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OTTAWA November 30th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1330.

Examination of Universal Carrier Track Pins from Field Tests C-6, 13-W, 16-W, Windsor, Ontario.

(Copy No. 24.)

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 and Object of Investigation:

In connection with three recent field tests of Universal Carrier track pins, carried out at the Ford Motor Co. of Canada's proving ground at Windsor, Ontario, it has been requested by the Track Pin Committee that a thorough investigation be made on:

(a) Pins prior to field test;
(b) Pins which have broken during test; and
(c) Pins which have not broken during test.

General Information on Field Tests:

Test O-6 had:

(1) Control pins SAE 3115 cased pins.
(2) SAE 9255 homogeneously hardened pins.

Test 13-W had:

(1) Control pins SAE 3115 cased pins.
(2) Hard (400 V.P.N. approx.) core NE 8124 cased pins.
(3) Soft (300 V.P.N. approx.) core NE 8124 cased pins.

Test 16-W had:

(1) Control pins SAE 3115 cased pins.
(2) Hard (400 V.P.N. approx.) core SAE X1020 cased pins.
(3) Soft (300 V.P.N. approx.) core SAE X1020 cased pins.

Chemical Analysis:

Chemical analyses were made on the various samples submitted. The results were:

SAE 9255 Pins.

		As Found	Specification Limits
		- Per cent -	
Carbon	-	0.54	0.50 - 0.60
Manganese	-	0.79	0.60 - 0.90
Silicon	-	2.20	1.80 - 2.20
Phosphorus	-	0.015	0.040 max.
Sulphur	-	0.037	0.050 max.

SAE 3115 Pins.*

Carbon	-	0.19	0.10 - 0.20
Manganese	-	0.52	0.30 - 0.60
Silicon	-	0.24	0.15 min.
Phosphorus	-	0.036	0.040 max.
Sulphur	-	0.021	0.050 max.
Nickel	-	1.40	1.00 - 1.50
Chromium	-	0.62	0.45 - 0.75

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* Early 1942 production.

(Chemical Analysis, cont'd) -

NE 8124 Pins.

		AS FOUND		Specification Limits
		- Per cent -		
		Soft Core	Hard Core	
Carbon	-	0.19	0.20	0.22 - 0.28
Manganese	-	1.50	1.48	1.30 - 1.60
Phosphorus	-	0.017	0.017	0.040 max.
Sulphur	-	0.013	0.017	0.040 max.
Silicon	-	0.29	0.29	0.20 - 0.35
Molybdenum	-	0.27	0.27	0.25 - 0.35

SAE X-1020 Pins.

Carbon	-	0.20	0.18	0.15 - 0.25
Manganese	-	0.92	0.91	0.70 - 1.00
Phosphorus	-	0.009	0.009	0.045 max.
Sulphur	-	0.027	0.030	0.055 max.

Bend Tests:

Bend tests were carried out on the Amsler Universal testing machine using a 12-inch radius and 8-inch centres. The bending block was 3-7/16" wide. Charts of increment vs. load were plotted. The elastic limit, permanent bend, and the case break point were then determined from the charts. These tests were carried out on pins which had had no service in the field. Table I records the results obtained.

(Table I appears on Page 4)

TABLE I.

BEND TESTS ON ORIGINAL PINS.

	SAE 9255		SAE 3115 *		NE 8124, SOFT CORE		NE 8124, HARD CORE		SAE X1020, SOFT CORE		SAE X1020, HARD CORE	
	Angle	Load (lb.)	Angle	Load (lb.)	Angle	Load (lb.)	Angle	Load (lb.)	Angle	Load (lb.)	Angle	Load (lb.)
Elastic limit	5° 32'	2050	1° 44'	450	1° 55'	410	1° 32'	410	1°	256	2° 45'	550
Permanent bend	7° 46'	2480	3° 22'	690	2° 50'	507	2° 28'	550	1° 50'	378	4° 45'	750
Case break point	17° 4'	2910	3° 54'	700	4°	600	6° 3'	1000	7° 16'	650	7° 38'	1000

* Results are of one pin taken from June 1942 production.

