O T T A W A May 4th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1401.

A Survey of Valentine Tank Track Pins.

(Copy No. 27.)

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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Abstract.

This report discusses the test results obtained on Valentine tank track pins, both of the cased and the homogeneous type. Production pins from six manufacturers are thoroughly examined. Proposed specification limits are outlined.

Origin of Material and Object of Investigation:

During January, 1943, Mr. H. L. Batten, for A. D. Tech.(M) of the Inspection Board of United Kingdom and Canada, Ottawa, Ontario, requested that these Laboratories carry out a survey on the 7/8-inch cased Valentine track pins of U.S.A. and Canadian manufacture. It was felt that the data obtained from such an investigation would prove useful in developing a proper specification for this size of pin. Since homogeneous pins of the SAE 9255 type are

(Origin of Material and Object of Investigation, cont'd) -

also approved for use, figures on these are included in this investigation.

This report also embodies work requested by Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario, under Requisition No. 344, AEDB Lot No. 256, January 13th, 1943, and Requisition No. 367, AEDB Lots Nos. 294 and 295, January 25th, 1943.

The following pins were received for test work:

Source	Steel	Number	Type
Chicago Area, Kensington Steel Corpn.	NE 8620	24	Cased.
C.P.R. Angus Shops, Montreal, Que.	BSS 5005/102	24	Cased.
Campbell, Wyant & Cannon, Muskegon, Mich.	NE 8615	12	Cased.
Cockshutt Plow Co., Brantford, Ont.	BSS 5005/102	24	Cased.
O. D. M. L.	SAE 9255	12	Homogeneous.
Taylor-Wharton, High Bridge, N.J.	SAE 3115	3	Cased.
Ohio Crankshaft Co., Cleveland, Ohio.	SAE 1045	70	Cased.
Campbell, Wyant & Cannon,[*] Muskegon, Mich.	NE 8817	6	Cased.

The material from the first five sources in the above list were received during the months of February and March. Pins from the last three listed have been investigated previously and the results from those investigations are incorporated herein in order to make the report complete with regard to the 7/8-inch-size pin.

[*] Our Report of Investigation No. 1229, May 21st, 1942, discusses the results obtained for NE 8817 pins.

CHEMICAL ANALYSIS OF PINS EXAMINED IN THIS INVESTIGATION:

Chicago Area:

		As Found	Specification NE 8620
		- PER CENT -	
Carbon	=	0.20	0.18 - 0.23
Manganese	=	0.89	0.70 - 0.95
Silicon	=	0.26	0.20 - 0.35
Sulphur	=	0.011	0.040 max.
Phosphorus	=	0.013	0.040 max.
Nickel	=	0.50	0.40 - 0.60
Chromium	=	0.55	0.40 - 0.60
Molybdenum	=	0.29	0.15 - 0.25

C.P.R. Angus Shops:

		As Found	Specification BSS 5005/102
Carbon	=	0.11	0.15 max.
Manganese	=	0.37	0.60 max.
Silicon	=	0.11	0.30 max.
Sulphur	=	0.028	0.05 max.
Phosphorus	=	0.022	0.05 max.
Nickel	=	1.98	1.50 - 2.25
Chromium	=	0.29	0.30 max.

Campbell, Wyant & Cannon:

		As Found	Specification NE 8615
Carbon	=	0.18	0.13 - 0.18
Manganese	=	0.77	0.70 - 0.90
Silicon	=	0.24	0.20 - 0.35
Sulphur	=	0.012	0.040 max.
Phosphorus	=	0.014	0.040 max.
Nickel	=	0.50	0.40 - 0.70
Chromium	=	0.45	0.40 - 0.60
Molybdenum	=	0.16	0.15 - 0.25

Cockshutt Plow Company:

		As Found	Specification BSS 5005/102
Carbon	=	0.09	0.15 max.
Manganese	=	0.49	0.60 max.
Silicon	=	0.22	0.30 max.
Sulphur	=	0.018	0.05 max.
Phosphorus	=	0.012	0.05 max.
Nickel	=	2.17	1.50 - 2.25
Chromium	=	Trace.	0.30 max.

SAE 9255 - Specification Limits

Carbon	=	0.50 - 0.60
Manganese	=	0.60 - 0.90
Silicon	=	1.80 - 2.20
Phosphorus	=	0.040 max.
Sulphur	=	0.050 max.

