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OTTAWA October 30th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1522.

An Investigation into the Austempering Characteristics of "SAE 1095 Steel" as Used in Snowmobile Track Cleats.

(Copy No. 10.)

Abstract.

Track cleats made from "SAE 1095 steel" were quenched individually and in quantities of four at a time into a sodium nitrate-sodium nitrite salt bath, at temperatures ranging from 400° F. to 600° F., for times ranging from fifteen minutes to four hours. Microscopic examination and hardness testing showed that the rate of transformation of this steel was so fast that it was impossible to exceed the critical cooling rate, even in a 400° F. salt quench, in sections 3/16" x 2". A SAE 1085 steel, in a piece ¼" in diameter, could be austempered by quenching into salt at 600° F. On chemical analysis, both steels were found to be of almost identical composition. McQuaid-Ehn grain size tests at 1700° F. showed that the "SAE 1095 steel" had a grain size of 6 while the SAE 1085 steel had a grain size of 2. This difference in grain size accounted for the different rates of transformation of the steel.

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Bureau of Mines
Division of Metallic
Minerals
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Ore Dressing
and Metallurgical
Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

OTTAWA October 30th, 1943.

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1522.

An Investigation into the Austempering Characteristics of "SAE 1095 Steel" as Used in Snowmobile Track Cleats.

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Origin of Request and Object of Investigation:

On September 9th, 1943, a shipment of snowmobile track cleats was received from the Bombardier Snowmobile Limited, Valcourt, Quebec. This shipment was arranged for by Prof. J. U. MacEwan, Consultant to the Director of Metallurgy, Army Engineering Design Branch, Department of Munitions and Supply, Ottawa, Ontario.

In his covering Requisition No. 590 (Report No. 107, Lot No. 378), dated August 27th, 1943, Professor MacEwan had stated that these cleats were of SAE 1095 steel and requested that their response to austempering treatments be determined, a hardness of Rockwell "C" 50 (Vickers hardness number, 515) being desired.

PROCEDURE:

Track cleats made from "SAE 1095 steel" were quenched individually and in quantities of four at a time into a sodium nitrate-sodium nitrite salt bath, at temperatures ranging from 400° F. to 600° F., for times ranging from fifteen minutes to four hours. The quenching temperature was 1475° F. The volume of the salt bath used was 2½ cubic feet. The track cleats were essentially steel strips 2 inches wide and 3/16 inch thick.

In the first experiment a single track cleat was quenched into salt at 600° F. and held for half an hour. A hardness of 515 Vickers was developed. Four in a group were then quenched into the same salt bath and held for fifty minutes. This treatment produced a hardness of 425 Vickers.

The salt bath temperature was then dropped to 500° F. A group of six cleats were quenched into it from a temperature of 1475° F. These were allowed to transform for periods of fifteen minutes, thirty minutes, one hour, two hours, three hours, and four hours. The resultant hardnesses are given in Table I. The object of this was to determine the time at which transformation was complete at this temperature, and also what hardness could be developed by this treatment. Any untransformed austenite would transform to martensite on removal from the salt bath, thereby indicating incomplete transformation by increased hardness.

TABLE I.

Hardnesses Developed When Transformed at 500° F. for Various Periods of Time.

Time, in minutes		Vickers hardness
15	-	457
30	-	441
60	-	451
120	-	445
360	-	451
480	-	416

(Continued on next page)

(Procedure, cont'd) -

Results obtained from a variety of heat treatments are summarized in Table II below:

TABLE II.
Hardnesses Developed on Quenching into Various Quenching Baths.

	Salt at 600° F. for 50 minutes	Salt at 500° F. for 15 minutes	Salt at 450° F. for 15 minutes	Salt at 400° F. for 15 minutes	Water quenched
Vickers hardness -	425	450	450	732	781

At the same time, similar tests were being conducted on a steel designated as "SAE 1085 steel". When a ¼-inch-diameter section of this steel was quenched into salt at 600° F. and held for sixty minutes a hardness of Vickers 560 was obtained.

The cooling rate of the track cleat on water quenching was determined, with a view to developing a time-quenching treatment. It was found that the temperature fell to about 350° F. in two seconds. In successful time quenching of this steel, the temperature fall would have to be arrested before 400° F. was reached. Time quenching was therefore concluded to be impracticable.