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Depth-Hardness:

Hardness readings were taken across the face of transverse sections cut from the pins. The Vickers hardness machine and a 10-kilogram weight were used. Figures 1, 1a, and 2 are charts plotted from the hardness results obtained at varying distances from the surface. In Figure 1 (NE 8124), Curves Nos. 2, 3 and 4 were taken from three soft-core pins which had broken at 1000-1100 miles. Curve No. 5 is of an 'original' (unused) soft-core pin and Curve No. 6 is an 'original' hard-core pin. Figure 1a illustrates the curves obtained for the 'original' soft- and hard-core SAE X1020 pins. In Figure 2 three typical curves are shown of the April - May, 1942 production of SAE 3115 pins.

Figure 1.

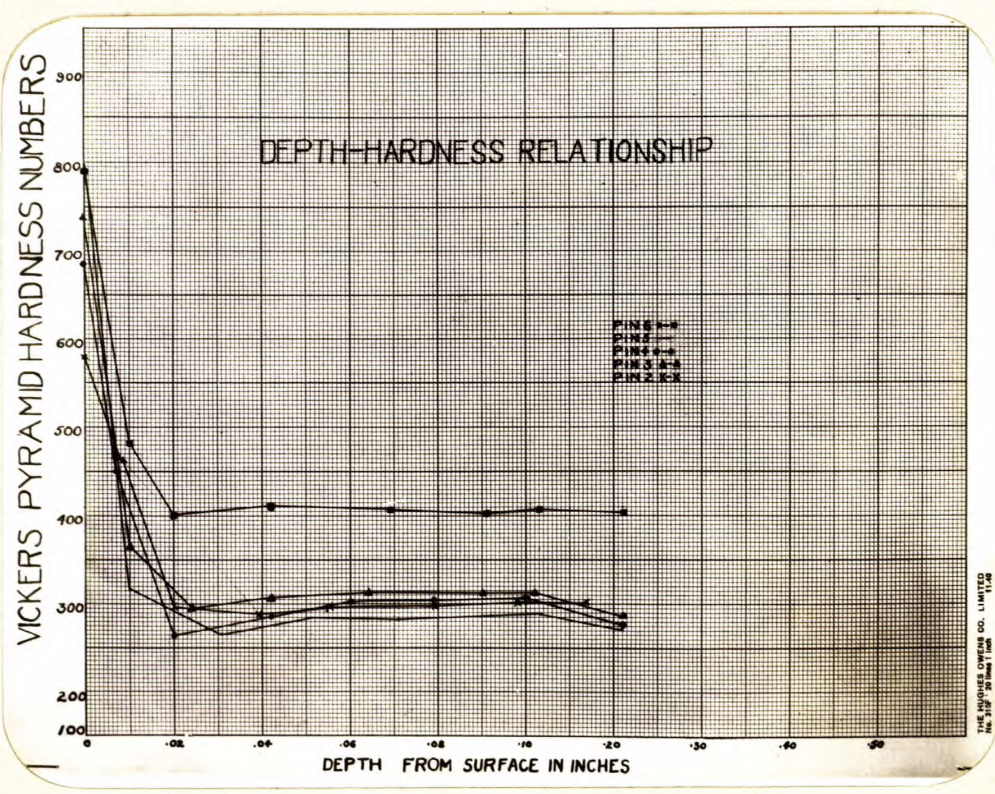

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Figure 1a.

