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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1653.

Metallurgical Examination of Ten C.D.P. Track Pins of Low Surface Hardness and Low Impact Strength.

(Copy No. 10.)

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REPORT

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Origin of Material and Object of Investigation:

On March 9th, 1944, ten (10) C.D.P. track pins were submitted (Requisition No. 775, A.E.D.B. Lot Nos. 917 to 926; Report No. 40, Test 1) by Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Toronto, Ontario. The material was received from the representative of the Inspection Board of United Kingdom and Canada at the Cockshutt Plow Company, Brantford, Ontario.

It was reported that eight of the pins had low surface hardness and that two broke under the third and fourth 400-ft.-lb. blow during impact test. It was requested that the following be determined:

(1) Depth and extent of decarburization.

(2) Reason for failure under impact test.

(3) Any other information considered necessary.

Identification:

The pins will be designated throughout this report by the A.E.D.B. Lot numbers. These numbers and the corresponding Cockshutt Plow Co. identifications are tabulated below:

TABLE I.

A.E.D.B. Lot No.		Cockshutt Plow Identification
917	-	Lot 36, Pin No. 14, Lab. sample.
918	-	Lot 35, Lab. sample.
919	-	Lot 35, Inspector's sample.
920	-	Lot 36, Pin No. 16, Lab. sample.
921	-	Lot 33, Inspection Board sample.
922	-	Lot 33, " " "
923	-	Lot 33, " " "
924	-	Lot 36, Pin No. 1, Lab. sample.
925	-	Lot 33, Pin No. 13.
926	-	Lot 26, Pin No. 26, on 2nd selection.

Nos. 917 to 924 were of low surface hardness.

Nos. 925 and 926 broke after three and four blows, respectively, in the impact test.

Chemical Analysis:

The chemical analysis of one pin of low surface hardness and of one pin which failed impact test requirements are shown in Table II.

TABLE II.

		AS FOUND		S.A.E. 9255
		No. 917*	No. 926**	SPECIFICATION
		- Per Cent -		
Carbon	-	0.54	0.52	0.50-0.60
Manganese	-	0.68	0.67	0.70-0.90
Silicon	-	2.32	1.87	1.80-2.20
Phosphorus	-	0.012	0.022	0.040 max.
Sulphur	-	0.025	0.017	0.040 max.

* Low surface hardness.

** Broke under impact test.

—

Hardness:

Rockwell 'C' surface and core hardnesses of all pins are shown in Table III.

TABLE III.

A.E.D.B. Lot No.		ROCKWELL 'C' Surface	Core
917	-	34-35	32-35
918	-	39-41	44-45
919	-	32-38	44-45
920	-	28-33	44-45
921	-	33-38	44-45
922	-	38-40	45-46
923	-	36-37	45-46
924	-	36	44-45
925	-	45-46	43-44
926	-	40-43	40-42

Hardness Survey of Decarburization:

Hardness values across the decarburized area were determined with the TUKON hardness tester. This hardness tester is similar to the Vickers machine in principle, but has several advantages for work such as the examination of relatively small decarburized areas. As installed in these Laboratories, the instrument is equipped with a mechanical stage by means of which a linear series of impressions 0.01 mm. apart may be made across the area under investigation. Lighter loads are used and smaller impressions are made, so that a greater number of readings can be taken per unit of area. The hardness values are expressed in Knoop* hardness numbers, which are reported to be in good agreement with Vickers. Exact correlation is not necessary for this investigation, since results are merely a comparison of hardness values to show the depth of decarburization.

