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DEPARTMENT OF MINES AND RESOURCES

BUREAU OF MINES

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Ottawa, August 24, 1946.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 2082.

Metallurgical Examination of Various Steels for Dumbell and Bushing Connectors in Dual Jungle Track.

(Copy No. 10.)

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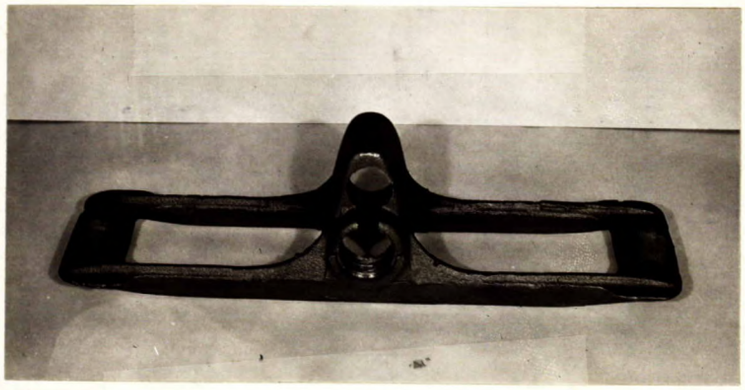
Origin of Material and Object of Investigation:

The object of this report is to describe, briefly, the results of work carried out in these Laboratories, over a period dating approximately from October 1945, on various steels for bushings and dumbells used in the dual jungle track. The problem was submitted by Lt.-Col. B. D. Irvin, of the Directorate of Vehicle Development, Department of National Defence, Army, Ottawa.

Figure 1 is a photograph of a cast steel shoe used in the dual type of jungle track.

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

Figure 1.



CAST STEEL SHOE USED IN DUAL JUNGLE TRACK.

(Approximately 1/6 actual size.)

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Previous Related Investigations:

1. Report of Investigation No. 1732, Nov. 2, 1944, "Metallurgical Examination of Track Link Connectors."
2. Report of Investigation No. 1843, April 18, 1945, "Heat Treatment of Jungle Track Link Connectors to Increase Surface Hardness."

PROCEDURE:

1. Chemical Examination:

The following table shows the results of chemical analyses made on jungle track which had failed in test after 625 miles.

TABLE I. - C.A. of Failed Jungle Track.

	Bushing	Dumbell	Shoe
		(Per Cent)	
Carbon -	0.39	0.39	0.33
Manganese -	0.70	0.71	0.75
Silicon -	0.21	0.20	0.20
Sulphur -	0.016	0.012	0.047
Phosphorus -	0.013	0.012	0.021
Nickel -	1.78	1.76	0.010
Chromium -	0.66	0.69	Nil.
Molybdenum -	0.25	0.16	"

Note: Bushing and dumbell are of SAE X4340 steel; shoe is of SAE 1035 steel.

(Procedure, cont'd) -

The results of chemical analyses made on bar stock used for bushings and bought as SAE 1020 and SAE 1055, are as follows:

TABLE Ia. - Chemical Analyses of Bar Stock.

	SAE 1020	"SAE 1055"*	
		No. 1.	No. 2.
	- (per Cent) -		
Carbon -	0.16	0.45	0.53
Manganese -	0.43	1.04	1.12
Silicon -	0.07	0.22	0.21
Sulphur -	0.036	0.064	0.070
Phosphorus -	0.010	0.034	0.033
Nickel -	Nil.	0.64	0.64
Chromium -	"	0.40	0.38
Molybdenum -	"	0.09	0.09

* This is actually NE 9445 steel.

2. Heat Treating Experiments:

Heating-treating experiments were carried out on NE 9445, SPS-245, and SAE 1045 steels to determine the correct heat treatment which would result in optimum mechanical properties of these steels, to be used for dumbells and bushings.