(Continued on next page)

(Chemical Analysis of Pins Examined, cont'd) -

Taylor-Wharton:

		As Found	Specification SAE 3115
		- PER CENT -	
Carbon	-	0.12	0.10 - 0.20
Manganese	-	0.45	0.30 - 0.60
Silicon	-	0.21	0.15 min.
Phosphorus	-	0.021	0.040 max.
Sulphur	-	0.021	0.050 max.
Nickel	-	1.41	1.00 - 1.50
Chromium	-	0.55	0.45 - 0.75

Ohio Crankshaft Company:

		As Found	Specification SAE 1045
Carbon	-	0.42	0.40 - 0.50
Manganese	-	0.80	0.60 - 0.90
Silicon	-	0.23	0.15 - 0.30
Phosphorus	-	0.022	0.045 max.
Sulphur	-	0.018	0.055 max.

Campbell, Wyant & Cannon:

		As Found	Specification NE 8817
Carbon	-	0.18	0.15 - 0.20
Manganese	-	0.80	0.70 - 0.90
Phosphorus	-	0.008	0.040 max.
Sulphur	-	0.015	0.040 max.
Silicon	-	0.27	0.20 - 0.35
Nickel	-	0.44	0.40 - 0.60
Chromium	-	0.52	0.40 - 0.60
Molybdenum	-	0.24	0.30 - 0.40

Physical Properties:

Tensile test specimens were cut from the core. They were 0.505 inch in diameter and the elongation reported is for a 2-inch gauge length. Table I lists the results.

(Continued on next page)

(Physical Properties, cont'd) -

Table I.

Producer	Type of steel	Ultimate stress, p.s.i.	Yield strength, p.s.i.	Elongation, per cent in 2 inches	Reduction of area, per cent
Chicago Area	SAE 3115	114,000	72,400	23.5	60.5
Campbell, Wyant & Cannon	NE 8615	127,000	84,200	21.5	59
C.P.R. Angus Shops	BSS 5005/102	100,000	71,200	25	66.5
C.P.R. Angus Shops	BSS 5005/102	72,100	43,200 (0.1% proof stress)	29	75
Cockshutt Plow Company	BSS 5005/102	85,500	48,800	30.5	70.5
Cockshutt Plow Company	BSS 5005/102	77,000	54,000	35	73
Campbell, Wyant & Cannon	NE 8817	138,000	86,000	12	26
Taylor-Wharton	SAE 3115	112,200	68,900 (0.1% proof stress)	19	56.5

Bend Tests:

Bend tests were carried out on the Amsler Universal testing machine. A 12-inch radius and 8-inch centres were used. An extensometer was placed on the machine to indicate the deflection in inches. Results are given in Table II.

(Continued on next page)

(Bend Tests, cont'd) -

Table II.

Source	Deflection at first crack of case, inches	Load at first crack of case	Load at pin failure	Deflection at pin failure, inches
Chicago	0.162	8,875	11,150	-
"	-	5,800	8,000	0.730
"	0.154	8,600	10,950	-
Cockshutt Plow	0.207	3,875	-	-
" "	0.198	4,250	-	-
" "	0.205	4,800	9,000	-
" "	0.250	4,450	7,850	-
" "	-	-	9,300	1.040
C.W. & C. NE 8615	0.180	6,850	8,600	-
" "	0.215	7,750	9,050	-
C.P.R.	0.180	11,000	16,200	-
"	0.160	12,450	13,550	-
"	0.215	4,450	-	-
"	-	-	12,200	1.45
Tocco	0.790	13,750	-	-
"	0.970	12,500	-	-
Taylor-Wharton	0.215	4,450	-	-
C.W. & C. NE 8817	0.270	5,250	-	-
" "	0.290	5,150	-	-
SAE 9255	Unbroken at 17,500 load and 0.505 inch deflection.			
"	Unbroken at 17,500 load and 0.505 inch deflection.			

Drop Impact Tests:

Drop impact tests were made using a 75-lb. weight. One drop only from the indicated height was made. Failure is considered to be a complete breaking of the pin. Most passed pins show surface cracking.

(Continued on next page)

(Drop Impact Tests, cont'd) -

Cockshutt Plow Company.

