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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1716.

Investigation of a Heat of SAE 3115 Steel for Cased Universal Carrier Track Pins.

(Copy No. 18 .)

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ORE DRESSING AND METALLURGICAL LABORATORIES.

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Investigation of a Heat of SAE 3115 Steel for Cased Universal Carrier Track Pins.

Origin of Material and Object of Investigation:

On August 5th, 1944, under Requisition No. 832, A.E.D.B. Lots Nos. 1113 to 1124 inclusive (Report No. 9, Section A, Test 28), Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario, submitted twelve (12) unheat-treated track pins to these Laboratories for examination. On August 17th, ten (10) additional pins, Lots Nos. 1129 to 1138, were received.

It was reported that these pins were taken from a heat of steel having the following composition (in per cent): carbon, 0.15-0.17; manganese, 0.48-0.50; chromium, 0.30-0.32. A request was made that heat-treating conditions should be

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

established so that the pins would meet Specification O.A. 214. Manufacturers were encountering some difficulty in meeting the specified core hardness of Rockwell 'C' 24-32.

At a later date, Lieut. G. Spencer, of Detroit Ordnance District, submitted approximately 100 more pins of the same heat of steel, for further experiments.

Chemical Analysis:

Drillings were taken from the core for chemical analysis:

		Per Cent
Carbon	-	0.18
Manganese	-	0.48
Chromium	-	0.31
Nickel	-	1.25
Silicon	-	0.23
Sulphur	-	0.016
Phosphorus	-	0.017
Molybdenum	-	0.04

HEAT TREATMENTS:

Table I illustrates the heat treatments employed and the resultant pin properties obtained. Quenching was done by hand in a still oil bath (15-inch diameter by 3 feet). Houghton's oils were used in all treatments. A Vapocarb unit was employed for all the gas carburizing experiments. Case depths were kept at from 0.012 to 0.20 inch, with the exception of one lot. Surface hardnesses were over 80 Rockwell 'A'.

(Table I follows, on Pages 3 to 5.)
(Text continues on Page 6.)

TABLE I.

PIN NO.	CARBURIZING MEDIUM	TEMPERATURE AND TIME	TYPE OF OIL, AND TEMPERATURE	CORE HARDNESS, Rockwell 'C'	IMPACT TEST, (45 foot-pounds)	BEND TEST*
1	Cn	1575° F. -- 2½ hrs.	No. 3 -- 110-120° F.	22		
2	Cn	1600° F. -- 2¼ hrs.	No. 3 -- 110-120° F.	18		
3	Cn	1600° F. -- 2¼ hrs.	No. 3 -- 90° F.	23-24		
4	Cn	1600° F. -- 2½ hrs.	G oil -- 85° F.	20		
5	Gas	1600° F. -- 1¼ hrs.	G oil -- 85° F.	22-23	Passed.	
6	"	" -- "	" -- "	22-23	"	
7	"	" -- "	" -- "	22-23	"	
8	"	" -- "	" -- "	23	"	
9	"	" -- "	" -- "	23	"	
10	"	" -- "	" -- "	22-23	"	
	Pins Nos. 5 to 10 were all quenched at the same time.					
11	Cn	1625° F. -- 2¼ hrs.	No. 3 -- 110-120° F.	20		
12	Cn	1650° F. -- 2¼ hrs.	No. 3 -- 110-120° F.	20		
13	Gas	1650° F. -- 1½ hrs.	No. 3 -- 90° F.	24-25		
14	Gas	1650° F. -- 1½ hrs.	No. 3 -- 90° F.	22.5		
15	Gas	1650° F. -- 1½ hrs.	No. 3 -- 170° F.	24.5		
16	Gas	1650° F. -- 1½ hrs.	No. 3 -- 175° F.	22		
17	Gas	1650° F. -- 1½ hrs.	G oil -- 85° F.	23.5-24.0		
18	Gas	1650° F. -- 1½ hrs., transferred to neutral vapocarb at 1400° F. for ¼ hr.	G oil -- 90° F.	25-27	Passed.	
19	Gas	1650° F. -- 1½ hrs., transferred to neutral vapocarb at 1400° F. for ¼ hr.	G oil -- 90° F.	23		0.35

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(Continued on next page)

TABLE I (Continued).

