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O T T A W A January 14th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1342.

Examination of Track Link and Track Pin
from a German P.Z.K.W. Mk II Tank.

(Copy No. 38.)

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:

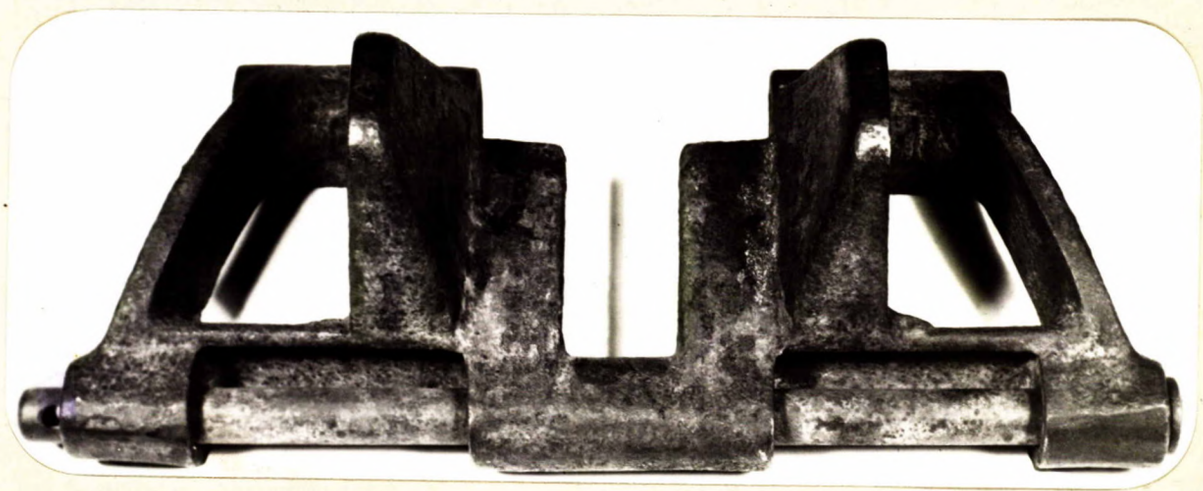
On December 16th, 1942, a track link-and-pin assembly from a German P.Z.K.W. Mk II tank was submitted by Mr. H. L. Batten, of the Inspection Board of United Kingdom and Canada, Ottawa, Ontario.

Requisition No. 552, AEDB Lot No. 199, to cover this work, has been received from Dr. C. W. Drury, Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply Ottawa. This requests a complete examination of these two parts.

Macro-Examination:

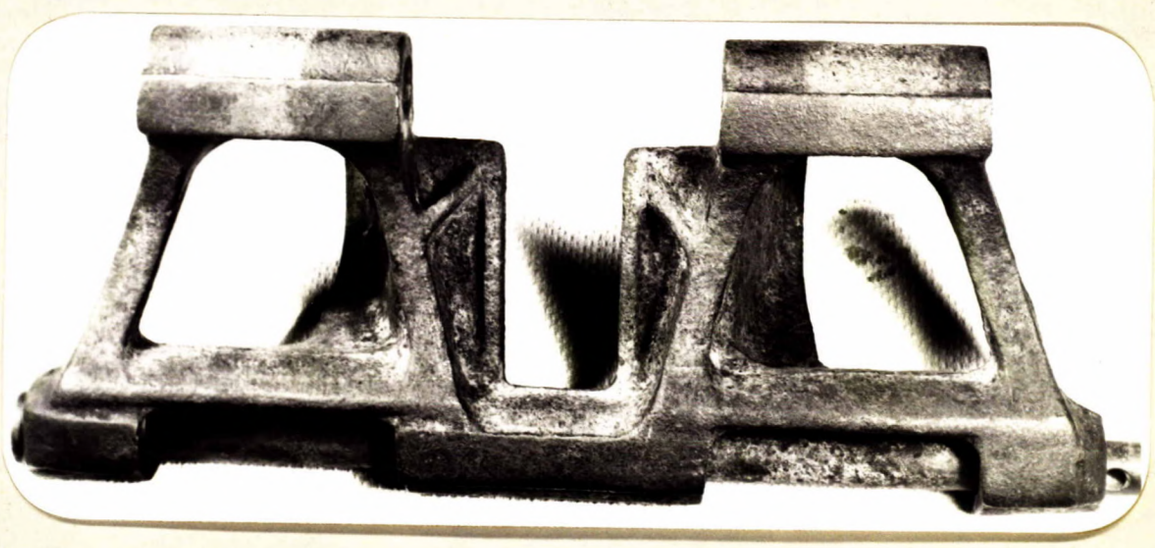
The dimensions of the link and pin are given in I.B.U.K. & C. Drawing No. A.D. Tech. (M)20. Figure 1 illustrates the link-and-pin assembly. Figure 2 shows the contact face of the shoe.