One pin was tested by dropping the weight from 175 cm. This pin passed. Seven pins which were tested from 200 cm. all passed.

C.P.R.

4 out of 12 pins tested from 200 cm. failed. Three of the unbroken pins did not show any cracks on the surface.

Chicago Area.

3 out of 12 pins tried from 200 cm. failed.

Campbell, Wyant & Cannon NE 8615.

No. of pins tested	Height, cm.	Remarks
1	200	Failed.
1	175	Failed.
1	150	Failed.
1	125	Failed.
1	110	Passed.
2	100	Passed.

SAE 9255.

No. of pins tested	Height of drop, cm.	Remarks
2	200	Passed.
1*	180	Failed.
1*	220	Passed.
1*	140	Failed.

Ohio Crankshaft Tocco.

No. of pins tested	Height of drop, cm.	Remarks
2*	180	Passed (case cracked only).
1*	220	Passed.

* On these pins the 75-lb. weight was dropped successively every 20 cm. to the final indicated height.

Hardness:

Hardness readings were taken of the surface and of the cores of the pins used for the impact tests. The Rockwell 'B' scale was used for core values of less than 100, the 'C' scale for harder cores. Conversions of these hardness readings have been made to the Brinell figure (3,000-lb. weight) using the Wilson Mechanical Instrument Company's chart. The Scott-Gray tables do not list Rockwell 'B' scale values. The Vickers machine, 30-kg. load, was used for the surface hardnesses. Tables III, IV, V, and VI indicate the results obtained:

Table III. - Brinell Core Hardness of Pins Which Passed Impact Tests.

Chicago	C.W. & C. NE 8615	C.P.R.	Cockshutt	SAE 9255	Tocco
195-228	290	216-240	165-180	426-460	194
213-230	270	172-176	156-162	484-496	222
228-234	283	169-172	190-205		198
195-200		153-156	172-190		215
185-190		205-216	176-195		
234		153-165	185-200		
185		185-205	162-176		
210			159-165		
195-210					
235					

Table IV. - Brinell Hardness of the Cores of the Pins Which Failed the Impact Tests.

Chicago	C.W. & C. NE 8615	C.P.R.
270-283	265	180-205
200-205	265	290-305
	270	276-290
		297-313

(Continued on next page)

(Hardness, cont'd) -

Table V. - Vickers Surface Hardness of Pins Which Passed Impact Tests.

Chicago	C.W. & C. NE 8615	C.P.R.	Cockshutt	SAE 9255	Tocco
590-602	680-710	436-476*	631-644	602-606	554
568-614	720-725	432-459*	635-652	598-610	546
540-583	666-720	465-473*	639-675		543
601-626		610-618	671-695		569
583-618		527-533	614-635		
		571-598			

* The above low hardness pins showed no cracks on the surface after the drop impact test.