The results are as follows:

TABLE II. - Mechanical Properties of NE 9440 Steel, Quenched into Oil from 1525° F.*

(Specimen size, 0.50 inch thick)

Draw Temp. ° F.	Yield Point, p.s.i.	Tensile Strength, p.s.i.	Elongation, per cent	R.A., per cent	B.H. No.	Izod, ft.lb.
400	265,000	280,000	9	37	555	12
500	250,000	270,000	10	39	534	8
600	230,000	250,000	10	42	495	8
700	208,000	228,000	11	44	461	12

* Taken from "NE Steels" - by Republic Steel Co.

(Procedure, cont'd) -

TABLE III. - Hardness of NE 9440 Steel, Quenched into Oil from 1525° F.

(Specimen size, 1/4 inch.)

Draw	Hardness, Rockwell "C"
350° F.	56
400° F.	55
450° F.	54½
500° F.	54

Note: The above tables indicate that the draw temperature resulting in optimum combination of hardness and impact values is 400° F.

TABLE IV. - Properties of SPS-245 Steel (used for both dumbells and bushings) Heated to 1525° F. and Quenched in Oil.

(Specimen size, 0.505 inch diameter.)

Draw Temp. ° F.	Tensile Strength, p.s.i.	Yield Point, p.s.i.	Elongation, per cent	Reduction of Area, per cent	Hardness, Rockwell "C"	Izod Impact, Value, ft-lb.
400	-	-	-	-	54	-
600	257,100	248,900	8	-	49.5	10
700	228,000	216,000	7	24.6	45	11

Note: Little difference in Izod value between 600° F. and 700° F. draw.

Hence, use 400° F. for bushings,
600° F. for dumbells.

TABLE V. - Mechanical Properties of SAE 1045 Steel Quenched into Water from 1525° F.

(Specimen size, 1/4 inch.)

Draw Temperature, °F.	Hardness, R. "C"	Izod,* ft-lb.
300	58	3
400	55½	7
500	50½	4
600	48	5

* Impact values are purely relative.

Use 400° F. for bushings.

(Procedure, cont'd) -

TABLE VI. - Comparison of Mechanical Properties of Dumbells Made from Case-Hardened SAE 1015 Steel and Homogeneously Hardened SPS-245 Steel.

	Breaking Load, p.s.i.	Tensile Strength, p.s.i.	Yield Point, p.s.i.	Elongation per cent	Reduction of area	Hardness, R. "C"
Case-Hardened SAE 1015 Steel Dumbells.						
No. 1 -	19,700	90,400	-	-	-	59
No. 2 -	20,300	101,500	-	-	-	59
*Homogeneously Hardened SPS-245 Steel Dumbells						
No. 1	46,600	237,800	232,000	8	25.5	49
No. 2	51,200	257,100	248,900	8	-	49

* Heated to 1525° F., quenched in oil and drawn at 600° F.

-

TABLE VII. - Hardness Readings Taken on SPS-245 Dumbells Which had Failed Under Very Severe Test Conditions. (See Figure 3.)

Sample No.		Hardness, Rockwell "C"
0	-	48
1	-	49
2	-	48½
3	-	48
4	-	47
5	-	48

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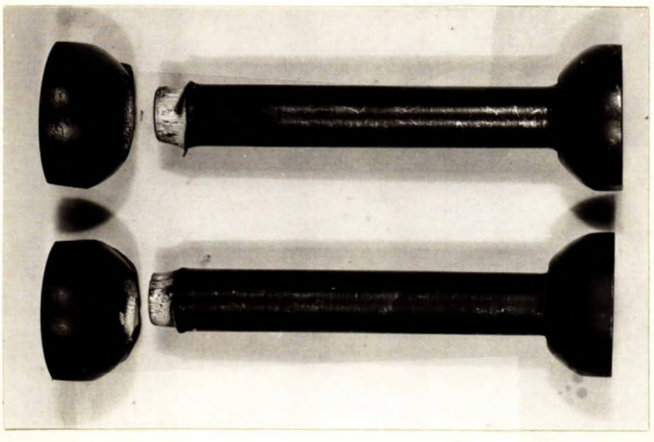
Figure 2.