Chemical Analyses:

Samples of both the "SAE 1095" steel and the SAE 1085 steel were obtained for chemical analysis. The results are given in Table III.

TABLE III. - Chemical Analysis.

		"SAE 1095" steel	SAE 1085 steel
		- Per cent -	
Carbon	-	0.88	0.88
Silicon	-	0.18	0.24
Manganese	-	0.46	0.57
Nickel	-	Not determined.	0.04
Chromium	-	" "	Not detected.
Vanadium	-	" "	" "

Microscopic Examination:

Sections were prepared for the microscope. The structure obtained on quenching into salt at 600° F. and holding for thirty minutes is shown in Figure 1, at a magnification of 2,000 diameters. The constituent is very fine pearlite. When four cleats were quenched simultaneously into the same salt bath for fifty minutes, the structure shown in Figure 2 (at 2,000 diameters magnification) resulted. Note that this differs from Figure 1 in that there are tiny particles of carbide present, indicating a slower cooling rate.

The structure obtained on the SAE 1085 steel under similar conditions is bainite, as is shown in Figure 3, at 1,000 diameters magnification.

When the "SAE 1095" steel track cleats are quenched into salt at 450° F. for fifteen minutes, the structure shown in Figure 4 (at a magnification of 250 diameters) is developed. Note that most of the metal has transformed to very fine pearlite, as shown in Figures 1 and 2. A small amount of austenite was left, which transformed to martensite after removal from the salt bath. The structure obtained on quenching the same material into salt at 400° F. for 15 minutes is shown in Figure 5 at a magnification of 250 diameters and in Figure 6 at a magnification of 2,000 diameters. Most of the metal here is martensite, with small areas of pearlite. The water quench, as would be expected, produced a totally martensitic structure, as is shown in Figure 7 at a magnification of 250 diameters.

The McQuaid-Ehn grain sizes at 1700° F. of both the SAE 1085 steel and the "SAE 1095" steel are shown respectively in Figures 8 and 9 (at a magnification of 100 diameters). The SAE 1085 steel has a grain size of 2, while the "SAE 1095" steel has a grain size of 6.

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Discussion of Results:

It is interesting to note that while the "SAE 1095" steel and the SAE 1085 steel have the same analysis, their transformation rates differ greatly, the cooling rate produced by a quench into salt at 600° F. being sufficient to harden the latter material, whereas the former will not harden well even after quenching into salt at 400° F. This, of course, is due to the inherent grain size.

It has been pointed out, under "Procedure", that the cooling rate on quenching in water was found to be too fast to consider the development of a time-quenching treatment. It would be necessary to transfer the cleats to the salt bath less than two seconds after they had entered the water quench.

Since the only difference between the two steels is in the grain size, and therefore the hardenability, it is conceivable that were the track cleats made from a SAE 1085 or SAE 1090 steel having a grain size of 2, they could be successfully austempered. Whether or not the material would have satisfactory low-temperature impact properties is, of course, another question.

CONCLUSION:

The characteristics of the steel from which the track cleats, AEDB Lot No. 378, were produced are such that it is not suited to hardening by austempering. Accordingly, the cleats will be water-quenched and drawn to a hardness of Rockwell "C" 40 to 45.

Recommendations:

Certain alternative steels for snowmobile track cleats were suggested in our P.M. Laboratory Report No. 6639 (October 14th, 1943), a copy of which appears, as an appendix, on Pages 10 and 11 of this report.

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Figure 1.

Photomicrograph,
X2000, picral etch.

TRACK CLEAT QUENCHED SINGLY FROM 1475° F. INTO SALT AT 600° F. FOR 30 MINUTES, AIR COOLED.

Structure consists of very fine pearlite.