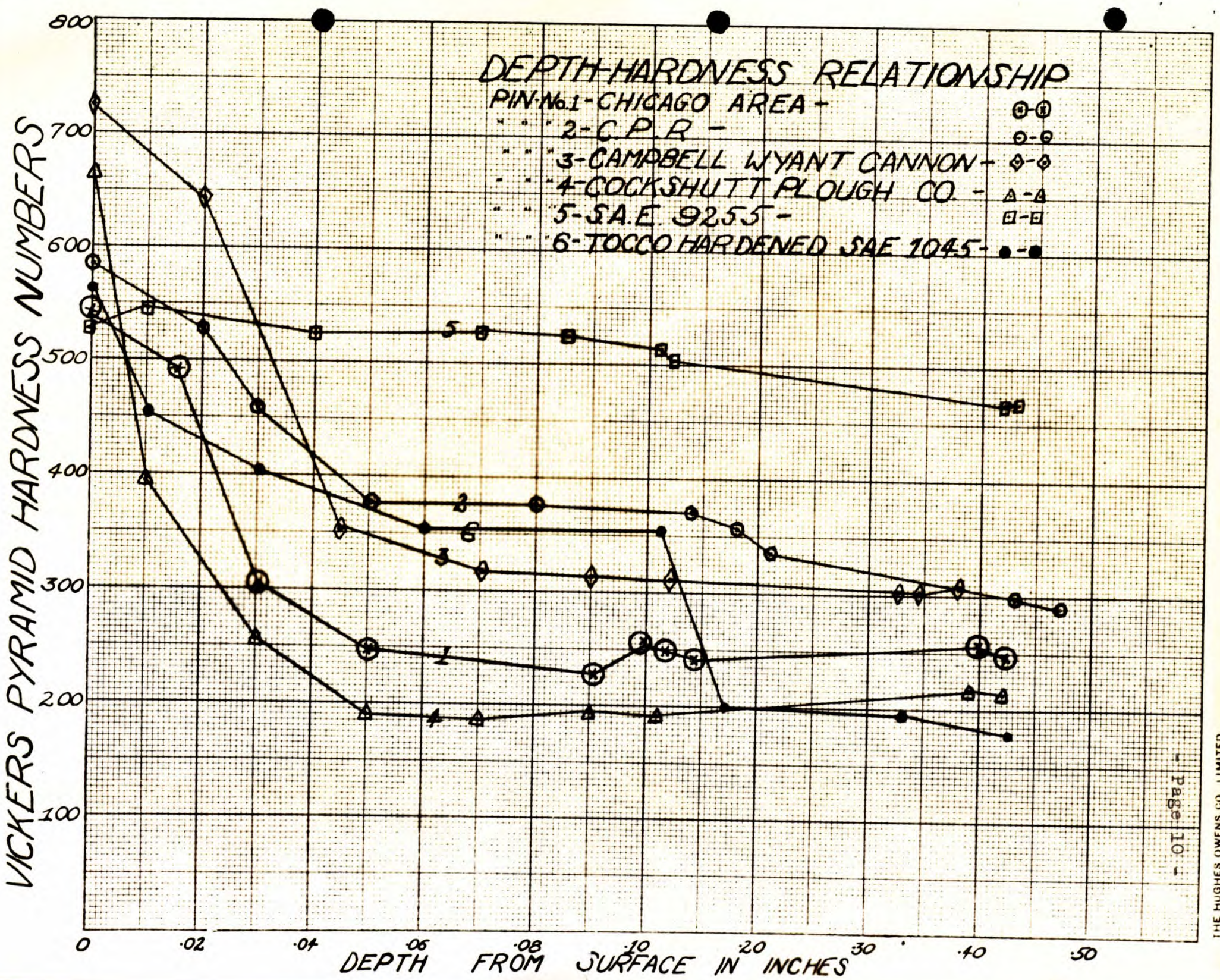
Table VI. - Vickers Surface Hardness of Pins Which Failed Impact Tests.

Chicago	C.W. & C. NE 8615	C.P.R.
606	675-746	614-631
644	741	554-583
	680-705	557-594
		481

Depth-Hardness:

Transverse microspecimens were cut from the pin of each type. Hardness readings were taken across the face, using the Vickers hardness machine and a 10-kg. load. The depth-hardness curves obtained are shown in Figure 1.

(Figure 1 appears on Page 10)
(Text continues on Page 11.)



THE HUGHES OWENS CO. LIMITED
No. 3155 20 lines 1 inch U.40

Case Depth:

The case depth was measured using the Brinell microscope. Only the black etched area was considered as the case. The results were:

	Unbroken on Impact (in inches)		Broken on Impact
Chicago.			
	0.018	-	0.026
	0.014	-	0.028
	0.032		
	0.020		
	0.016		
	0.012		
	0.018		
	0.037		
C. P. R.			
	0.032	-	0.026
	0.026	-	0.026
	0.030	-	0.034
	0.032		
	0.022		
	0.035		
	0.032		
	0.034		
Campbell, Wyant & Cannon.			
	0.030	-	0.030
	0.032	-	0.026
	0.028	-	0.028
		-	0.024
Cockshutt Plow.			
	0.028		
	0.028		
	0.022		
	0.028		
	0.022		
	0.028		
	0.026		
	0.028		
Tocco.			
	0.093		
	0.094		

Microscopic Examination:

Transverse microspecimens were cut from one pin of each type. They were polished and etched in 2 per cent nital. All photomicrographs are taken at X1000 magnification, except the cores of Taylor-Wharton, Tocco, and Campbell, Wyant and