CASE-HARDENED DUMBELLS
BROKEN IN TENSILE MACHINE.

Note failure at fillet area.

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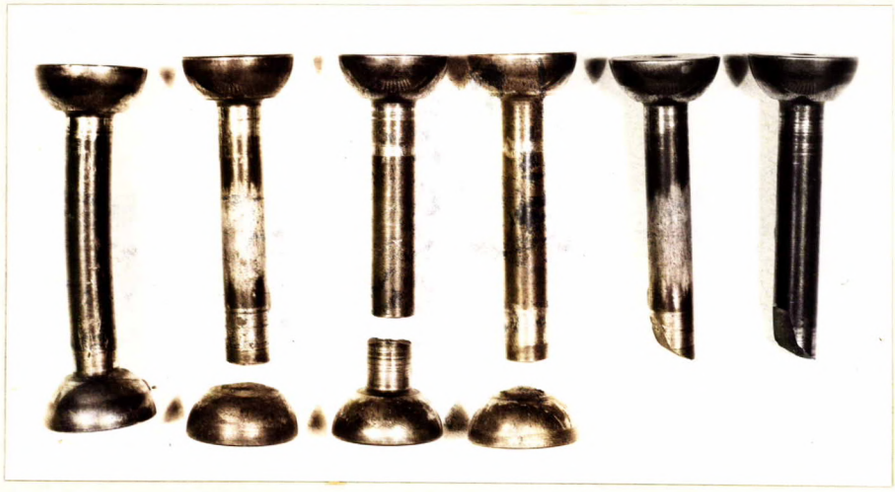
(Procedure, cont'd) -

Figure 3.



0 1 2 3 4 5

DUMBELLS MADE FROM SPS-245 STEEL.
(Oil-quenched from 1525° F. and drawn at 600° F.)

Failed in test under very extreme conditions.

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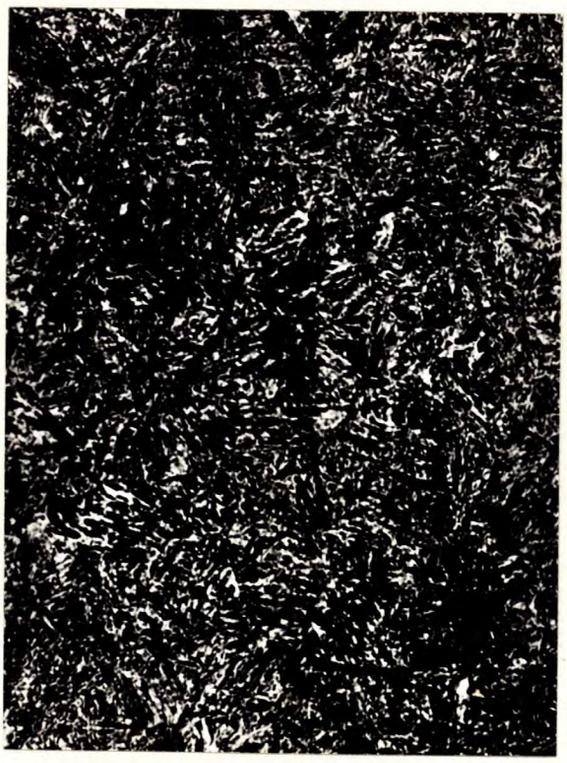
3. Microscopic Examination:

Figures 4 and 5, taken at X750 magnification, show the microstructures of the bushings and dumbells in the final heat-treated condition.

(Continued on next page)

(Procedure, cont'd) -

Figure 4.