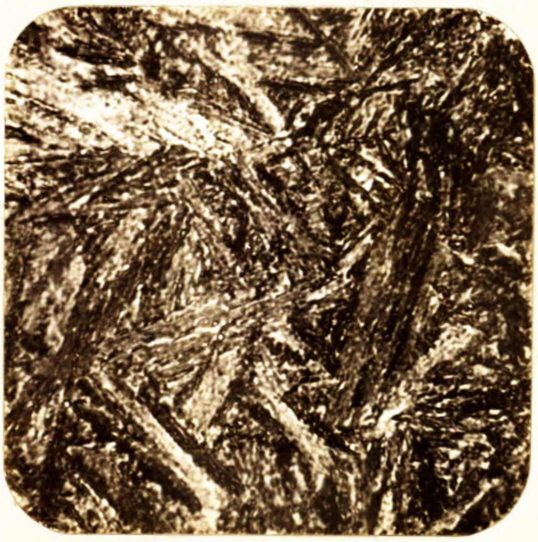
Figure 2.

Photomicrograph,
X2000, picral etch.

TRACK CLEAT QUENCHED, FOUR AT A TIME, FROM 1475° F. INTO SALT AT 600° F. FOR 50 MINUTES, AIR COOLED.

Note presence of carbides and fine pearlite, indicating a slower cooling rate than Figure 1.

Figure 3.



Photomicrograph,
X1000, nital etch.

¼-INCH DIAMETER, SAE 1085 STEEL, QUENCHED FROM 1475° F. INTO SALT AT 600° F. FOR 50 MINUTES.

Note that structure is bainite.

Figure 4.

Photomicrograph,
X250, picral etch.

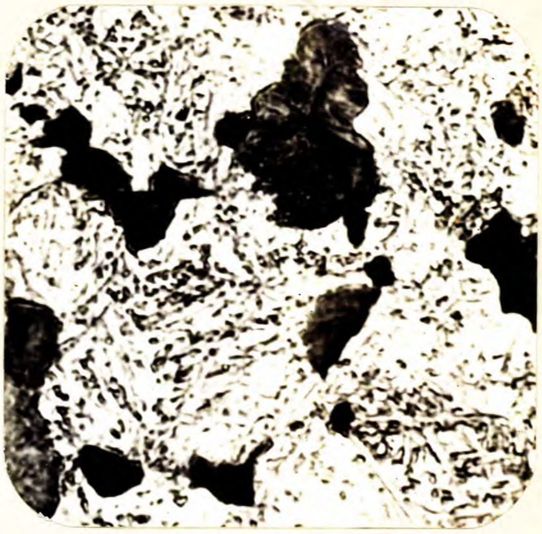
TRACK CLEAT QUENCHED FROM 1475° F. INTO SALT AT 450° F. FOR 15 MINUTES.

Note small amount of martensite formed during air cooling from 450° F.

Figure 5.

Photomicrograph,
X250, picral etch.

Figure 6.



Photomicrograph,
X2000, picral etch.

TRACK CLEAT QUENCHED FROM 1475° F.
INTO SALT AT 400° F. FOR 15 MINUTES.

Note small amount of fine pearlite formed at high temperature but most of metal is martensite formed on cooling after removal from salt.

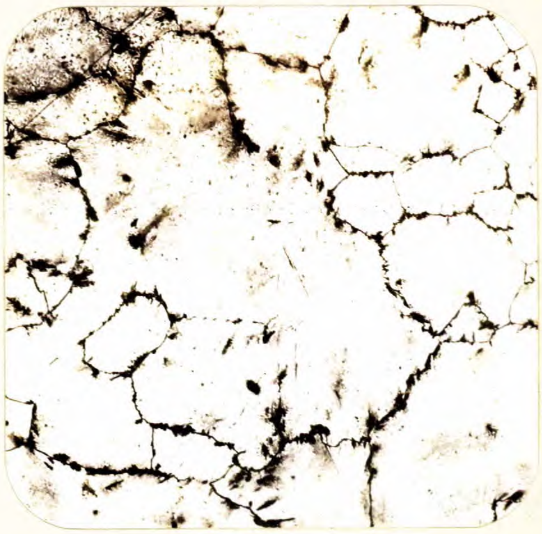
Figure 7.

Photomicrograph,
X250, picral etch.

TRACK CLEAT QUENCHED FROM
1475° F. INTO WATER.

Note that structure is entirely martensitic.