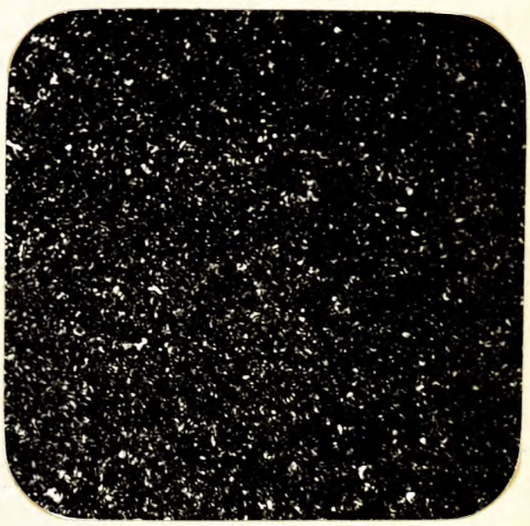
(Microscopic Examination, cont'd) -

Cannon's NE 8817. These are taken at X500. The structures of all the cases are tempered martensite, the Chicago and Tocco types consisting of very fine nodules. The structures of the cores show varying amounts of ferrite. The Tocco case is spheroidized. The homogeneous SAE 9255 structure is tempered martensite.

Figure 2.

Core.

Figure 3.



Case.

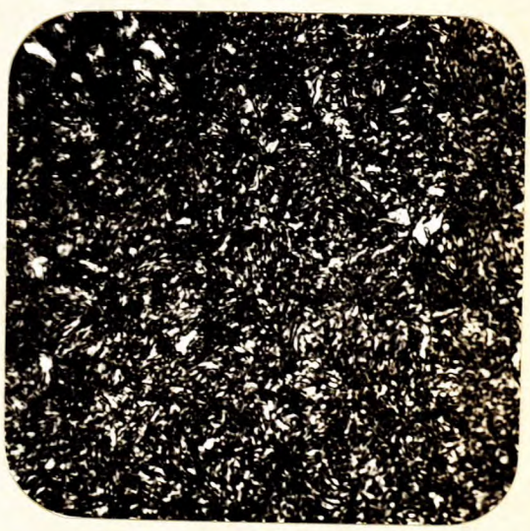
X1000, nital etched.

CHICAGO AREA PIN.

Figure 4.

Core.

Figure 5.



Case.

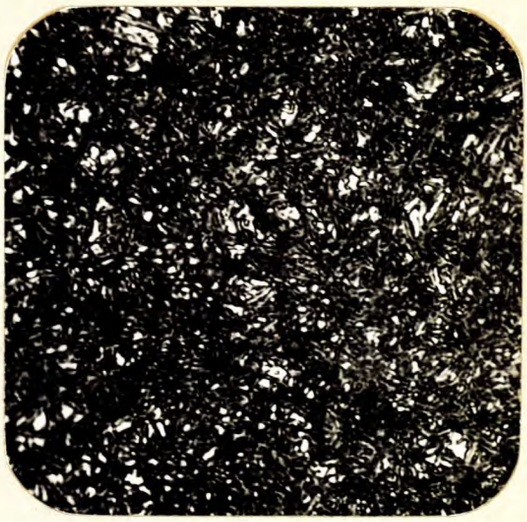
X1000, nital etched.

C.P.R. PIN.

Figure 6.

Core.

Figure 7.



Case.

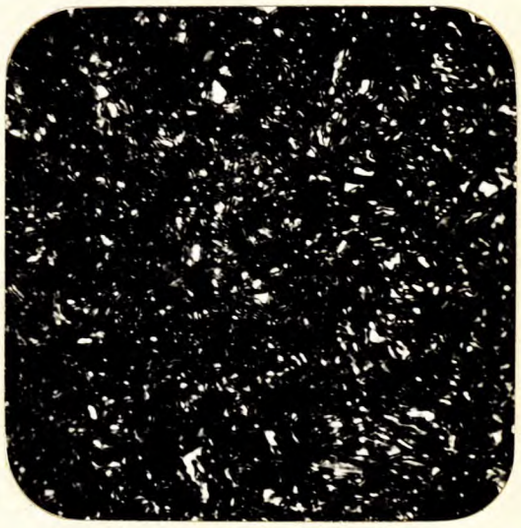
X1000, nital etched.

CAMPBELL, WYANT & CANNON NE 8615 PIN.

Figure 8.

Core.

Figure 9.