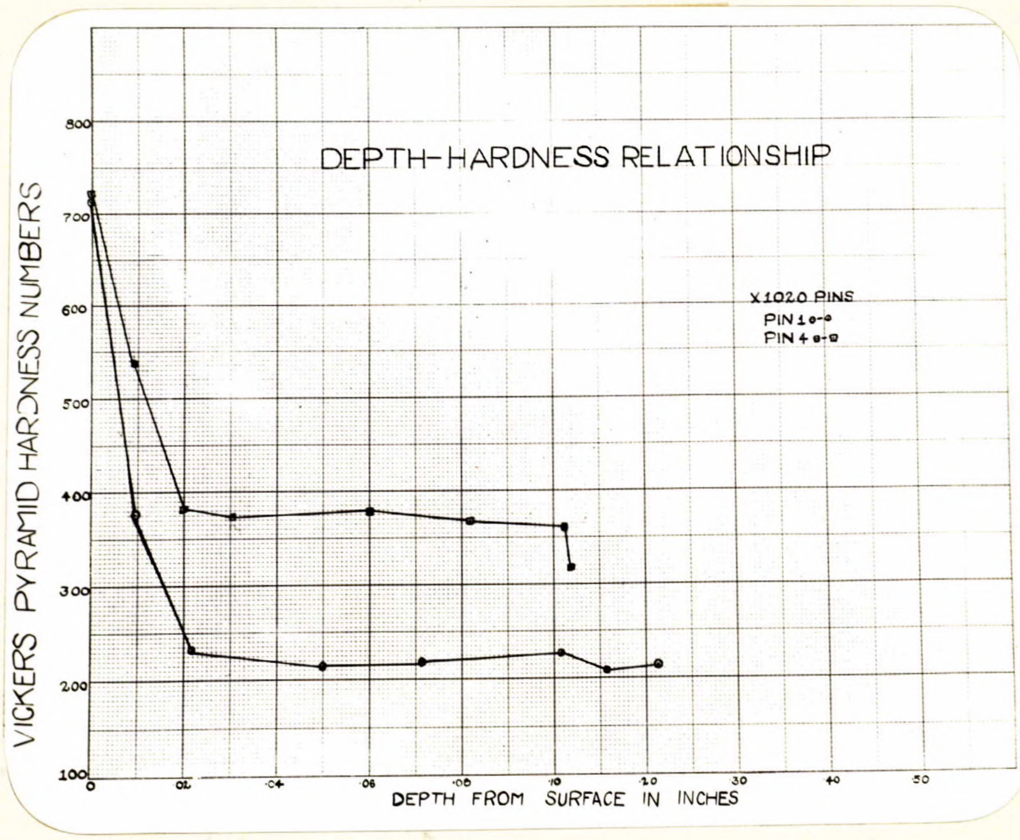
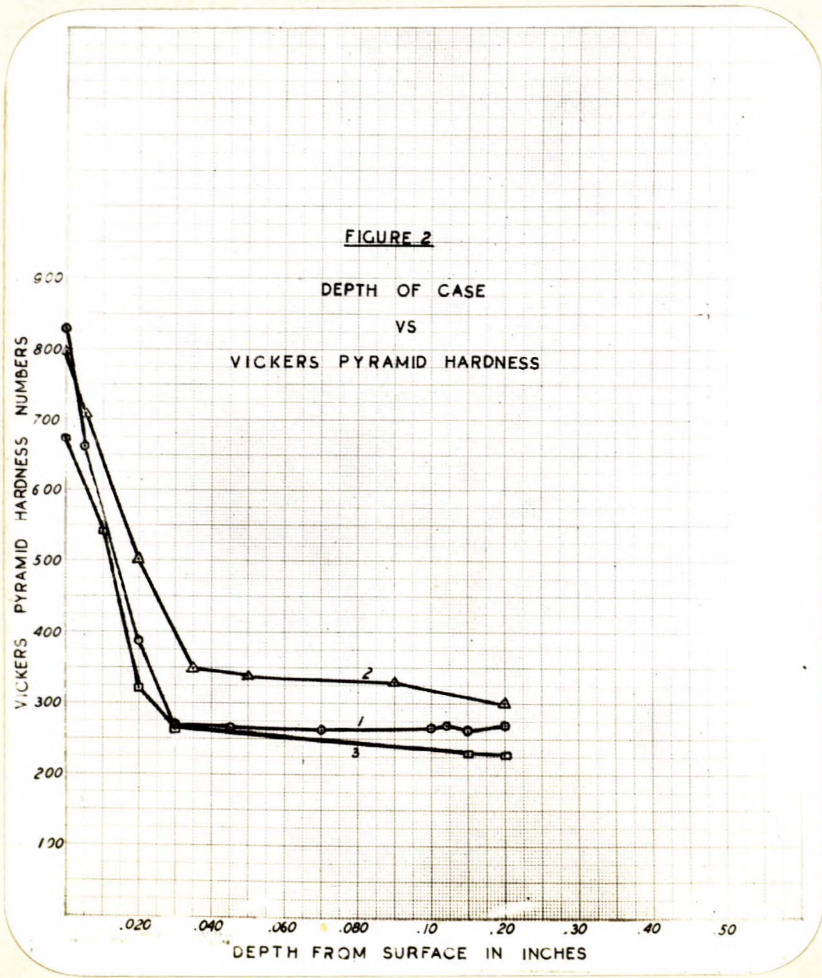


