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OTTAWA June 21st, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1667.

Metallurgical Examination of Broken
Main Leaves of Springs.

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(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

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Origin of Material and Purpose of Investigation:

On May 26th, 1944, one main leaf of a spring was received from the Ontario Steel Products Company Limited, Gananoque, Ontario, for examination. The accompanying letter, dated May 25th, 1944, stated that the leaf had failed at the eye and that the fracture (see Figure 1) occurred when the leaf was being assembled as a part of a complete spring. The leaf had been made under the following specifications:

Material, G.M.C. X-5150-A.
Hardening operation, 1700° to 1800° F.;
  temperature of quenching oil, 170° F.
Drawing operation, 900° to 1000° F.;
  cooled in air.
Brinell hardness, 364 to 444.

The letter also stated that "the ends of the leaf were heated for the eye-forming operation, allowed to cool in air, then the entire leaf was hardened and drawn." It was suggested that a quench check caused failure, and a complete examination was requested.

On June 6th, 1944, three additional broken main leaves were received. The accompanying letter, dated June 6th, stated that the leaves had broken when they were tested on the

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

compression machine. A determination of the grain size was requested, as a check on normalcy for G.M.C. X-5150-A steel hardened at 1750° F. and drawn at 1000° F. A following letter, dated June 13th, stated that the broken springs were made of G.M.C. X-5150-A steel having the following chemical limits:

		Per cent
Carbon	-	0.48-0.53
Manganese	-	0.60-0.90
Chromium	-	0.60-0.90
Silicon	-	0.15-0.30
Phosphorus	-	0.04 max.
Sulphur	-	0.05 max.

The following steel treatment was also cited:

"Harden by heating to proper temperature, to thoroughly refine grain, and quench. Temper or draw to obtain Brinell hardness 364-444. Surface decarburization must not exceed 0.010 inch in depth."

For the purpose of identification the larger spring, received on May 26th, will be referred to as "large spring" and the three smaller springs, received on June 6th, will be termed "small spring".

Chemical Analysis:

The results of the chemical analysis of a sample taken from the large spring are given in Table I.

TABLE I. - ANALYSIS OF LARGE SPRING.

		Per cent
Carbon	-	0.51
Manganese	-	0.85
Phosphorus	-	0.023
Sulphur	-	0.035
Silicon	-	0.23
Chromium	-	0.78
Nickel	-	0.10
Molybdenum	-	Trace.

-

Microscopic Examination:

Sections for microscopic examination were taken from both large and small springs. Figures 2, 3, 4 and 5 are photomicrographs obtained from sections of the large spring, and Figures 6, 7 and 8 are of sections from the small spring. Figure 2, taken at a magnification of X100, shows the inclusions in the steel in the unetched condition. Figure 3, taken at a magnification of X100, shows evidence of decarburization. Figures 4 and 5, taken at magnifications of X250 and X1000 respectively, indicate the microstructure of the large spring "as received". Figure 6 (at X1000) shows the microstructure of the small spring in the "as received" condition. Figure 7 is a photomicrograph showing the grain size of the small spring as obtained in the McQuaid-Ehn test (carburized at 1750° F. for 8 hours). Figure 8 is a photomicrograph (at X1000) showing the microstructure of the small spring after quenching in oil from 1525° F., drawing at 1000° F., and cooling in air.

Hardness Tests:

Hardness tests were made on both large and small springs, to determine surface and body hardness. The results are given in Table II.

TABLE II.

	SURFACE	BODY	
	Rockwell 'C'	Rockwell 'C'	Brinell
Large spring -	38	43	408
Small spring -	42	48	469

Heat-Treating Experiments:

Samples were cut from the small spring and heat-treated at various quenching temperatures, in order to determine the grain size. Four samples were heated at 1525°, 1600°, 1700°

(Heat-Treating Experiments, cont'd) -

and 1750° F. respectively, quenched in oil, and drawn at 900° F. The pieces were then fractured and the grain sizes were obtained by comparing with standard grain size fractures. The results are given in Table III.

TABLE III.

Quenching temperature, ° F.	Drawing temperature, ° F.	Hardness, Rockwell 'C'	Grain size
1525	900	43*	5
1600	"	44	4 to 5
1700	"	45.5	3 to 4
1750	"	47	3 to 4

* 408 Brinell.

In order to determine the effect of the quenching temperature on the impact value of the steel, four more specimens were cut from the small spring. These were shaped as nearly as possible like that of a regular Izod test piece, and then subjected to different quenching temperatures. After heat treatment, the specimens were broken in an Izod testing machine. The results are given in Table IV.

TABLE IV.

Quench temp., ° F.	Draw temp., ° F.	Hardness Rockwell 'C'	Impact value,** foot-pounds
1525	1000	40*	11
1600	"	41	7
1700	"	42	5
1800	"	42	5½

* 375 Brinell.

** These values are purely relative, since the test pieces were not of standard size.

Discussion of Results; Conclusions:

The steel composition falls within the limits of Specification G.M.C. X-5150-A. This is equivalent to the

(Discussion of Results; Conclusions, cont'd) -

following limits specified for SAE 5150 steel:

		Per cent
Carbon	-	0.45-0.55
Manganese	-	0.60-0.90
Phosphorus	-	0.04 max.
Sulphur	-	0.05 max.
Silicon	-	0.15-0.30
Chromium	-	0.80-1.10

The hardness tests definitely showed that some decarburization had taken place, but this would not have caused failure of the type encountered. The decarburization, however, would be expected to lower the fatigue strength of the spring.