Case.

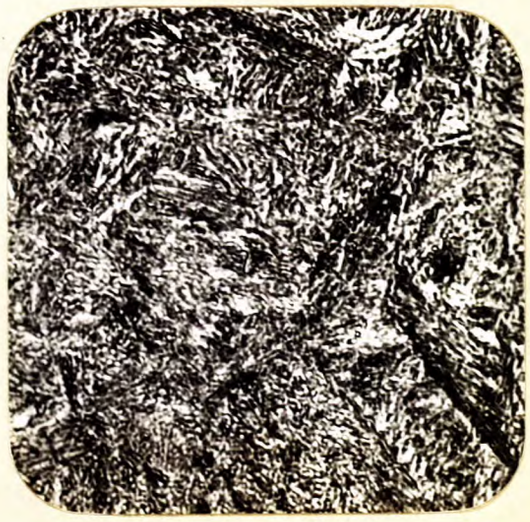
X1000, nital etched.

COCKSHUTT PLOW PIN.

Figure 10.

Core.
X500, nital etched.

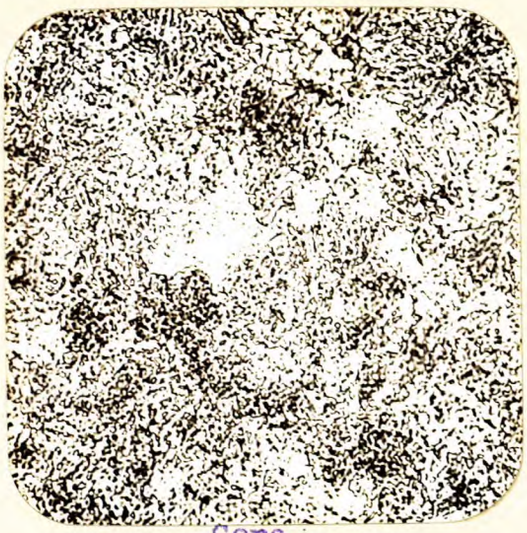
Figure 11.



Case.
X1000, nital etched.

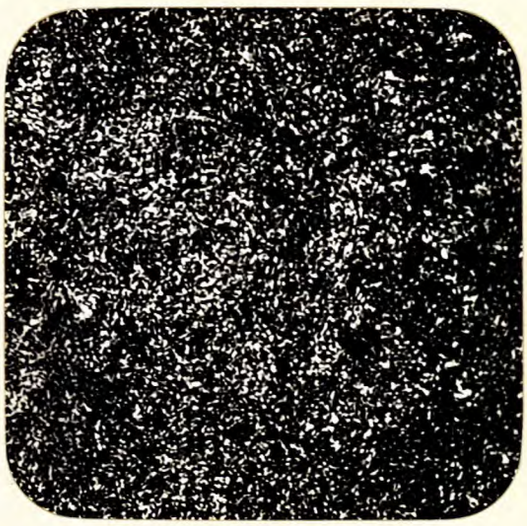
TAYLOR-WHARTON PIN.

Figure 12.



Core.
X500, nital etched.

Figure 13.



Case.
X1000, nital etched.

TOCCO PIN.

Figure 14.

Core.
X500, nital etched.

Figure 15.

Case.
X1000, nital etched.

CAMPBELL, WYANT & CANNON NE 8817 PIN.

Figure 16.

X1000, nital etched.

SAE 9255 PIN.

DISCUSSION:

PRACTICE IN ENGLAND.

In a cablegram (Coslo 2427) received from London, England, on December 29th, 1942, the heat treatment given and general properties obtained for the 7/8-inch Valentine pin are outlined. The following is a brief synopsis of the contents of this cablegram:

Heat Treatment -

1. (a) Carburize in a cyanide bath at 1615° F. sufficient time to give 0.030 to 0.035 in. case, water quench; and

   (b) Reheat to 1400° F., soak not more than 10 minutes, water quench.

or

2. (a) Carburize at 1740° F., air cool;

   (b) Reheat to 1615° F., water quench; and

   (c) Reheat to 1400° F., water quench.

No tempering is required. A 2 per cent nickel case-hardening steel is used.

The above-mentioned heat treatments gave a minumum tensile of 78,400 p.s.i., 25 per cent elongation, 50 per cent minimum reduction of area, and 60 foot pounds notched-bar impact on the core.

