.N.

The physical properties are normal for the steel and

(Discussion, cont'd) -
Crusader Pins, cont'd -

for the treatment given.

The results of the bend tests are typical of pins with such heavy cases (0.031 to 0.043 inch). When tested on the Amsler Universal testing machine none of the pins took a deflection of 0.10 inch before the cases cracked. The one pin tested on the standard bend testing machine took a deflection of 0.15 inch before the case cracked. This larger deflection is probably due to the greater speed of loading of the standard machine.

The pins have a rather low resistance to impact. It is felt that if the case depth were decreased the impact resistance would be raised.

Microscopic examination showed that the core (Figure 4) was low-carbon martensite, indicating a quench from a fairly high temperature. The case structure (Figure 9) consisted of fairly coarse martensite.

<u>MATILDA PINS</u> -

The chemical analysis of the pin steel shows that the steel is of the quality C.H.2.N. This is similar to the specifications for B.S.S. 5005/102.

The physical properties are normal for the type of steel and the treatment given.

The bend test results are again typical of pins having a heavy case. The deflections at the first crack in the case varied from 0.127 to 0.210 inch. The deflections at failure ranged from 0.380 to 1.20 inches.

The impact resistance is about normal for this type of pin. It might be improved somewhat by lowering the case depth (which is from 0.035 to 0.051 inch). It is felt that this

(Discussion, cont'd) -
Matilda Pins, cont'd -

case is too thick for the pin diameter.

The micro-examination shows the case structure (Figure 10) to be martensite. The core structure (Figure 5) is a very low-carbon martensite in a background of ferrite, indicating a low-temperature quench.

VALENTINE PINS -

The following specification was recommended by these Laboratories for cased Valentine track pins of 7/8 inch diameter, after examining pins produced by several Canadian and American companies:

> The pins should take a minimum deflection of 0.5 inch with a minimum load of 7,500 pounds without fracturing completely.
>
> A drop impact of a minimum of 350 foot-pounds should be withstood by the pins.
>
> Surface hardness should be 650 ±50 V.P.N.
> Core hardness should be 250 V.P.N. maximum.
> The case depth should be from 0.20 to 0.035 inch.

The chemical analysis of the Valentine pin steel shows it to be of the quality C.H.2.N. It corresponds to the specification for B.S.S. 5005/102.

The physical properties are normal for the type of steel and the heat treatment given.

All six pins subjected to the bend test passed the recommended specification mentioned above very satisfactorily. The deflections at the first crack in the case varied from 0.08 to 0.20 inch.

All pins passed the 350-foot-pound blow, and three pins withstood a 400-foot-pound blow. Four of the pins withstood a 400-foot-pound blow after being first subjected to blows of either 350 or 400 foot-pounds. It is felt that the second blow does not mean a great deal, as the first blow bends

(Discussion, cont'd) -
Valentine Pins, cont'd -

the pin and cracks the case.

The surface hardnesses of all pins tested are all above the maximum of 700 V.P.N. recommended, the lowest hardness recorded being 83 Rockwell 'A' (780 V.P.N., converted) and the highest being 85 Rockwell 'A' (890 V.P.N., converted). The core hardnesses are all below 250 V.P.N., ranging from 169 to 206 V.P.N.

The case depths of all pins are within the specified limits of 0.020 to 0.035 inch.

Microscopic examination shows the core to have a structure of low-carbon martensite in a ferritic matrix (see Figure 6), indicating a low-temperature quench. The case structure (Figure 11) is martensite arranged in a nodular pattern. On etching in Murikami's reagent the presence of carbides in the case was confirmed. With this reagent the carbides are etched black and show up against the white background of unattacked material. In other applications it has been shown that the presence of these free carbides leads to a reduction in fatigue strength.

CHURCHILL PINS -

The chemical analysis of the pin steel shows that the steel is probably of the quality C.H. Mild.

The physical properties are normal for this type of steel and heat treatment.

The bend tests show up the effect of the heavy case on the pins. The deflections at the first crack in the case varied from 0.14 to 0.177 inch, while the deflection at failure varied from 0.198 to 1.10 inches. The normal deflection at failure is around 0.20 inch.

The drop impact tests also show the embrittling effect of the heavy case on the pins. Two hundred foot-pounds

(Discussion, cont'd) -

Churchill Pins, cont'd -

is the maximum impact withstood.

