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O T T A W A November 4th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1733.

Examination of a Mine Shaft Hoisting Steel Rope.

(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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Source of Material and Object of Investigation:

On October 11th, 1944, Mr. P. H. Hopkins, President and Managing Director, Dominion Wire Rope and Cable Company Limited, Montreal, Quebec, submitted, for examination, a sample 6-foot length of 1¾-inch-diameter mine shaft hoisting rope. It was stated that this rope had been in service at the Frood mine of the International Nickel Company Limited. A full metallurgical examination was requested.

Rope Construction:

The cable was stated to have been constructed of special improved plow steel wire. The cable consisted of six (6) strands, each strand containing nineteen wires plus six filler wires (being what is known as Spacer Seale, Hemp Core, Lang's lay construction). The gauges of the wires were stated to be as follows:

Outside 12 wires, 0.117 inch.
Inside 6 wires, 0.121 inch.
Coil wire, 1 wire, 0.126 inch.
Filler wires, 6 wires, 0.052 inch.
Full outside diameter of rope, 1.750 inches.

The Canadian Engineering Standards specification for Wire Rope states that the filler wires should not be considered as contributing to the strength of the rope; consequently, no work was done on this material.

Diameter Measurements:

The diameters of the three large sizes of wire were measured with a micrometer gauge, samples being taken from each of the six strands. The following readings were obtained:

	Diameter measurements, in inches
12 outside wires	0.117
6 inside "	0.121
1 " "	0.126

The diameter of the rope as measured over its extreme outside wires was found to be 1.790 inches.

Tensile Tests:

Samples of three sizes of wire, taken from each of the six strands, were tested in the Baldwin-Southwark tensile testing machine, the wires being held in Templin wedge-type grips. The same rate of loading was used in all

(Tensile Tests, cont'd) -

tests. The following table gives the results obtained:

Wire Diameter, inches	Breaking Load, pounds	Ultimate Stress, p.s.i.
0.117	3000	279,000
"	2900	270,000
"	2850	265,000
"	2900	270,000
"	2960	275,300
"	2910	265,100
0.121	3100	269,600
"	3100	269,600
"	3000	260,900
"	3120	271,300
"	3280	285,200
"	3000	260,900
0.126	3400	272,000
"	3200	256,600
"	3300	264,600
"	3440	275,900
"	3220	259,000
"	3340	267,700

A full section of the cable was mounted in two steel holders with zinc and tested in tension in the Amsler 100-ton tensile testing machine. (This test was more of a proof load test, as it was realized that the rope should be able to withstand this load without breaking.) None of the wires in the cable broke under a pull of 200,000 pounds.

Torsion Tests:

The test was carried out as follows: One end of the wire was attached to a stationary clamp provided with a special set of gears upon which was mounted a counter for measuring the number of turns. The other end was attached to a clamp which was free to move longitudinally. To a wire on this clamp was attached a rope which ran over a pulley. A weight was attached to this rope which applied a tension of 2,000 pounds per square inch on the wire. The length of the wire between clamps was ten inches. The number of complete turns of 360° required to rupture the wire was recorded. From

(Torsion Tests, cont'd) -

this value the number of turns per length of 100 diameters for the three sizes of wires was calculated.

Summary of Torsion Tests

(Average of Six Tests on Each Size Wire.)

Diameter of Wire, inches		Turns per length of 100 diameters
0.117	-	22.4
0.121	-	26.6
0.126	-	23.8

Hardness Tests:

The hardness of the three sizes of wire was determined by the Vickers method, using a 10-kilogram load. The following table gives the values obtained, together with the converted Brinell and Rockwell 'C' scale hardness numbers.