Figure 2.



Core Hardness - Depth of Case - Physical Properties:

Table II lists the core hardnesses, case depths, physical properties, and other salient points of the 'original' pins, unbroken pins, and broken pins in Test O-6.

Tables III and IV are summations of the results obtained for Tests 13-W and 16-W respectively. The physical specimens were taken from the pins after the cases had been ground off. They were of 0.252-inch diameter and 2-inch gauge length.

It should be added that these are not all of the broken pins obtained in the tests. The results, however, represent a great majority of the pins which had broken up to the maximum mileage quoted for each test.

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(Tables II, III and IV occupy)
(Pages 8 to 11, inclusive.)

(Text is resumed on Page 12)

TABLE II. - Carrier No. 1; SAE 9255, 5115. - Test 0-6.

ODML No.	Pin No. in field	STEEL	Hard or soft	Condition of pin and fracture	Mileage at breakage or removal	Vickers core hardness	Case depth, in.	Ultimate strength, p.s.i.	0.1% proof stress, p.s.i.	Elongation, %	Red. of area, %	Remarks.
A-14	156-R	3115		Unbroken.	3671	340	.020-.022	141,200	99,200	-	52	
A-15	87-L	9255		Unbroken.	3670	502						Link broke; pin did not.
A-1	161-L	3115		Fatigue fracture, 2½" from head.	3620	300	.014-.020	148,000	104,000	11.5	54	Broken on concrete.
A-2	142-L	3115		Broken 2½" from head.	47	287	.020-.022	124,400	80,000	12.5	56	Broken in quarry.
A-4	155-R	3115		do do	4226	276	.018-.020	144,800	100,800	9.5	54	Broken on concrete.
A-5	137-L	3115		Fatigue fracture, 2½" from head.	4444	282	.020	128,000	86,000	14.0	64	do do
A-6	146-R	3115		Broken near the head.	3453	249	.014-.018	132,000	91,600	12.0	52	do do
A-7	149-L	3115		Fatigue fracture, 2½" from head.	1958	321	.018-.020	150,000	103,200	11.0	54	do do
A-8	140-L	3115		Broken, fatigue, near unheaded end.	2372	242	.020	151,200	97,600	-	50	-
A-9	141-L	3115		Broken, fatigue, near unheaded end.	3352	299	.018-.020	145,600	102,000	11.0	56	Broken on concrete.
A-10	1-L	3115		Broken at 2 points.	3209	365	.020-.022	-	-	-	--	Broken in quarry.
A-11	153-L	3115		Broken near the head.	3620	337	.020	153,600	106,000	9.0	48	Broken on concrete.
A-13	162-L	3115		Fatigue fracture, 2½" from head.	3620	296	.018	151,200	99,000	11.0	50	Failed on concrete.
A-3	140-L	8620		Broken 2½" from head.	(?) 3820	381	.020-.022	201,200	145,200	6.0	58	This is a replacement pin.
A-12	119-L	2115		Broken, fatigue, near unheaded end.	4059	413	.010-.012	193,600	149,600	7.5	42	Broken on concrete.