The case depths varied from 0.051 to 0.071 inch. It is reported that the pins were carburized to a case depth of 0.045 to 0.050 inch. It is felt that if the case depths were reduced to this value, a better performance under bend and impact tests would result.

The surface hardnesses are all well above the Rockwell 'C' 60 minimum desired. Some small soft spots were noted on the surfaces of some pins, possibly resulting from a localized retarding of the cooling rate in quenching. The core hardnesses are low, varying from 157 to 214 V.P.N.

Microscopic examination of the core (Figure 7) shows it to consist of pearlite, of various degrees of fineness, dispersed in a ferritic matrix. The case structure (Figure 12) consists of fairly fine martensite.

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General Discussion -

The most important result in the test work described is the effect of the case on the physical properties of the pins. The British tend to produce a pin with a soft core and a very hard case. Two of the types examined, the Universal Carrier pins and the Valentine pins, have fairly thin cases in comparison with the pin diameter. The remaining three types, namely the Crusader, Matilda and Churchill pins, had comparatively thick cases. The core hardnesses of all types of pins are comparable.

The drop impact tests bring out very clearly the weakening effect of a heavy case under impact. Comparing the results of tests on Valentine and Churchill pins, it is seen that the Valentine pins withstood blows of 350 and 400

(Discussion, cont'd) -

foot-pounds, while one out of three of the Churchill pins failed a blow of 200 foot-pounds. The results of Izod impact specimens from the cores of each of these pins gave values of 83 foot-pounds for the Valentine pins and 70 foot-pounds for the Churchill pins.

It has long been the opinion of these Laboratories that a homogeneously hardened pin is superior to a case-hardened pin. As mentioned previously in this report, a homogeneously hardened Universal Carrier pin produced by an austempering treatment has given very encouraging results under laboratory tests. A homogeneous pin has greater impact resistance than a cased pin and has better ductility, as measured by the bend test. Also, field tests and fatigue tests, performed by Prof. J. M. Lessells at the Massachusetts Institute of Technology, Cambridge, Mass., indicate a high resistance to the effect of alternating stresses. The surface hardness is not as high but it is felt that the slight drop in wear resistance resulting from this is more than compensated for by the excellent properties. Field tests at Windsor, Ontario, indicate very little difference in wear between homogeneous and cased pins. It should be mentioned in connection with the homogeneously hardened pin that a decarburized layer is very likely to be incurred at the surface and that this should be removed either by centreless grinding or by a recarburizing heat treatment. The latter procedure involves some difficulties, as previous reports by these Laboratories show.

CONCLUSIONS:

1. Bend and impact tests results appear to correlate well with service performance of a pin. Also, in some instances, loading conditions are such that good bend properties are required of pins to prevent early failure.

2. The British Universal Carrier pins passed the requirements of Specification O.A. 214 in all respects except the bend tests and core hardnesses. Four out of six pins tested failed to take the specified 0.25-inch deflection before the case cracked and all pins tested were below the 250 V.P.N. minimum in core hardness.

3. The Crusader and Matilda pins have a rather heavy case for their diameter. This results in a lowering of the impact resistance of the pins. This is particularly true for the Crusader pins.

4. The Valentine pins passed the recommended specification in all respects except the surface hardness, which was above the 700 V.P.N. maximum. However, the pins may be considered satisfactory.

5. The Churchill pins have a very thick case which causes a very marked lowering of the physical properties of the pins.

6. It is typical of British production methods to produce a pin with a hard surface and a soft core. The theory has been advanced that cased pins fail due to subcutaneous fatigue cracks in the region between the case and the core. Recent field tests on British Universal Carrier pins tend to indicate that they do not give as satisfactory a performance as harder-cored pins of Canadian and American manufacture, and so it is felt that a core hardness below 250 V.P.N. is not a good condition.

7. Laboratory tests show that a homogeneous pin has superior bend and impact properties to the cased pin, and field tests indicate that the former pin also has a longer service life.