PIN NO.	CARBURIZING MEDIUM	TEMPERATURE AND TIME	TYPE OF OIL, AND TEMPERATURE	CORE HARDNESS, Rockwell 'C'	IMPACT TEST, (45 foot-pounds)	BEND TEST⊕
20	Gas	1650° F. -- 1½ hrs.	G oil -- 110-120° F.	25	Passed.	
21	"	" -- "	" -- "	24-25	"	
22	"	" -- "	" -- "	22-23	"	
23	"	" -- "	" -- "	24-26	"	
24	"	" -- "	" -- "	25	"	
25	"	" -- "	" -- "	25-26	"	
26	"	" -- "	" -- "	25-26	"	
27	"	" -- "	" -- "	24-25	"	
	Pins Nos. 20 to 27 were all quenched simultaneously.					
28	Gas	1675° F. -- 1 hr., transferred to neutral vapocarb at 1450° for ¼ hr.	G oil -- 90° F.	25	Passed.	
29	Gas	1675° F. -- ½ hr.	G oil -- 90° F.	22-25		
30	Gas	1675° F. -- 1¼ hrs., transferred to neutral vapocarb at 1400° F. for ¼ hr.	G oil -- 90° F.	28	Passed.	
31	Gas	1675° F. -- 1¼ hrs., transferred to neutral vapocarb at 1400° F. for ¼ hr.	G oil -- 90° F.	25		0.32
⊕⊕ 32	Gas	1675° F. -- 1½ hrs.	G oil -- 110-120° F.	(x)35-36	Failed.	
33	Gas	" -- "	" -- "	25	Passed.	
34	"	" -- "	" -- "	36-37	Failed.	
35	"	" -- "	" -- "	27-28	Passed.	
36	"	" -- "	" -- "	27	Passed.	
37	"	" -- "	" -- "	30-31	Failed.	
38	"	" -- "	" -- "	(y)23.5-25.0	Passed.	
39	"	" -- "	" -- "	30-31	Failed.	
	Pins Nos. 32 to 39 were all quenched simultaneously.					

(Continued on next page)

TABLE I (Continued).

PIN NO.	CARBURIZING MEDIUM	TEMPERATURE AND TIME	TYPE OF OIL, AND TEMPERATURE	CORE HARDNESS, Rockwell 'C'	IMPACT TEST, (45 foot-pounds)	BEND TEST*
40	Gas	1700° F. -- 1 hr.	No. 2 -- 90° F.	25-27		
41	"	1700° F. -- 1 hr.	G oil -- 90° F.	28-30		
42	"	1700° F. -- 1 hr.	G oil -- 95° F.	30	Passed.	
43	"	1700° F. -- ½ hr., dropped to 1400° F. for ¼ hr.	G oil -- 90° F.	27-28		
44	Gas	1700° F. -- 1 hr., dropped to 1400° F. for ¼ hr.	G oil -- 90° F.	29-31	Passed.	
45	Gas	1700° F. -- 1 hr., dropped to 1400° F. for ¼ hr.	G oil -- 90° F.	27-28		0.32
46	Gas	1725° F. -- 1 hr., dropped to 1400° F. for ¼ hr.	G oil -- 90° F.	32.5	Passed.	
47	Gas	1725° F. -- 1 hr., dropped to 1400° F. for ¼ hr.	G oil -- 90° F.	32	Passed.	

* Minimum bend deflection requirement is 0.25 inch.

** Pins Nos. 32 to 39 were all found to have case depths over 0.030 inch.

(x) and (y) Drillings of the cores of Pins Nos. 32 and 38 were analysed:

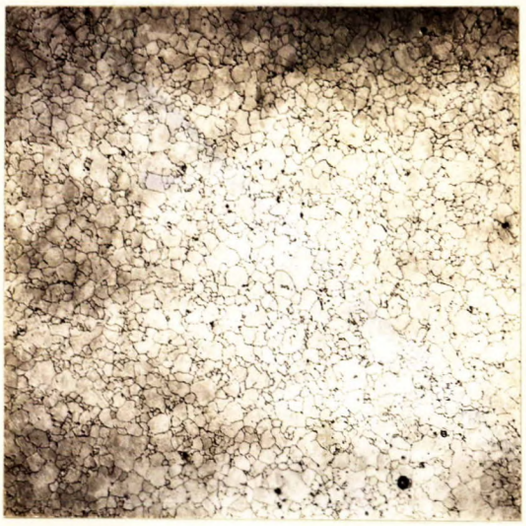
	(x) Pin No. 32 - Per Cent -	(y) Pin No. 38
Carbon	0.19	0.16
Manganese	0.42	0.45
Chromium	0.38	0.30
Silicon	0.33	0.25
Phosphorus	0.010	0.010

Grain Size:

McQuaid-Ehn grain size determinations were made at 1650° F. and 1700° F. The results obtained are shown in Figures 1 and 2 (X100).

	Grain Size
1650° F.	6-7
1700° F.	2-3

Figure 1.

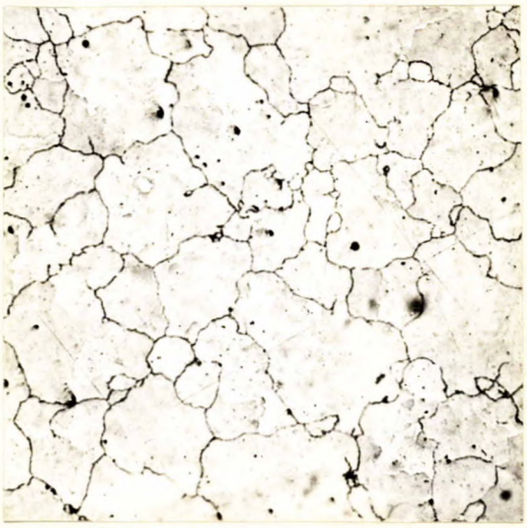


X100, sodium picrate etch.