I. - Longitudinal Specimens Ground to a Flat Surface.

Diameter of Wire, inches		Vickers Hardness Number	Brinell (Converted)	Rockwell ('C' Scale) (Converted)
0.117	-	515	484	50
0.121	-	487	460	46
0.126	-	502	474	49

II. - Cross-Sectional Specimens.

Vickers hardness tests carried out on cross-sectional specimens of the three wires showed a slightly lower hardness on the outer surface. The following Vickers hardness values were obtained:

Diameter of wire, inches		Vickers Hardness Numbers Edge	Centre
0.117	-	482	515
0.121	-	435	487
0.126	-	473	502

(Continued on next page)

(Hardness Tests, cont'd) -

III.- Surface Hardness Tests.

Rockwell surface hardness determinations were carried out on the three sizes of wires from each strand and the following results were obtained:

Diameter of wire, inches		Rockwell Hardness Numbers, 'C' Scale					
		Strand 1	Strand 2	Strand 3	Strand 4	Strand 5	Strand 6
0.117	-	33½	33	33	31	32½	27
0.121	-	34	37	34	33	34	36
0.126	-	32	37	32	35	33	33

Note: All hardness values are the average of three readings.

Chemical Analysis:

Samples taken from the three sizes of large wires were found to have the following chemical compositions:

		0.117-in-diam. wire	0.121-in-diam. wire	0.126-in-diam. wire
		- Per Cent -		
Carbon	-	0.75	0.76	0.81
Manganese	-	0.55	0.60	0.53
Silicon	-	0.26	0.26	0.37
Phosphorus	-	0.023	0.019	0.025
Sulphur	-	0.031	0.034	0.039
Chromium	-	Trace.	Trace.	Trace.
Nickel	-	None.	None.	None.
Molybdenum	-	Trace.	Trace.	Trace.
Copper	-	None.	None.	None.

Bending Tests:

Bending tests were carried out on a sample of 0.117- and 0.121-inch diameter wires taken from each strand, the wires being bent the indicated number of turns through 180° over a 0.2-inch radius.

(Continued on next page)

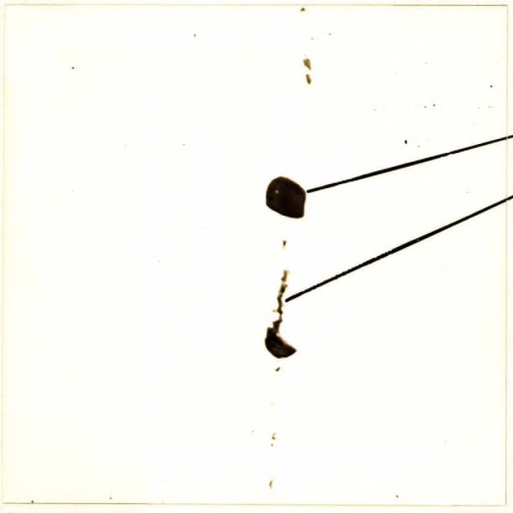
(Bending Tests, cont'd) -

Wire Diameter, inch		#1	#2	#3	#4	#5	#6
0.121	-	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{3}{4}$	$3\frac{1}{2}$
0.117	-	$4\frac{1}{2}$	4	$3\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$

Microscopic Examination:

Specimens of the three large wires were mounted in bakelite, polished, and examined under the microscope in the unetched condition. The inclusion content of the steels was found to be fairly high. These inclusions were identified as chiefly iron oxide and iron-manganese silicates (see Figure 1).

Figure 1.



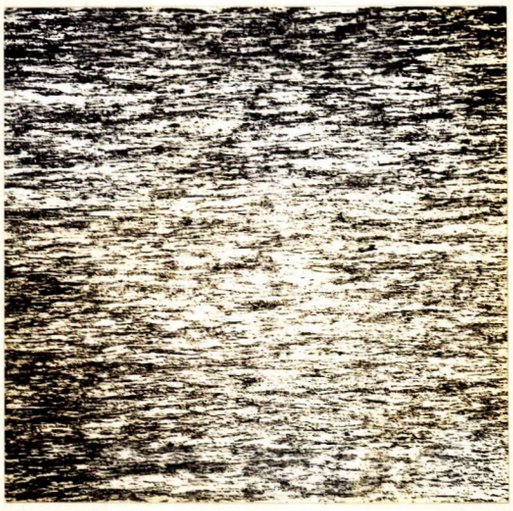
X500, unetched.