TABLE III. - Carrier No. 2: NE 8124 Hard and Soft Core, SAE 3115. - Test 13-W.

ODML No.	No. in field	STEEL	Hard or soft	Condition of pin and fracture	Mileage at breakage or removal	Vickers core hardness	Case depth, in.	Ultimate strength, p.s.i.	0.1% proof stress, p.s.i.	Elongation, %	Red. of area, %	Remarks.
6		8124	H	Original.	0	410	.010	212,000	138,300	9.5	50.7	
5		8124	S	Original.	0	287	.008	115,300	58,500	-	60.0	
B-2	22-L	8124	H	Unbroken.	2418	394	.006-.008	211,200	142,000	6.5	50.0	Removed from track.
		*8124	H	do	2571	338	-	216,900	211,320	1.561	49.51	
		*8124	H	do	2571	366	-	220,400	216,300	4.601	45.71	
		*8124	H	do	2571	366	-	217,643	203,921	1.001	47.11	
		*8124	S	do	2571	238	-	162,000	142,000	6.251	26.01	
		*8124	S	do	2571	258	-	168,000	148,000	6.251	22.01	
		*8124	S	do	2571	246	-	160,000	136,000	7.801	26.01	
B-22	117-L	3115	-	do	2350	232	.014	160,000	107,600	8.5	24.0	-
B-23	117-R	3115	-	do	2350	221	.018	126,900	86,700	11.0	55.0	-
B-1	162-L	3115	-	Welded collar lost, pin unbroken.	2937	239	.016-.020	134,800	86,000	11.0	50.0	-
		*3115	-	Unbroken.	2571	226	-	157,100	146,900	7.81	32.71	
		*3115	-	do	2571	226	-	153,000	144,900	6.31	38.7	
		*3115	-	do	2571	226	-	132,653	124,500	9.31	61.21	
B-24	116-R	2115	-	do	2350	405	.012	194,400	156,000	8.0	50.0	-
B-31	147-R	2115	-	do	2300	427	.014-.016	196,000	147,000	9.5	50.0	-
B-3	28-L	8124	H	Broken near the head.	2686	419	.020	214,400	138,000	Outside gauge break.	34.0	Broken on a hill.
2	30-R	8124	S	Fatigue fracture, nearer headed end.	1196	302	.004-.006	150,500	67,000	13.0	40.0	Broken in quarry.
3	9-L	8124	S	Fatigue fracture, near unheaded end.	1089	310	.006-.007	159,600	70,200	12.0	34.0	Broken on concrete.
4	1-R	8124	S	Fatigue fracture, near headed end.	1029	305	.008	161,600	73,600	12.5	35.0	Broken on concrete.

* These pins were tested at the Ford Motor Company of Canada, Windsor, Ontario. For these the figure quoted under the heading of 0.1% Proof Stress is Yield Point.

(Continued on next page)

TABLE III, continued. - Carrier No. 2: NE 8124 Hard and Soft Core, SAE 3115. - Test 13-W.