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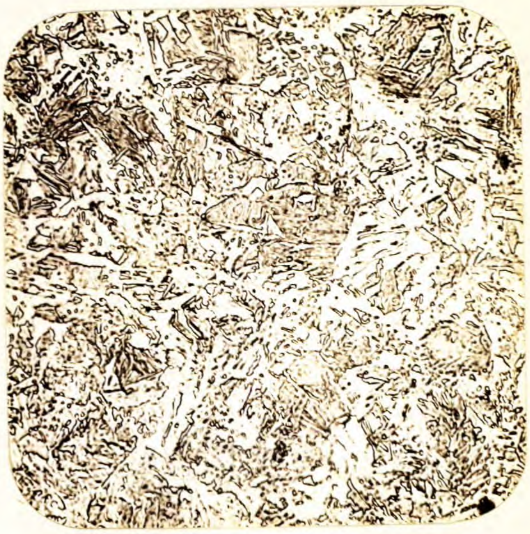
JPO:LB:GHB.

Figure 3.

X500, nital etch.
TYPICAL CORE OF
UNIVERSAL CARRIER PIN.

Figure 4.

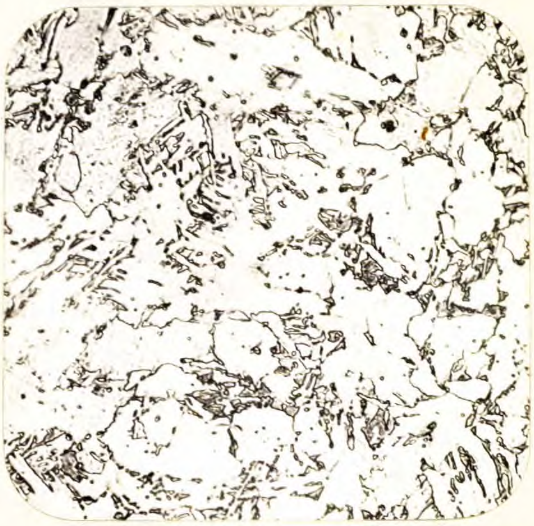


X500, nital etch.
TYPICAL CORE OF
CRUSADER PIN.

Figure 5.

X500, nital etch.
TYPICAL CORE OF
MATILDA PIN.

Figure 6.



X500, nital etch.
TYPICAL CORE OF
VALENTINE PIN.

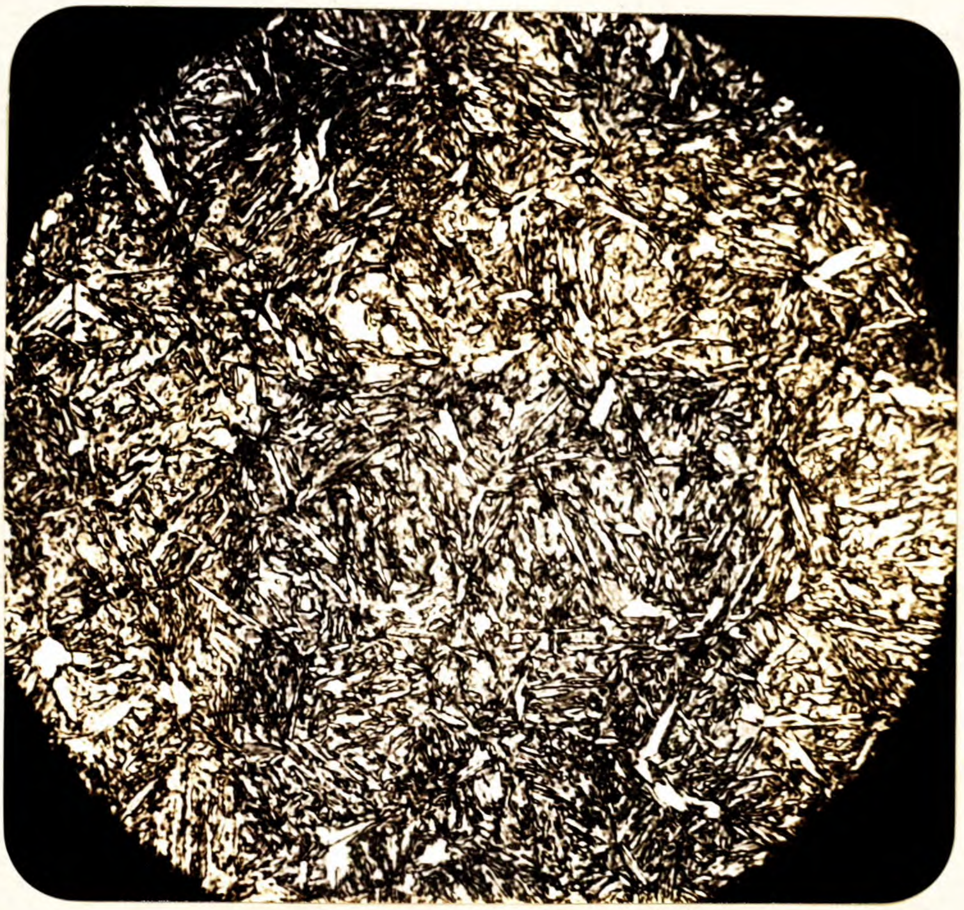
Figure 7.