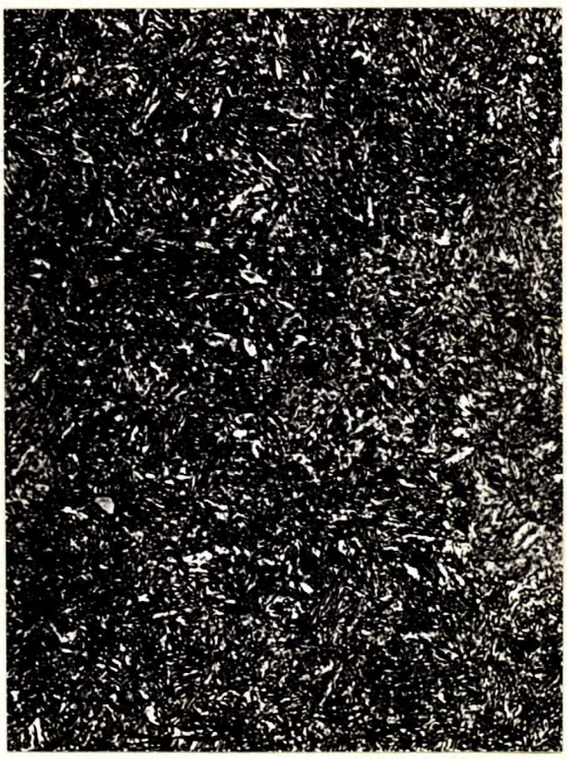


X750, nital etch.

BUSHINGS HEAT-TREATED TO 55 R. "C".

(NE 9445 steel)

Figure 5.



X750, nital etch.

DUMBELLS HEAT-TREATED TO 49 R. "C".

(SPS-245 steel)

DISCUSSION:

The service conditions under which the dumbell and bushing connectors operate are such as to require a steel combining the mechanical properties of great strength, high hardness and sufficient ductility to prevent brittle failure. Because of restrictions in design, the maximum diameter of the dumbell is limited to 0.5 inch. In the single track, the shoes are linked by a double set of dumbells, one at each end (see Investigation Report No. 1843), but in the case of the dual jungle track, the shoes are linked with a single set of connectors (see Figure 1). Since the dual jungle track is intended for very heavy vehicles it is obvious that the dumbells would have to be fabricated from a steel which is

(Discussion, cont'd) -

capable of withstanding tremendous stresses, while at the same time be hard enough to prevent wear and sufficiently ductile to prevent brittle failure.

In the selection of steels for these connectors, it was necessary to decide between the use of case-hardened, low-carbon carburizing steels, and higher-carbon, homogeneously hardened steels. Investigation No. 1732 (November 2, 1944) reported on case-hardened dumbells for single track which had failed prematurely. In this investigation it was recommended that the dumbell be fabricated from a homogeneously hardened steel, at a hardness of 45 ±3 Rockwell "C".

Investigation No. 1843 (April 18, 1945) recommended that both dumbells and bushings be made from a homogeneously hardened steel at 45 ±3 Rockwell "C". The steels recommended were NE 8650, and SAE 4140, 4340, 3140 and 3250.

In November, 1945, a field test was performed on a vehicle equipped with the single track which consisted of shoes made from SAE 1035 steel, and dumbells and bushings machined from SAE X4340 steel, hardened to 42-45 Rockwell "C". Failure, which occurred after 620 miles, was caused by the wearing out of the bushings. Hence, it was concluded that the bushings, and possibly the dumbells, would have to be made harder.