ODML No.	Pin No. in field	STEEL	Hard or soft	Condition of pin and fracture	Mileage at breakage or removal	Vickers core hardness	Case depth, in.	Ultimate strength, p.s.i.	0.1% proof stress, p.s.i.	Elongation, %	Red. of area, %	Remarks.
B-5	51-R	8124	S	Broken near the head.	3216	303	0-.005	-	-	-	-	Broken on concrete.
B-6	49-L	8124	S	Broken, fatigue, unheaded end.	2952	315	0-.006	150,800	96,000	13.0	52.0	do do
~~B-7~~	~~16-R~~	~~8124~~	~~S~~	~~Broken, fatigue, unheaded end.~~	~~3011~~	~~310~~	~~.006-.008~~	~~148,000~~	~~92,800~~	~~14.5~~	~~46.0~~	~~-~~
B-8	71-L	8124	S	Fatigue fracture, unheaded end.	3060	314	0-.003	160,000	70,400	14.5	32.0	Broken in quarry.
B-9	82-L	8124	S	Fatigue fracture, unheaded end.	3007	512	.004-.006	115,600	68,000	-	56.0	Broken on concrete.
B-10	15-R	8124	S	Fatigue, unheaded end.	3060	317	.012-.013	138,000	88,000	14.0	58.0	Broke in quarry.
B-11	20-R	8124	S	do do	2972	309	.006	142,000	85,200	13.0	46.0	Failed on concrete.
B-12	19-R	8124	S	do do	2952	330	.006-.008	158,000	76,000	14.0	40.0	Failed on concrete.
B-14	61-L	8124	S, med.	Brittle.	3060	342	.005-.007	151,000	97,100	10.0	40.0	Broke in quarry.
B-15	81-L	8124	S	Brittle, near the head.	3060	301	.004	153,400	87,700	13.0	41.0	Broke in quarry.
B-17	29-R	8124	S	Broke in centre.	3101	322	.018-.019	136,400	92,800	11.5	56.0	Failed on concrete.
B-18	72-L	8124	S	Brittle, broke near unheaded end.	2598	225	.010	155,600	80,800	16.0	40.0	Broke in quarry.
B-21	5-R	8124	S	Broken, fatigue, unheaded end.	2920	270	.008	140,000	85,000	15.0	52.0	Broke on concrete.
B-16	123	3115	-	Fatigue failure near head.	3135	413	.014	192,400	136,000	8.5	50.0	do do
B-19	132-R	3115	-	Broke in centre, brittle.	2598	342	.018-.020	-	-	-	-	Broke in quarry.
B-4	53-L	2115	-	fatigue, near unheaded end.	?3060	409	.014	193,600	130,000	8.0	52.0	Replacement pin.
B-13	131-R	2115	-	Fatigue, broke near the head.	?2937	429	.016	193,600	150,000	9.0	52.0	Broke on concrete; replacement pin.

TABLE IV. - Carrier No. 3: SAE X1020 Soft and Hard Core, 3115. - Test 16-W.

ODML No.	Pin No. in field	STEEL	Hard or soft	Condition of pin and fracture	Mileage at breakage or removal	Vickers core hardness	Case depth, in.	Ultimate strength, p.s.i.	0.1% proof stress, p.s.i.	Elongation, %	Red. of area, %	Remarks.
C-8		X1020	S	Original pin.	0	225	.008	113,000	59,100	15.5	62.7	
C-9		X1020	H	Original pin.	0	360	.010	165,500	69,400	9.5	57.2	
C-6	122-R	X1020	H	Unbroken.	2828	383	.016-.018	168,000	110,000	6.0	18.0	
C-7	122-L	X1020	H	do	2828	449	.022	202,000	135,000	7.0	38.0	
		⊕X1020	H	Unbroken.	3223	296	-	176,000	162,000	6.251	38.01	
		⊕X1020	H	do	3223	294	-	180,000	170,000	6.251	34.01	
		⊕X1020	H	do	3223	330	-	182,000	172,000	6.251	40.01	
		⊕X1020	S	do	3223	207	-	112,000	100,000	12.51	62.0	
		⊕X1020	S	do	3223	169	-	90,000	72,000	15.51	76.0	
		⊕X1020	S	do	3223	219	-	116,000	80,000	10.91	58.0	
		⊕3115		do	3223	283	-	160,000	148,000	4.71	28.01	
		⊕3115		do	3223	304	-	192,000	166,000	7.81	40.01	
		⊕3115		do	3223	271	-	160,000	150,000	4.71	24.01	
C-1	30-L	X1020	S	Broken on a twist.	152	202	.012	96,800	64,600	17.5	62.0	
C-2	9-L	X1020	S	Broken in torsion.	693	265	.008-.010	114,700	80,800	16.5	56.0	
C-3	36-L	X1020	S	Fatigue failure near head.	3126	208	.006	102,800	69,600	19.5	60.0	
C-5	49-R	X1020	S	Broken, fatigue, unheaded end.	2942	238	.008	112,600	81,200	16.0	56.0	
C-4	121-R	3115		Brittle.	2772	442	.018	212,900	150,800	7.5	46.0	

⊕ These pins were tested at the Ford Motor Company of Canada, Windsor, Ontario. For these the figure quoted under the heading of 0.1% Proof Stress is Yield Point.