Figure 2 shows that the steel is quite dirty.

Figures 3, 4 and 5 are the normal microstructure obtained when this steel is treated according to the specifications, viz.,

Harden at 1700° F. to 1800° F.;
oil quench.
Draw at 900° F. to 1000° F.

The use of the high quenching temperature of 1700° F. to 1800° F. was immediately suspected as being the source of the trouble since the specifications for SAE 5150 steel call for a quenching temperature of 1525° F. (The normalizing temperature is 1625° F., and annealing 1450° F.). Table IV indicates that the quenching temperature has a marked effect upon the impact properties of the steel.

A comparison of the fracture of the small spring with that of fractures of samples of the steel which had been quenched from various temperatures shows conclusively that the springs had been heated to at least 1700° F.

Recommendations:

It is recommended that the springs be given the following heat treatment:

Heat to 1525° F. for quenching;
quench in oil.
Draw at 1000° F.

This heat treatment should result in a hardness of approximately 40 Rockwell 'C' (375 Brinell).

Special care must be taken to prevent overheating before quenching, if failure of the type encountered is to be eliminated. It is strongly recommended that a pyrometer be installed in the furnace to assist the operator in maintaining correct furnace temperature.

Decarburization should be kept to a minimum, by controlling furnace atmosphere in so far as this is possible, both in the manufacture of the spring steel and in the final heat treatment of the spring.

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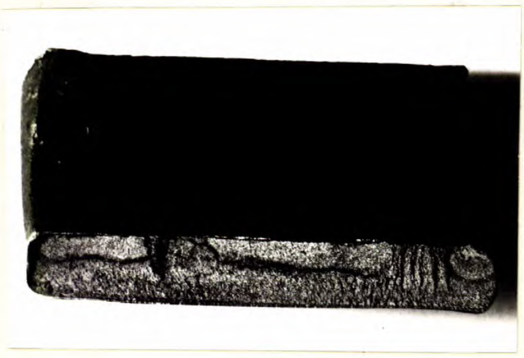
Figure 1.



Normal size.

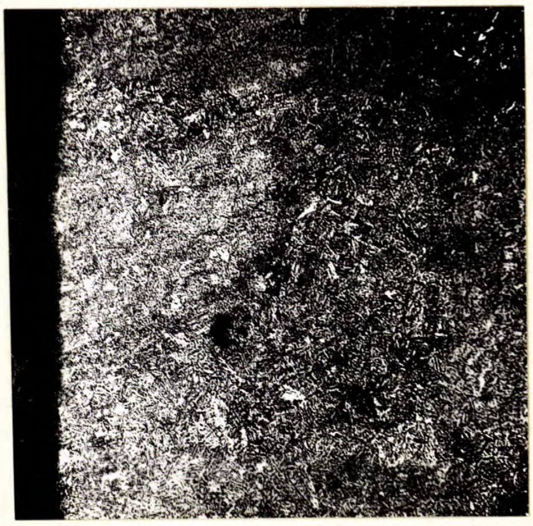
FRACTURE OF MAIN LEAF
OF SPRING AT EYE.

Figure 2.

X100, unetched.

INCLUSIONS IN
LARGE SPRING.

Figure 3.



X100, nital etch.

EVIDENCE OF DECARBURIZATION
IN LARGE SPRING.

Figure 4.

X250, nital etch.

MICROSTRUCTURE OF LARGE SPRING
IN "AS RECEIVED" CONDITION.

Figure 5.

X1000, nital etch.

MICROSTRUCTURE OF
LARGE SPRING IN
"AS RECEIVED" CONDITION.

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Figure 6.

X1000, nital etch.

MICROSTRUCTURE OF
SMALL SPRING IN
"AS RECEIVED" CONDITION.

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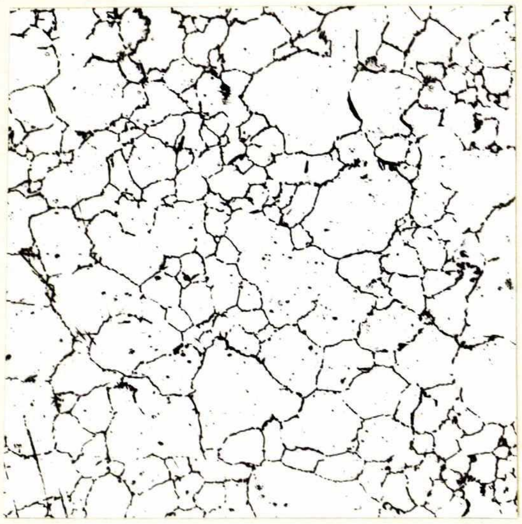
Figure 7.



X100, sodium picrate etch.

MCQUAID-EHN GRAIN SIZE OF
SMALL SPRING
(CARBURIZED AT 1750° F.).

Grain size, 3 to 4.

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Figure 8.

X1000, nital etch.

MICROSTRUCTURE OF SMALL
SPRING, AFTER QUENCHING IN
OIL FROM 1525° F.
AND DRAWING AT 1000° F.

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