X500, nital etch.
TYPICAL CORE OF
CHURCHILL PIN.

Figure 8.

X1000, nital etch.
CASE STRUCTURE OF UNIVERSAL CARRIER PIN.
Note black constituent outlining grain boundaries at surface.

Figure 9.



X1000, nital etch.
CASE STRUCTURE OF CRUSADER PIN.

Figure 10.

X1000, nital etch.

CASE STRUCTURE OF MATILDA PIN.

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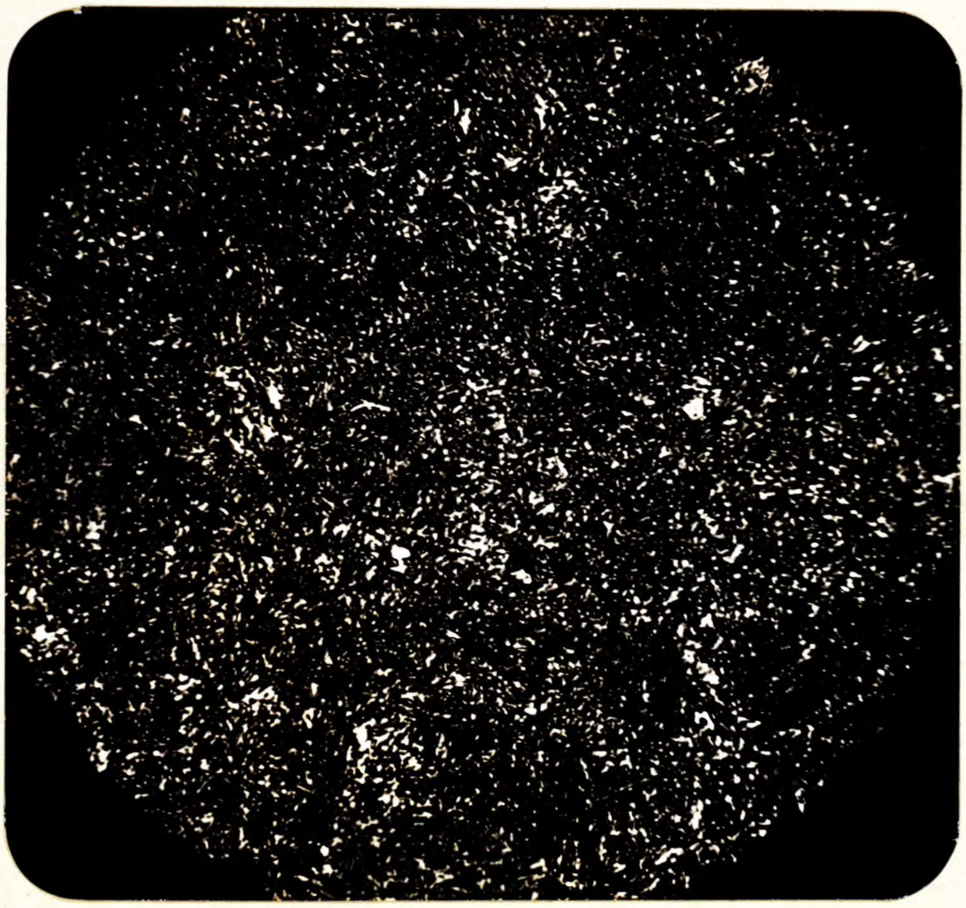
Figure 11.



X1000, nital etch.

CASE STRUCTURE OF VALENTINE PIN.

Note presence of carbides
(white constituent).

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Figure 12.

X1000, nital etch.
CASE STRUCTURE OF CHURCHILL PIN.

JPO:GHB.