Figure 1.



LINK AND PIN ASSEMBLY.
(Approximately ~~5/6~~ size).

Figure 2.



CONTACT FACE OF SHOE.

Weights:

The weight of the link	=	4 lb. 15 oz.
The weight of the pin	=	12 "
The weight of the link and pin	=	5 lb. 11 "

TRACK LINK.

Chemical Analysis:

		As Found	Recommended Specification
		- Per cent -	
Carbon	=	1.10	1.00 - 1.40
Manganese	=	12.61	10.00 - 14.00
Silicon	=	0.69	0.30 - 1.00
Phosphorus	=	0.061	0.10 max.
Sulphur	=	0.010	0.05 max.
Chromium	=	0.71	-

Hardness:

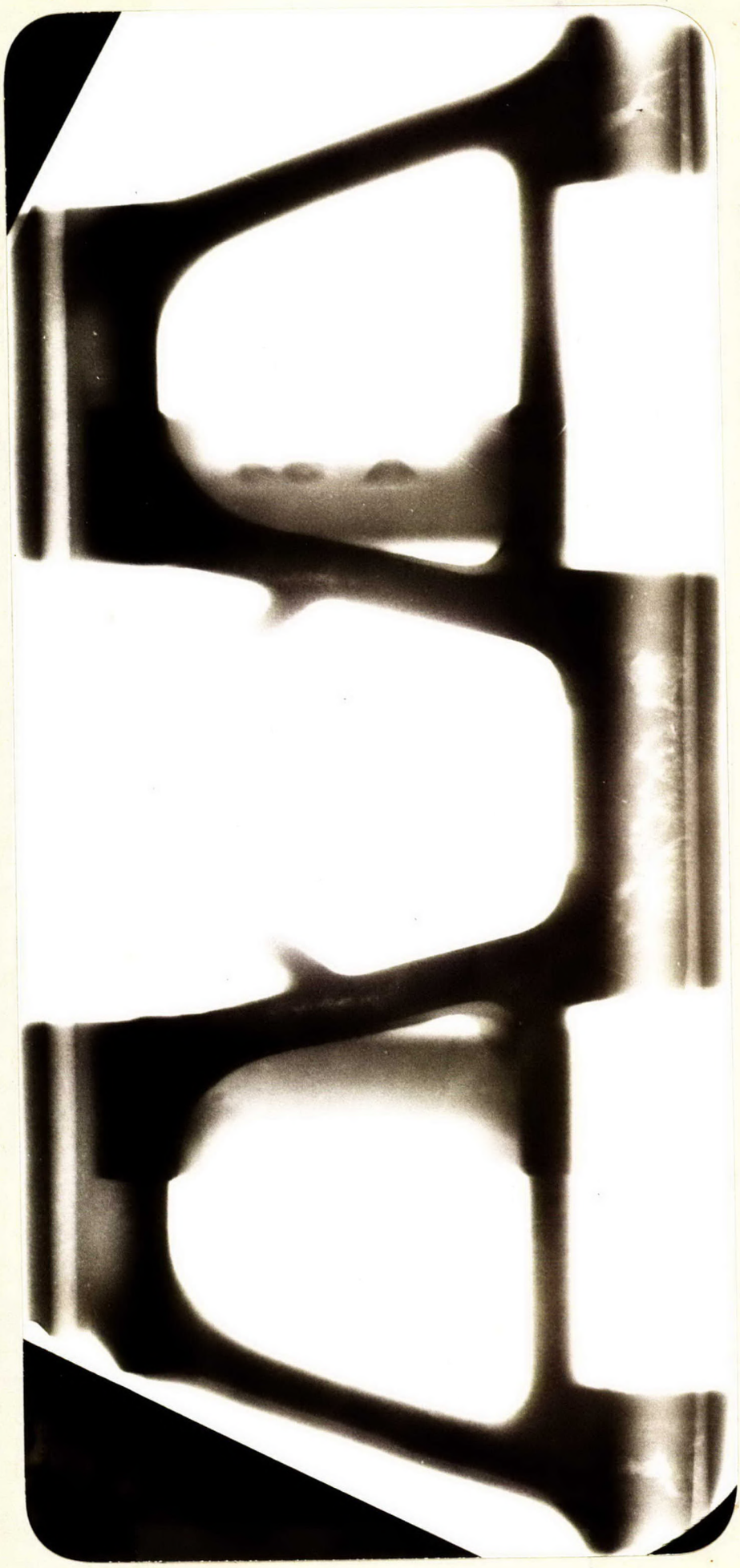
The Brinell hardness of the link was 200. This is within the usual range (180-220) obtained for heat-treated high-manganese steel.