Microscopic Examination:

Transverse microsections were cut from the 'original' pins, polished, etched in nital, and then examined under the microscope. The photomicrographs of the cores are all taken at X500 magnification (Figures 3, 5, 7, 9, and 12), those of the cases are at X1000 (Figures 4, 6, 8, 10, and 13). Figure 11, at X1000 magnification, illustrates the structure of the SAE 9255 pin.

(THE PHOTOMICROGRAPHS ARE
AT THE END OF THIS REPORT.)

Discussion:

The chemical analyses of the SAE 9255 and SAE 3115 pins show that the steel conforms to the specification limits.

The chemical analysis of the NE 8124 pins indicates that a lower carbon content was used than was demanded by the specification. A lower carbon content is in accordance with good carburizing practice. It would be expected that different test results would be obtained from pins of the specified analysis. It appears that the same heat of steel was employed to obtain both the hard core and soft core pins.

The chemical analysis of the SAE X1020 conforms to the limits specified for this type of steel. Here, also, the same heat of steel appears to have been used to obtain the hard and the soft core pins.

The bend test results, given in degrees of the bend angle, were obtained by geometrical calculation from the deflection in inches. If the angles could be measured under load, using a protractor, greater bend angles would be

(Discussion, cont'd) -

obtained, since the protractor would measure the angle formed by the pin approximately 2 inches away from the centre of either side. It is well known that with a 3-7/16" contact bending block, the pin bends under load in an arc rather than to a point in the centre.

It will be observed from Table I that it was necessary to apply a greater load in order to produce the first crack in the case for the hard-core pins than was necessary for the case of the soft core, and both these pins have approximately the same case depth. The SAE 9255 pins give a greater bend angle and withstand a much greater load than the cased pins.

The case depths of the unused pins indicate that both the NE 8124 and the SAE X1020 had shallow cases.

Of all the broken pins shown in Table III (NE 8124), one was a hard-core pin and all the rest had soft cores. This hard-core pin, however, had a case depth of 0.20 inch. The assumption can therefore be made that few, if any, hard-core pins with shallow cases (0.008 - 0.010 in.) failed. It appears that the quality of a thin-cased pin is mainly dependent upon the properties of its core or is similar to a homogeneous pin. The hard cores, with their greater strength, are better able to withstand the stresses than the soft-core pins.

Alternatively, with a heavily cased pin, the properties of the case largely determine the quality of the pin. Consequently, a heavy case backed by a hard core does not have the same properties as does a shallow case backed by a hard core.

Table IV, of the SAE X1020 pins, indicates that no hard-core pins have failed.

The SAE 3115 control pins which failed in the tests

(Discussion, cont'd) -

varied in core hardness from 242 - 442 V.P.N. and in case depth from 0.014 - 0.022. From the mileages it would seem that the reliability of these pins becomes erratic after 2000 miles. It is difficult to determine the physicals which would give the maximum mileage, since a pin with a certain set of physicals breaks at a relatively early mileage and another pin with approximately the same physicals goes unbroken for much greater mileages. The indications are that the pins are breaking in fatigue and that breakage is more a function of service conditions than of pin properties.

The photomicrographs of the cores of the NE 8124 and SAE X1020 pins indicate that the manufacturer quenched all of the pins from approximately the same temperature, as all pins contain about the same small amount of ferrite. It follows, then, that the soft-core pins were obtained by a slower quench. Figure 7, showing the case structure of a soft-cored SAE X1020 pin, indicates the presence of troostite. This is also the result of a slow quench. A more drastic quench would eliminate this troostite, which has an embrittling effect on the case.