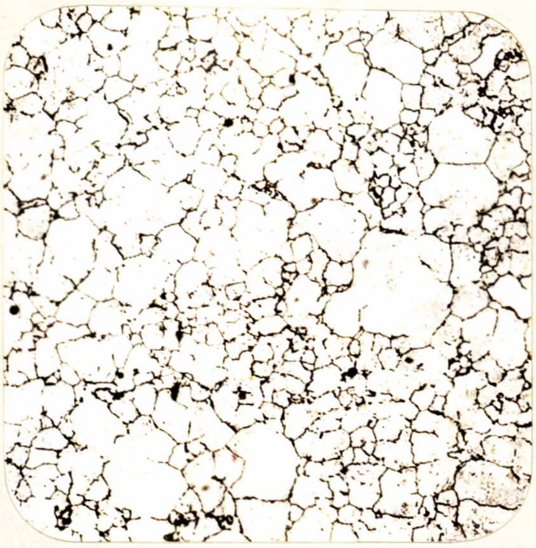
Figure 8.



Photomicrograph,
X100, alkaline
sodium picrate etch.

SHOWING GRAIN SIZE OF SAE
1085 STEEL AT 1700° F.;
GRAIN SIZE, 2.

Figure 9.



Photomicrograph, X100, alkaline sodium picrate etch.

SHOWING GRAIN SIZE OF "SAE 1095" TRACK CLEAT STEEL AT 1700° F.; GRAIN SIZE, 6.

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APPENDIX

(COPY)

552 Booth Street,
Ottawa, Ontario,
October 14, 1943.

P. M. Lab. Report No. 6639.

To: Dr. C. W. Drury,
Director of Metallurgy,
Army Engineering Design Branch,
Department of Munitions and Supply,
Room 303, No. 4 Bldg.,
Ottawa, Ontario.

Re: Impact Properties of Some Steels for Snowmobile Track Cleats.

In compliance with a verbal request received from Dr. C. W. Drury on October 14, room-temperature impact properties for the following steels,

SAE 1095, SAE 4140, SAE 4340, SAE 4650, and N.E. 8749,

at hardness of Rockwell "C" 40-50, and also cold-temperature impact properties for SAE 1095, 4145, 4340 and N.E. 8749 in the hardness range of Rockwell "C" 40-50, were obtained.

The room-temperature Izod impact properties are given in Table I, and the cold-temperature Charpy impact properties in Table II.

TABLE I.

Room-Temperature Izod Impact Properties of Some Alloy Steels.

Hardness, Rockwell "C"	Izod Impact, foot-pounds — Steels: SAE 4140	SAE 4650	SAE 4340	N.E. 8749
50	8.5	9.5	9.5	
48	8.0	10.0	10.0	
45	10.0	13.5	20.0	11.0
42	17.0	21.0	24.0	21.5
40	24.0	25.0	35.0	24.0

(Continued on next page)

(Appendix, cont'd) -

TABLE II.

Cold-Temperature Charpy Impact
Properties of Some Alloy Steels.

Steel	Hardness Rockwell "C"	Charpy Impact, foot-pounds				
		Room Temp.	0° F.	-25° F.	-40° F.	-65° F.
SAE 1095	41	4	4		8	
SAE 4145	43		15	13		11.5
NE 8749	46		22	14.1		15.8
SAE 4340	44		21	20		18

It is evident, from a study of the above data, that high impact properties are not a requirement of the snowmobile track cleat, since SAE 1095 steel at a hardness of Rockwell "C" 42 has been used satisfactorily. The steel used had a McQuaid-Ehn grain size of 6 at 1700° F., a fairly fine-grained steel. It is also evident that this steel is not susceptible to temper embrittlement.

Any of the above alloy steels should make a satisfactory track cleat. A much higher hardness should be available without dangerous embrittlement and, of course, the low-temperature impact properties are all much superior to SAE 1095. NE 9255 steel, which was also considered, has the drawback of being very easily decarburized. This feature would add to the difficulty of fabricating from this steel.

It is also worth noting that SAE 1095, probably being a marginal material at the best, and being susceptible to variations in steel-making practice to probably a greater degree than alloy steels, would not be as reliable a steel to use.

(Signed) H. V. Kinsey,

for C. S. Parsons,
Chief of Division.

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