X-Ray Examination:

Mr. A. Morrison of the National Research Council, Ottawa, carried out an X-ray examination of the link. Figure 3 is a positive taken from the radiograph. The white shadows indicate the presence of a number of cavities. The centre eye-hole of the three-eye side of the link was cut open to reveal the cavities (Figure 4), shown in this section by the X-ray.

(Continued on next two pages)

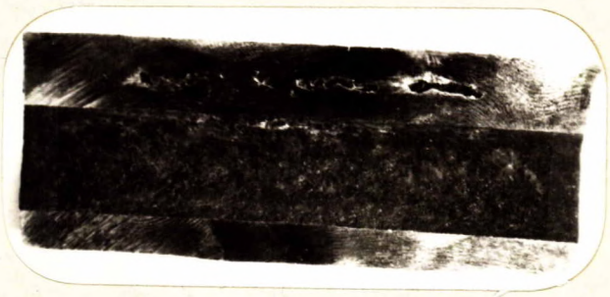
Figure 3.



X-RAY POSITIVE OF LINK.
White shadows indicate presence of cavities.

(X-Ray Examination, cont'd) -

Figure 4.



SHRINKAGE CAVITIES IN CENTRE EYE-HOLE SECTION.

—

Micro-Examination:

Specimens were cut from the link and examined under the microscope. The unetched specimens showed that the steel was quite clean. The nital-etched specimen showed the structure illustrated in Figure 5 (taken at X100 magnification).

Figure 5.

X100, nital etch.

STRUCTURE OF LINK.

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TRACK PIN.

Chemical Analysis:

Drillings were taken from the core of the pin for chemical analysis.

		As Found	S.A.E. 1010
		- Per cent -	
Carbon	-	0.12	0.05 - 0.15
Manganese	-	0.36	0.30 - 0.60
Silicon	-	0.17	0.15 min.
Phosphorus	-	0.017	0.045 max.
Sulphur	-	0.042	0.055 max.
Nickel	-	Not detected	-
Chromium	-	Not detected	-
Molybdenum	-	Not detected	-

Method of Heading:

X-ray diffraction tests, using the back-reflection method, indicate that the pin has been hot-headed.

Physical Tests:

A 0.252-inch-diameter specimen was obtained from the core of the pin and a 2-inch gauge length was used. The results were:

Ultimate strength	-	94,700 p.s.i.
.1% proof stress	-	63,200 p.s.i.
Elongation	-	16 per cent.
Reduction of area	-	53 "

Bend Test:

A bend test was carried out on an Amsler Universal testing machine using a 12-inch radius and 8-inch centres. The increment vs. load was plotted. Elastic limit, permanent bend, and case break point were then determined from the chart and the angles were calculated geometrically. The method used was illustrated in the report of a previous investigation, No. 1197 (April 2nd, 1942), carried out in these laboratories. The results

(Bent Test, cont'd)

were:*

	Load, in pounds	Angle
Elastic limit -	810	1° 8'
Permanent bend -	1,010	3° 10'
Case break point -	1,150	5° 20'

Case Depth:

The depth of case of the pin was measured, using the Brinell microscope. It was found to be 0.047 inch (this is taken on the etched sample - from the surface to the point of colour change).

Depth-Hardness Relationship:

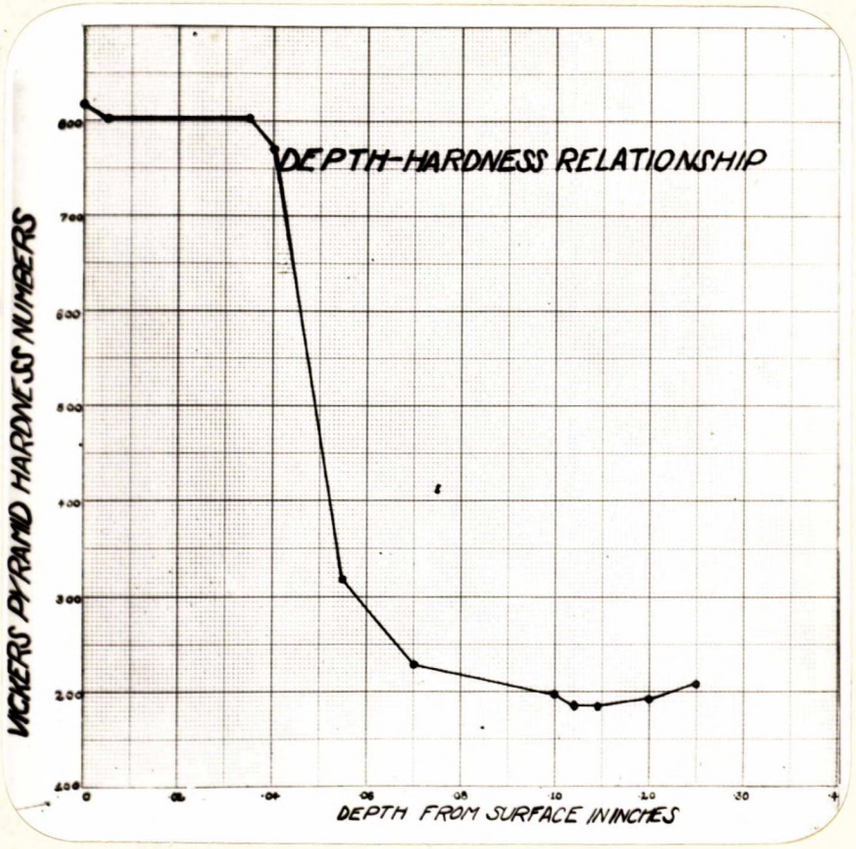
A transverse section of the pin was cut and hardness readings were taken across the face of the section, using the Vickers hardness machine and a 10-kilogram load. Figure 6 is a depth-hardness chart plotted from the hardness results obtained. It can be seen that the surface hardness is 815 V.P.N. and the core hardness 195 V.P.N.