Deflection tests on Valentine pins from three sources gave 0.60, 0.97, and 0.53 inch at fracture with loads of 11,400, 12,100, and 11,600 pounds respectively. The samples varied in analysis, the highest being: carbon 0.18, manganese 0.61, nickel 1.76, chromium 0.25, and molybdenum 0.10 per cent.

It is felt in England that a pin having a good charpy impact and a good bend deflection gives satisfactory service. They have found that in some cases failure in service is associated with considerable falling-off in resistance to bend and impact at temperatures of plus 50 and plus 32 degrees (F). The Vickers hardness gradient which has been found to give satisfactory service is as follows:

850	from surface to 0.015 inch depth,
740	at 0.020 inch,
670	at 0.025 " ,
580	at 0.030 " ,
350	at 0.060 " ,
160-230,	core hardness.

(Discussion, cont'd) -

HOW DO THE RESULTS OF PINS PRODUCED ON THIS CONTINENT COMPARE WITH THOSE OF ENGLISH PRODUCTION?

It must first be mentioned that the surface hardness minimum specified here is 650 ± 50 V.P.N. It is felt that harder pins, in spite of their higher fatigue strength, may be notch-sensitive. Softer pins may have too low fatigue strength and also, of course, are subject to more rapid wear.

These pins have been produced for some time now and it would be interesting to find out whether pins on Canadian tanks are wearing very much more than English pins under European conditions. If the pitch on Canadian tracks (wear of pin, wear and stretch of link) greatly exceeds that of the British tracks then the matter of surface hardness of pins might again be considered. Field tests carried out in Canada have given 4,000 miles service which is considered to be reasonably good. Consequently, it has been felt that the surface hardness of pins produced here is adequate in regard to total pitch increase of the tracks. It is unfortunate that so few field tests have been carried out, since these constitute the best possible test for pins. In the absence of these, laboratory tests are used to indicate the quality of the pin.

Methods of Carburizing Used on This Continent:

The heat treatment of Taylor-Wharton and Chicago Area pins is not known. It would appear, from the micro-structure, that the Chicago pins are being double-quenched.

(Continued on next page)

(Discussion, cont'd) -
(Methods of Carburizing Used on This Continent, cont'd) -

C.P.R. -

It is our understanding that this pin is pack-carburized by standard methods, cooled in the box, is reheated to above the case critical, 1400 to 1425° F., then oil quenched. To get 550 to 650 hardness the pins are then drawn.

Cockshutt Plow -

Placed in cyanide bath at 1600° F. and air cooled. Reheated to 1425° F. and water quenched. The pins are drawn back to the stipulated hardness.

Campbell, Wyant & Cannon -

This firm uses the carbo-nitriding process for the NE 8615 pins.

No. of pushes	Time per push	Furnace temperatures	Quenching temperature
30	14 min.	Zone 1, 1580° F. Zone 2, 1600° F. Zone 3, 1650° F.	1650° F.

This firm does not draw back their pins as the U.S.A. specification merely quotes 550 V.P.N. minimum.

Case Depth:

All manufacturers have been producing a case depth to the present specified 0.020 to 0.035 inch.

At the start of production in Canada, case depths went as high as 0.065 inch with 850 V.P.N. surface hardness. Complaints about pin breakage were received from England. A field test showed that after 900 miles 23 pins failed. Their examination revealed that the thick hard case caused brittleness. Since the case depth has been reduced, no

(Discussion, cont'd) -

further complaints have been received from overseas. Our own experience, however, indicates the occasional early failure of a pin and a great deal of research has been made on pins in order to eliminate this low percentage, if possible.

Chemical Analysis:

It is of note that, with the exception of low molybdenum in the Campbell, Wyant and Cannon pins (probably reduced to conserve alloys), all the pins fall within the specified analysis.

Physical Properties:

The physical properties of the cores of the pins produced here vary considerably:

Tensile strength, p.s.i.	-	72,100	to	138,000.
Yield strength, p.s.i.	-	48,800	to	86,000.
Elongation, per cent in 2 inches	-	12	to	35.
Reduction of area, per cent	-	26	to	75.