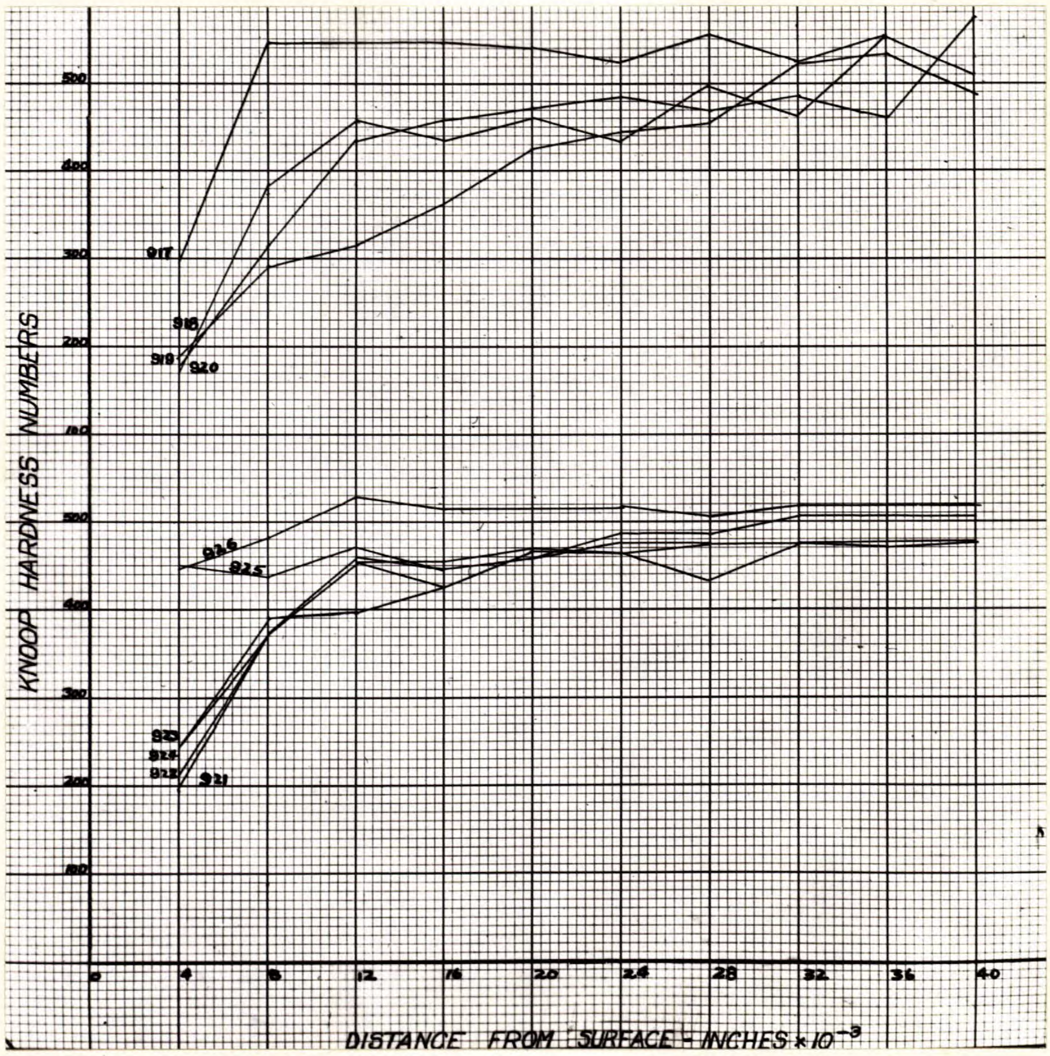
Plottings of hardness value against distance from the

* F. Knoop, C. G. Peters, W. B. Emerson: "Sensitive, Pyramidal Diamond Tool for Indentation Measurements." Journal of Research, National Bureau of Standards, Vol. 23, No. 1, July 1939.

(Hardness Survey of Decarburization, cont'd) -

surface are shown in Figure 1.

Figure 1.



Carbon Analysis of Step-Cut Samples:

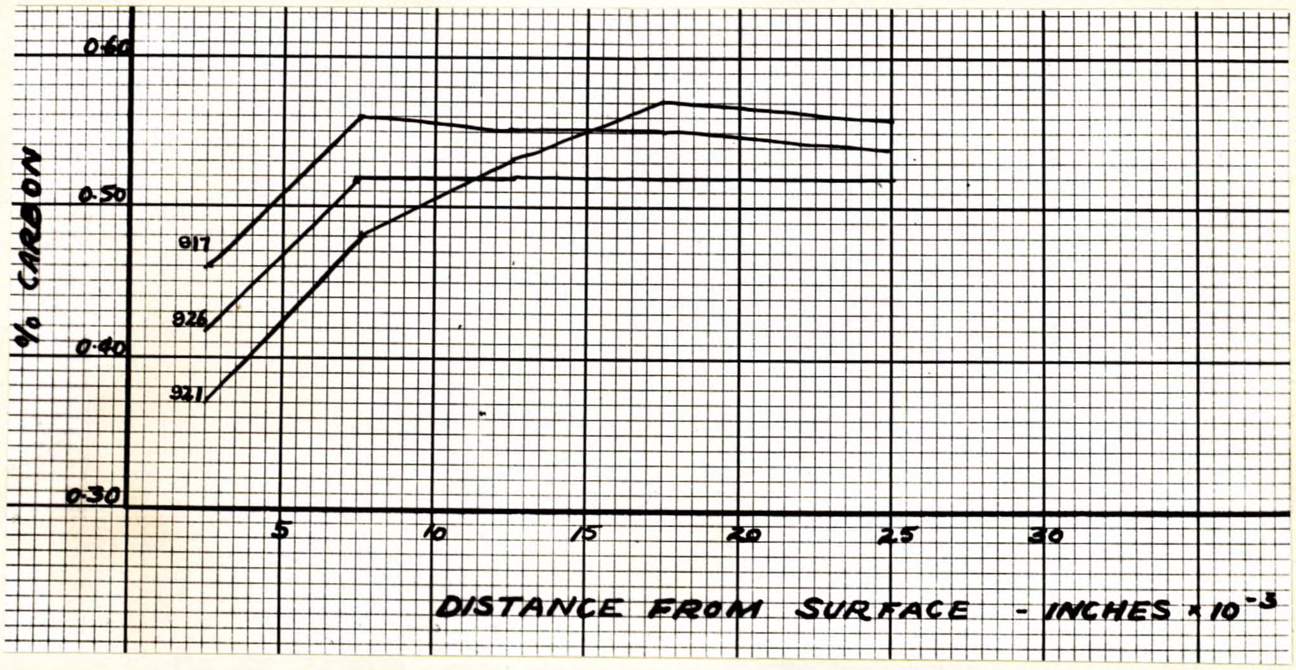
Samples of three pins (Nos. 917, 921 and 926) were first softened by heating in a neutral atmosphere at 1200° F. for 15 minutes and then cooled in lime. Step-cut samples were machined off the surface at steps of 0.005, 0.010, 0.015, 0.020, and 0.030 inch. The carbon content of each sample was determined by the usual combustion method.