The steels were then etched in a solution of 2 per cent nitric acid in alcohol and re-examined. The nital-etched structure of a longitudinal section of one of the large wires is illustrated in Figures 2 and 3, photomicrographs at X100

(Microscopic Examination, cont'd) -

and X1000 respectively. The structure is typical of that of cold-drawn high-carbon steel wire and shows the deformation of the original structure of fine pearlite. This structure is typical of all three large sizes of wire.

Figure 2.



X100, etched in
2 per cent nital.

Figure 3.

X1000, etched in
2 per cent nital.

Discussion of Results:

Wire Diameters -

The Canadian Engineering Standards specification gives the following permissible variation in wire diameters: the wire shall be cylindrical and smooth and its diameter shall be uniform to within +0.005 inch for wires of 0.064 inch and over. No appreciable variation was observed in the three sizes of large wires examined in each of the six strands. The specification states that the wires in the rope shall be of one class. However, this rope is apparently a modification of standard 6 x 19 x 6 construction, as the rope is made up of three different sizes of large wires.

Rope Diameters -

It is specified that the diameter of the rope as measured over the extreme outer wires shall in no case be less than the nominal size and shall not exceed the same by more than 3/32 inch in ropes of 1-inch diameter and over. The rope was found to be 0.040 inch over the nominal diameter and consequently conforms to specification.

Tensile Tests -

It is specified that the ultimate tensile strength of the finished rope should in no case be less than that specified by the vendor. It is not known what strength was specified for this rope. The average breaking strength of $1\frac{3}{4}$ inch diameter Special Plow Steel rope is stated in the American Society for Metals Handbook 1939, page 1196, as being 248,000 pounds. The rope was found to withstand a proof load of 200,000 pounds (the capacity of the Bureau of Mines' Amsler tensile testing machine) without any failure taking place.

It is also stated that the ultimate strength of

(Discussion of Results, cont'd) -

the individual wires shall not be less than the value specified by the vendor in his tender and that their minimum strength be 220,000 p.s.i. (for the best grade of special plow steel). The ultimate strength of all wires examined exceeded this specified minimum.

Torsion Tests -

The specification requires that the individual wires should withstand 25 complete turns per length of 100 diameters without breaking or showing any defect. Torsion tests on two sizes of wire, namely the 0.117 and 0.126 inch diameter wires, did not meet these requirements.

Chemical Composition and Microscopic Examination -

The specification requires that the rope be made from acid open hearth steel containing more than 0.50 per cent carbon. The steels were found to have the specified carbon content. However, it is not possible to state by what process the steel was made.

The microscopic examination showed that the steels were fairly dirty. The elongation of the grains of the wire occurred as a result of cold work that the wire received in fabrication. All wires had this characteristic structure of high-carbon, cold-drawn steel wire.

Hardness -

Hardness tests carried out on longitudinal specimens of the three large wires gave values in line with their tensile properties.

The results of hardness tests on cross-sectional specimens of the wires indicated slight surface decarburization.

In the "Modern Wire Rope Digest," a book issued by

(Discussion of Results, cont'd) -

the American Chain and Cable Co. Inc., Wilkesbarre, Penn., the surface hardness value of wires in Special Plow Steel wire rope is stated as 26 to 28 Rockwell "C". It will be noted that only one wire out of the 18 tested had a Rockwell hardness value within this range. This may indicate that there was an excessive amount of cold work put into the wire in the final drawing operation.

Bend Tests -

The results of the reverse bend tests were found to just meet the requirements for high test wire.

Summary:

Summarizing, the investigation showed that the cable was not metallurgically defective, although the wire may be somewhat hard and, as a consequence, have low flexibility. However, it is thought that rope installation should be checked if trouble is being encountered with this cable.

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