1650° F.

Grain size, 6-7.

Figure 2.



X100, sodium picrate etch.

1700° F.

Grain size, 2-3.

Microscopic Examination:

Transverse specimens were cut from pins which had been heat-treated at 1600° and 1650° F. These were polished and etched in 2 per cent nital. Figures 3 and 4, taken at X500 magnification, illustrate the core structures obtained. Figure 5 (X250) shows a typical case structure obtained on gas carburizing.

(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 3.

X500, nital etch.

1600° F.

Note ferrite and low-carbon martensite.

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Figure 4.

X500, nital etch.

1650° F.

Note ferrite and coarser low-carbon martensite.

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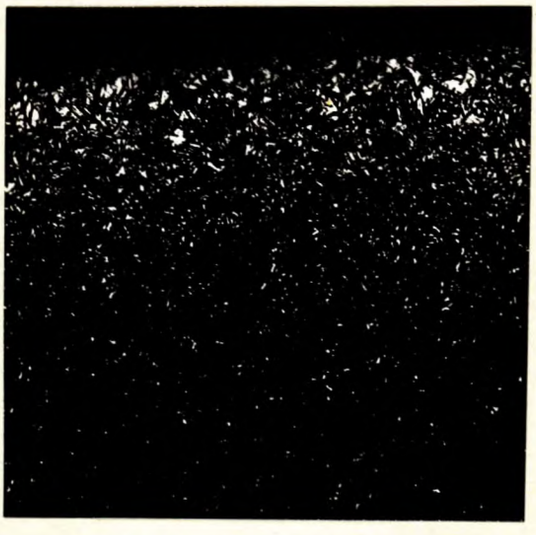
Figure 5.



X250, nital etch.

TEMPERED MARTENSITE.

Typical case structure produced by gas carburizing.

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Discussion:

Houghton's "G" oil is recommended by the company for fast oil-quenching. It was found that very little difference in hardness was obtained when the temperature of the oil was varied from 85 to 120° F.

Erratic impact results were obtained with Pins Nos. 32 to 39. Further investigation showed case depths of 0.030 to 0.035 inch in these pins. Chemical analysis of a low core hardness pin (No. 38) and a high core hardness pin (No. 32) showed a variation in the carbon, chromium and silicon contents. This appears to indicate the presence of two heats of steel. Due to the high core hardness of only two pins (Nos. 32 and 34) out of all those tested, it is felt that these two pins are the only ones which have been encountered from the higher carbon, higher chromium heat.

Heat treating the pins from 1650° F., rather than 1600° F., and quenching in Houghton's G oil, appears to produce an increase in core hardness. The range obtained for 1600° F. was 20 to 23 Rockwell 'C', while for 1650° F. it was 22 to 26.

An attempt was made to get the McQuaid-Ehn grain size of pins at 1600°, 1650° and 1700° F. It was not possible to obtain a positive test at 1600° F. At 1650° F., however, the grain size was 6-7, and at 1700° F. it was 2-3. Figures 3 and 4, taken of the core of pins after heat treatment at 1600° and 1650° F. respectively, clearly indicate that a coarser core structure has been produced by the higher temperature. The increase in core hardness obtained at this temperature is due to this slight coarsening which has somewhat increased the hardenability.

It is of interest that none of the pins which had been heat-treated at 1650° showed coarse-grained fractures. At 1675° F., however, approximately 10 to 15 per cent of a

(Discussion, cont'd) -

fractured surface was coarse grained. At 1700° F., 80 to 90 per cent of the fractured surface was coarsely crystalline. This would indicate that 1650° F. is the highest temperature at which it would be safe to heat-treat these pins. Higher temperatures would cause grain coarsening, with the possibility of impact failures resulting. At 1650° F., it could not be expected that all pins would meet the 24 Rockwell 'C' minimum, as can be seen even by the small number of pins tested in this investigation. It is felt, however, that pins of hardnesses below 20 Rockwell 'C' would be much less likely to result if heat treatments were carried out at 1650° F. rather than at 1600° F. The impact strength is satisfactory at 1650° F.

CONCLUSIONS:

1. Pins heat-treated at 1650° F. and quenched in Houghton's G oil at 85 to 120° F. have hardnesses 2 to 3 points (Rockwell 'C') higher than those produced at 1600° F. under the same conditions.

2. Slight coarsening of the core structure causes the increase in hardness obtained at 1650° F. McQuaid-Ehn tests at this temperature show a grain size of 6 to 7.

3. 1650° F. is the maximum temperature at which the pins can be heat-treated. The impact strength is satisfactory at this temperature.

4. Even if 1650° F. were used as the hardening temperature, some pins would still be produced with core hardnesses below 24 Rockwell 'C'. The core hardness average, however, should be higher than in pins treated at 1600° F.

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SLG:GHB.