The structure of the SAE 9255 pin indicates the presence of free ferrite. This is to be expected, since the pins were quenched from 1500° F., which is within the critical range.

CONCLUSIONS:

1. The SAE 9255 pins used in this field test gave excellent results. These pins were quenched from 1500° F. It is felt that quenching from 1625 ± 25° F. will give even better results.

2. The hard and soft core (NE 8124) pins were produced from steel of the same analysis, probably from the same heat.

3. The SAE X1020 hard and soft core pins are also of the same analysis.

4. The soft cores were obtained by employing a less severe quench.

5. The soft cores are approximately 300 V.P.N. The hard cores are 400 V.P.N.

6. The depth of case for the majority of the pins used in Test 15-W and 16-W was from 0.008 - 0.010 inch. This is below the limit set in the Canadian specification.

7. NO HARD CORE, SHALLOW-CASED PINS WERE FOUND AMONG THE BROKEN PINS RECEIVED.

8. Broken control pins of SAE 3115 vary greatly in core hardness, case depth, and physicals. No conclusions can be drawn as to a set of physicals which would definitely give a superior pin. The pins appear to be breaking in fatigue and the breakage is more a function of service conditions than of pin properties.

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SLG:PES:GHB.

Figure 3.

X500.

CORE OF NE 8124
SOFT-CENTRE PIN.

(Note: White constituent - ferrite;)
(dark - lamellar carbide.)

1600 - 1 hr - oil quench
draw 1300 - oil quench

Figure 4.

X1000.

CASE OF NE 8124
SOFT-CENTRE PIN.

Tempered martensite.

Figure 5.

X500.

CORE OF NE 8124
HARD-CENTRE PIN.

Structure is tempered martensite
with elongated nodules.

Figure 6.

X1000.

CASE OF NE 8124
HARD-CENTRE PIN.

Tempered martensite.

(ALL OF ABOVE ARE ETCHED IN NITAL)

Figure 7.

X500.

CORE OF SAE X1020
SOFT-CENTRE PIN.

(Note: White constituent - ferrite; black areas - sorbite; also nodules of carbide present.)

oil quench

Figure 8.

CASE OF SAE X1020
SOFT-CENTRE PIN.

Note presence of troostite (black constituent) around grain boundaries.

Figure 9.

X500.

CORE OF SAE X1020
HARD-CENTRE PIN.

Note presence of ferrite (white constituent), nodules of carbide, and amount of sorbite.

1600-1625 water quench

Figure 10.

X1000.

CASE OF SAE X1020
HARD-CENTRE PIN.

Tempered martensite.

(ALL OF ABOVE ARE ETCHED IN NITAL)

Figure 11.

X1000, nital etch.

SAE 9255 STRUCTURE.

Note presence of free ferrite (white constituent).

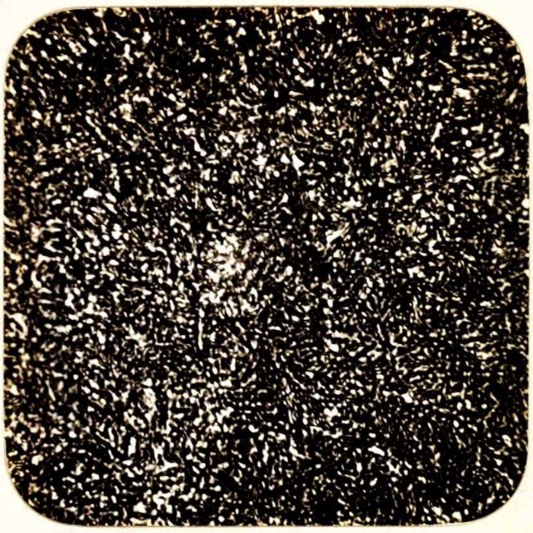
Figure 12.

X500, nital etch.

CORE OF SAE 3115 PIN.

Note ferrite (white constituent) and nodular carbides.

Figure 13.



X1000, nital etch.

CASE OF SAE 3115 PIN.

Tempered martensite.

SLG:GHB.