The carbon content plotted against distance from the

(Carbon Analysis of Step-Cut Samples, cont'd) -

surface is shown in Figure 2.

Figure 2.



Microscopic Examination:

Microscopic examination of longitudinal specimens showed a partially decarburized zone, 0.007 to 0.016 inch in depth, at the surface of the eight pins which had low surface hardness. Figure 3, a photomicrograph at X250 magnification, shows a typical decarburized area with a line of Tukon hardness impressions across it.

The pins which failed under impact test, Nos. 925 and 926, are only slightly decarburized, as shown in Figure 4, a photomicrograph at 250 diameters. Some of the white particles shown in Figure 4 are very suggestive of cementite. Etching with Murakami's reagent, the usual etch for cementite, failed to substantiate this.

Further examination of the core of these longitudinal

(Microscopic Examination, cont'd) -

sections revealed a microstructure of tempered martensite, with various degrees of banding in eight of the pins.

In Pin No. 917, however, the banded appearance was due to bands of ferrite which had precipitated as shown in Figure 5 (a photomicrograph at X100). The same condition, although to a lesser degree, was found in the core structure of Pin No. 926 (see Figure 6).

Figure 7 shows the microstructure of Pin No. 917 after the specimen was requenched from 1700° F. and drawn for 30 minutes at 850° F. There is no ferrite present.

Discussion:

The chemical compositions of the two pins analysed agree with S.A.E. 9255 specification, with the exception of the silicon content of Pin No. 917, which is 2.32 per cent and therefore 0.12 per cent about the specified maximum.

The reportedly low surface hardness of Pins Nos. 917 to 924 was found to vary between 28 and 41 Rockwell 'C'. Chemical analysis, microscopic examination and hardness surveys substantiated one another in showing this low surface hardness to be the result of a partially decarburized zone, 0.008 to 0.016 inch in depth. The core hardness of these pins was, with one exception, 44 to 45 Rockwell 'C' and in agreement with Specification O.A. 217. Pin No. 917, however, had a core hardness of 32 to 35 Rockwell 'C'.

Microscopic examination of Pin No. 917 showed a core structure of tempered martensite banded with ferrite. The ferrite was present in patches and not formed about the grain boundaries. This is a characteristic of a pin quenched from a temperature below the upper critical. This was substantiated

(Discussion, cont'd) -

by requenching the specimen from 1700° F. and drawing at 850° F. for 30 minutes. As shown in Figure 7, no ferrite is present.

It is interesting to note that in Pin No. 917 these bands of ferrite are accompanied by a silicon content of 2.32 per cent. It should be pointed out that the possibility exists of the formation of ferrite in longitudinal bands being caused by silicon segregation which raised the critical temperature in these areas. Consequently, the usual quenching temperature, 1600° to 1640° F., was below the upper critical of the pins at these points.

The two pins which failed under impact tests, Nos. 925 and 926, had surface hardness values of 45 to 46 and 40 to 43 Rockwell 'C' and core hardness values of 43 to 44 and 40 to 42, respectively. Hardness surveys do not indicate any decarburization, while chemical analysis and microscopic examination indicate approximately 0.005 inch.

Pin No. 925 had a normal quenched-and-drawn microstructure in the core. Pin No. 926 contained some ferrite in banded areas as described above. This condition explains the slightly low core hardness of 40 to 42 Rockwell 'C'.