In Table I it will be noted that Campbell, Wyant and Cannon's NE 8817 pins had the highest tensile and yield strength and very low elongation and reduction of area. These pins were given a field test and proved satisfactory. The first failure occurred at approximately 1,800 miles and four more failures were encountered up to a mileage of 4,200.

Failed pins, which have been investigated in these Laboratories from time to time, have also varied widely in their core physical properties. The practice has been to hold the tensile around 80,000 p.s.i. in Canada and about 95,000 p.s.i. in the U.S.A. At the present time it is believed physical core properties are not specified.

(Continued on next page)

(Discussion, cont'd) -

Bend Tests:

Table II shows that the loads at pin failure varied from 7,850 to 17,500 pounds (homogeneous pin). The deflections at failure were from 0.730 to 1.45 inches.

If it is wished to include into the specification a deflection in inches at pin failure, 0.50 inch minimum would appear to be a reasonable figure. The minimum load should be 7,500 pounds.

The first cracking of the case occurs from 0.154 inch deflection to 0.970 (for the Tocco pin). A minimum deflection of 0.140 at a load of 3,500 pounds could be specified. It should be stated that obtaining the result for the first cracking of the case may entail too much work for routine inspection as it necessitates drawing a stress-strain diagram by recording the deflection in inches at specific load intervals.

We believe that all pin plants are equipped with tensile test machines. If they are not, however, a press (10 ton) could be arranged to serve as a bend test machine.

Drop Impact Tests:

The drop impact test has been used in these Laboratories[*] as an indication of the toughness and shock resistance of a pin rather than a standard impact test on the core. It is felt that this tests the pin as it will be used in service.

A pin should be able to withstand a 350-foot-pound impact load. This standard would fail the Campbell, Wyant and Cannon NE 8615. If the core hardness of these pins was lowered it is felt that they would pass the test. Most of the pins which failed on impact had a core hardness of over 250 V.P.N. A pin with a very thick case will also fail the impact test.

The homogeneous SAE 9255 pin should also be able to

[*] Investigation No. 1197, issued April 2nd, 1942, illustrates the machine used.

(Discussion, cont'd) -

withstand 350 foot pounds.

Core Hardness:

The core hardnesses of the unbroken pins were:

Chicago	-	165-235 V.P.N.
C.P.R.	-	153-240 "
Cockshutt Plow	-	156-205 "
Tocco	-	194-215 "

It would appear that a maximum core hardness of 250 V.P.N. should be imposed for the cased pin.

...

Ninety-five per cent of the failures which occur are due to fatigue. It is not known whether the fatigue crack starts at the surface or the subsurface. With the Universal Carrier pin, which has a thin case, subsurface cracking outside the outer zone is a possibility. It is felt that with the thicker case on the Valentine pin the fatigue crack in all probability starts in the case. Fatigue tests definitely should be employed in research work on pins. Since such tests usually take some time to perform, however, they are not suitable for inspection tests and so are not specified. Bend and drop impact tests appear to correlate closely with results obtained in the field. Consequently, it is felt that control of these and the other properties specified on the next page will give a good pin.

RECOMMENDATIONS:

1. As in the Universal Carrier pin specification, it is felt that the criteria of acceptance for the 7/8-inch-size cased pin should be:

   (a) Bend deflection in inches and load at the fracture,
   (b) Drop impact,
   (c) Surface hardness,
   (d) Core hardness, and
   (e) Case depth.

2. The same tests as above may be applied for the homogeneous type pin, excepting case depth.

3. A bend deflection at fracture of 0.5 inch with a minimum load of 7,500 pounds for both the cased and homogeneous pins.

4. Drop impact minimum of 550 foot pounds for both the cased and homogeneous pins.

5. Surface hardness of 650 ± 50 V.P.N. for the cased pin.

6. Surface hardness of 48 ± 3 Rockwell 'C' for the homogeneous pin.

7. Core hardness maximum of 250 V.P.N. for the cased pin.

8. Core hardness minimum of 42 Rockwell 'C' for the homogeneous pin.

9. Case depth of 0.020 to 0.035 inch for the cased pin.

10. If manufacturing facilities allow a normalizing and quench, a double quench is advisable.

11. If the Tocco pin be approved for service, the surface hardness should be kept below 575 V.P.N. in order to counteract the embrittling effect of the thick case. A sorbitized stock should be used in the induction heat treatment.

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