(Figure 6 follows on next page)

* This was taken on a second Mk II pin submitted by AD(T. & M.T.), Detroit, of the Inspection Board of United Kingdom and Canada.

(Depth-Hardness Relationship, cont'd) -

Figure 6.



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Microscopic Examination:

A transverse section was cut from the pin and then polished. The unetched specimen indicated that the bar stock used was quite clean. Figures 7 and 8 are taken from the nital-etched specimen, at X500 and X1000, of the core and case respectively.

(Continued on next page)

(Microscopic Examination, cont'd) -

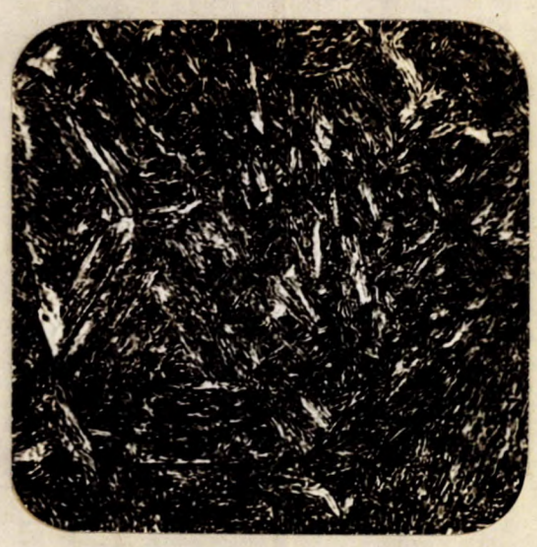
Figure 7.

X500, nital etch.

CORE OF PIN.

Note the presence of ferrite - white constituent.

Figure 8.



X1000, nital etch.

CASE OF PIN.

Note the coarsely acicular martensitic structure.

DISCUSSION:

Track Link -

The chemical analysis of the link shows that a high-manganese steel was used.

The composition of the steel, with the exception of chromium, is within the limits specified by the A.S.T.M. for austenitic steels. Chromium is not usually added to austenitic manganese steels. It is claimed that the addition of about 1 to 3 per cent of chromium reduces the amount of cold work required to properly harden this type of steel. If the eye-holes of the track links can be work-hardened more rapidly by addition of chromium, it would appear that the life mileage of the high-manganese steel links would be increased. A test would have to be carried out to determine whether the difference, if any, is sufficiently great to

(Discussion, cont'd) -

warrant the addition of chromium. Chromium also helps prevent the formation of free carbides.

The casting has a number of shrinkage cavities. The link would naturally be stronger if these had been eliminated. A change in the casting technique could produce a better link.

The microstructure shows a normal austenitic grain size, which indicates that the pouring temperature was satisfactory. The link also received the proper heat treatment for a high-manganese steel, i.e., water-quenched rapidly after holding at 1850-1940° F.

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Track Pin -

The chemical analysis indicates that the steel used for the track pin corresponds to SAE 1010 steel.

The bend test caused the case of the pin to crack at a low load, signifying that it was in a brittle condition. The coarsely acicular martensitic structure shown by the photomicrograph corroborates this fact. This structure, and also that of the core (coarse grain size and ferrite) indicates that the pin was pack-carburized at a relatively high temperature, 1700-1750° F. It was then cooled in the box to a point below the upper critical of the core and then quenched.

The case depth, 0.047 inch, is considered to be too thick. A large number of pins having approximately this depth and hardness (800 V.P.N.) failed in a field test carried out on the Valentine tank at the start of production in Canada.

The thickness of the case suggests that pack-carburizing was the method used to produce this case.