The microstructure at the surface of both pins contains small white particles very similar in appearance to cementite. These particles are whiter and sharper than the surrounding particles of ferrite. Etching with Murakami's reagent (which did not show cementite present in this instance) is not considered dependable for silico-manganese steel. Therefore, it is not unlikely that cementite is present in the microstructure of the metal adjacent to the surface. Previous experience with S.A.E. 9255 pins has shown that whenever this

(Discussion, cont'd) -

condition exists, a marked reduction in the impact strength of the pin may be expected.

CONCLUSIONS:

1. The low surface hardness of Pins Nos. 917 to 924 is the result of a partially decarburized zone 0.008 to 0.016 inch in depth.

2. Pins Nos. 925 and 926, which failed under impact test, appear to have some cementite in the metal adjacent to the surface. This is considered a likely cause of failure.

3. Pins Nos. 917 and 926 have, respectively, core hardness values of 32 to 35 and 40 to 42 Rockwell 'C'. These values are below the minimum specified by O.A. 217.

4. The low core hardness values are the result of quenching from a temperature below the upper critical.

5. It is suggested that silicon segregation in longitudinal bands has raised the critical temperature in these areas and resulted in bands of ferrite being formed during heat treatment.

6. Ferrite is not present when these pins are quenched from 1700° F.

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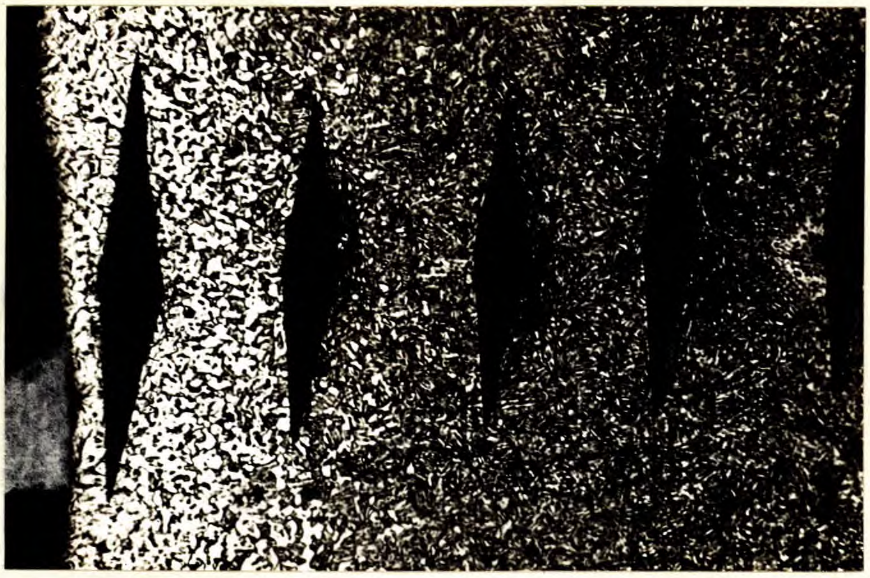
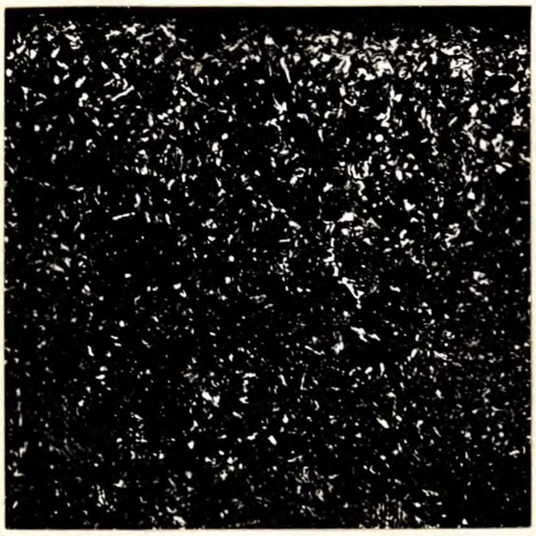
Figure 3.



X250, etched in 2 per cent nital.
TUKON HARDNESS IMPRESSIONS ACROSS
DECARBURIZED AREA.

Figure 4.



X250, etched in
2 per cent nital.
SURFACE, PIN NO. 926.

Figure 5.

X100, etched in
2 per cent nital.
CORE, PIN NO. 917.

Figure 6.

X250, etched in
2 per cent nital.
CORE, PIN NO. 926.

Figure 7.

X100, etched in
2 per cent nital.
CORE, PIN NO. 917.
Oil-quenched from 1700° F.

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