The idea of using case-hardened dumbells and bushings was not completely discarded for some time. In January, 1946, a field test was made on a dual track consisting of case-hardened dumbells using NE 8620 steel hardened to 59 R. "C", and bushings homogeneously hardened to 54.5-56 Rockwell "C", machined from NE 9440 steel which had been purchased as SAE 1055 steel. The fully loaded vehicle was made to run over logs so that the entire rear end was supported on the track. The result was immediate failure due to the snapping of the dumbells, which caused

(Discussion, cont'd) -

failure in the bushings as well. As a result of this test, it was decided to discard case-hardened dumbells in favour of the homogeneously hardened steel. The steel decided upon, because of its availability and other factors, was SPS-245, which contains approximately 0.4 per cent carbon, 0.6 per cent chromium, 1.25 per cent nickel and 0.15 per cent molybdenum, and is similar to the SAE 4340 steel. This SPS-245 steel, whose mechanical properties are given in Table IV, combines the desirable properties of great strength, considerable ductility and high hardness. Because of the slight improvement in the impact value resulting from drawing at 700° F. instead of 600° F. (see Table IV), it was felt that this was insufficient to warrant the decrease in hardness. Hence, the 600° F. draw was first decided upon, when used for dumbells. It was also decided to use this steel on commercial track for bushings, heat treated to 54 Rockwell "C", by drawing at 400° F.

A comparison of the strength of dumbells machined respectively from case-hardened low carbon steel and from homogeneously hardened SPS-245 steel is shown in Table VI. It is evident, from this table, that the strength of SPS-245 dumbells is approximately 2½ times as great as that of the case-hardened ones. The manner of failure of the case-hardened dumbells is shown in Figure 2.

On February 27, 1946, Colonel Irvin submitted six dumbells (fabricated from SPS-245, and hardened by oil quenching from 1525° F., followed by tempering at 600° F.) which had been removed from a dual track which had failed in test under very severe service conditions. Failure had been caused by the skidding of the heavily loaded vehicle into an embankment. Examination of the fractures (see Figure 3) revealed evidence to support the opinion that failure had

(Discussion, cont'd) -

occurred in bending. A hardness survey of the pieces showed very little difference in hardness value between the dumbells, and these values were such as to indicate correct heat treatment, i.e., oil quench from 1525° F. and draw at 600° F. (see Table VII). As a result of this mishap, considerable speculation arose as to the merits of increasing the draw temperature to 700° F., at a sacrifice of several points in hardness. It was felt, however, that this question could only be answered satisfactorily by a statistical analysis of the behaviour in service of dumbells heat-treated to the two different hardnesses. In spite of the failure of the dumbells no undue concern is felt for the choice of the steel used, since failure occurred under extreme conditions. It does, however, indicate very forcibly the great strength required for these particular parts.

A sample of the bar stock intended for bushings in the dual jungle track was submitted for examination. The steel was purchased as SAE 1055, but chemical analysis revealed that it was actually NE 9445 steel. The mechanical properties of this steel are shown in Tables II and III. Since the Izod value for the 400° F. draw is greater than that for either 500° or 600° F. it was decided to use the former. Attempts were made to increase the ductility of this steel by quenching into a salt bath. However, the results were negative and it was decided to continue with the standard practice of heating to 1525° F. and quenching in oil, followed by a draw at 400° F.

On April 25, 1946, Colonel Irvin informed the laboratory that the bushings would have to be machined from SAE 1045 steel. Accordingly, heat-treating experiments were carried out on specimens, 1/4 inch thick, cut from SAE 1045 bar stock. The results are given in Table V. From these

(Discussion, cont'd) -

experiments it was decided to use the following heat treatment: heat to 1525° F., quench into water, and draw at 400° F.

CONCLUSIONS:

The following steels and their corresponding heat treatments were selected as a result of this investigation:

Dumbells

SPS-245 steel, heat to 1525° F., quench in oil, and draw at 600° F. Resulting hardness, 49 Rockwell "C".

Bushings

1. SPS-245 steel, heat to 1525° F., quench in oil, and draw at 400° F. Resulting hardness, 54 Rockwell "C".

2. NE 9445 steel, heat to 1525° F., quench in oil, and draw at 400° F. Resulting hardness, 55 Rockwell "C".

3. SAE 1045 steel, heat to 1525° F., quench in water, and draw at 400° F. Resulting hardness, 55½ Rockwell "C".

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