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OTTAWA January 21st, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1578.

Examination of Steel Bolts From Welland Ship Canal Locks.

(Copy No. *10*.)

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Examination of Steel Bolts From Welland Ship Canal Locks.

Source of Material and Object of Investigation:

On January 13th, 1944, two broken and two undamaged bolts were received in these Laboratories from the Department of Transport.

In a letter dated January 7th, 1944, File No. 4314-71-12, Mr. E. B. Jost, General Superintendent of Canals, Department of Transport, Ottawa, Ontario, stated that these bolts were taken from wire rope fenders on the Welland Ship Canal. He requested that a full metallurgical examination be carried out in order to determine, if possible, the cause of

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

failure of the two broken bolts. Comments regarding the replacement of these bolts with a low carbon steel bolt containing 2.5 to 3.0 per cent nickel were also requested.

The bolts submitted were marked as follows:

Undamaged	bolt	from	No. 1	Fender,	Lock	No.	2.
"	"	"	No. 2	" ,	"	"	2.
Broken	"	"	No. 3	" ,	"	"	8.
"	"	"	No. 4	" ,	"	"	8.

They will be referred to in this report as Steels 1, 2, 3 and 4 respectively.

Chemical Analysis:

Drillings taken from each bolt were analysed and the following results were obtained:

Analysis.

Lab. Sample -	Steel 1	Steel 2	Steel 3	Steel 4
	- Per cent -			
Carbon	0.55	0.39	0.55	0.54
Manganese	0.66	1.16	0.62	0.63
Silicon	0.27	0.26	0.27	0.28
Phosphorus	0.017	0.038	0.016	0.013
Sulphur	0.028	0.072	0.030	0.029

Physical Tests:

Tensile test bars were machined from undamaged and broken bolts of approximately the same chemical composition. The results obtained are recorded below:

Mechanical Properties.

Sample Test Bar from Lab. Sample No.	Izod impact, ft-lb.	Ultimate stress, p.s.i.	Yield stress, p.s.i.	Elongation, per cent in 2 in.	Reduction in area, per cent	Brinell Hardness Number
No. 1	10	90,400	46,600	27.5	38.0	159
No. 4	10	87,700	45,000	27.5	41.0	163
No. 2	3					
No. 3	10					

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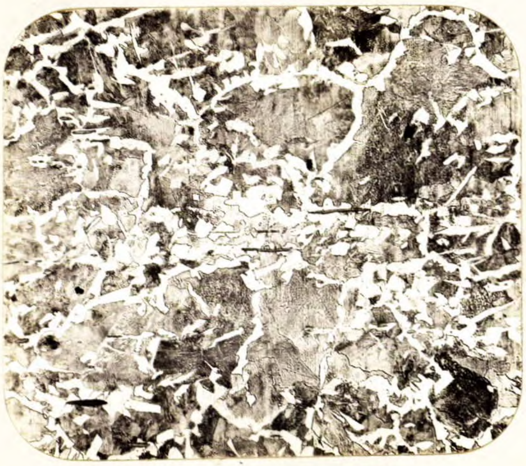
Microscopic Examination:

Specimens were cut from each bolt, polished, and then examined under the microscope in the unetched condition. Elongated inclusions of "manganese sulphide" appearance were observed to be present in all steels. Apart from this the steels were found to be fairly clean. The specimens were next etched in 2 per cent nital and re-examined. The microstructure indicated that all bolts had been made from rolled bar stock and had received a normalizing heat treatment. Steel 2 had a much coarser grain structure (see Figure 1) than the others (see Figure 2) and would appear to have been cooled from a considerably higher temperature. No metallurgical defects were observed in the two broken bolts.

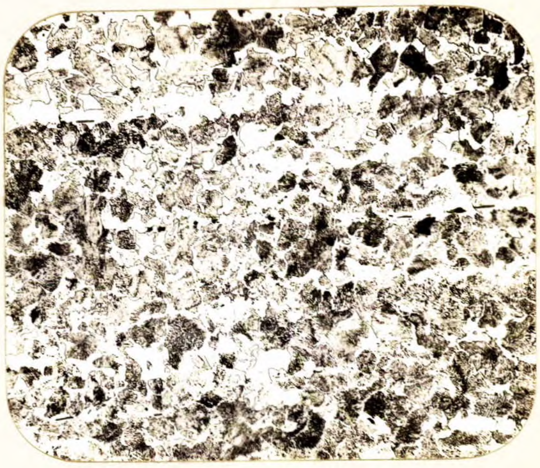
Figure 1.



X100, 2 per cent nital etch.

STEEL 2.

Figure 2.



X100, 2 per cent nital etch.

STEEL 3.

Discussion of Results:

The compositions of Steels 1, 3 and 4 were similar to that of an SAE 1050 steel. Steel 2 had the approximate composition of SAE X1340 steel. The tensile properties of one of the undamaged and one of the broken bolts were found to be

(Discussion of Results, cont'd) -

practically the same. The impact properties of these steels, while low, would appear to be sufficient for this service where failure under sudden stress is required. There were no metallurgical defects observed in the two broken bars. The duplex nature of the fractures indicates that these bolts failed by fatigue.

The apparent failure of the bolts in fatigue indicates definitely that a higher resistance to the action of alternating stresses is required. Other properties are apparently of minor importance because the service requirements are such that failure is required under sudden or steadily applied load of high magnitude. The fatigue strength of the material (with allowable variations) is definitely related to the ultimate strength, the fatigue strength being approximately 50 per cent of the ultimate. In view of this and the service requirements, then, it is not believed that the suggested replacement steel offers any improvement on the material being used, as both would have approximately the same fatigue strength. Indeed, the high strength of the suggested replacement material may very well be a disadvantage, although only one familiar with the service could state definitely whether this is actually the case. The use of a higher carbon alloy steel is recommended. Atlas S.P.S. 245, or a steel of similar composition, should prove suitable. The following table gives its composition:

Analysis.

		Per cent			Per cent
Carbon	-	0.40	Silicon	-	0.20
Manganese	-	0.75	Chromium	-	0.60
Phosphorus	-	0.030 max.	Nickel	-	1.25
Sulphur	-	0.030 "	Molybdenum	-	0.15

(Continued on next page)

(Discussion of Results, cont'd) -

The recommended heat treatment is as follows:

Normalize at 1600° to 1650° F.
Harden in oil from 1500° to 1550° F.
Draw at 1100° F. and quench in oil from the draw.

After the above heat treatment the following physical properties should be obtained on a 3-inch section:

Tensile stress, p.s.i.	Yield stress, p.s.i.	Elongation, per cent in 2 in.	Reduction in area, per cent	Izod impact, ft-lb.	Brinell Hardness Number
132,000	112,000	20.0	56.0	50.0	262

Inasmuch as fatigue failure almost invariably starts as a result of stress concentration at the surface (in this case the thread caused a concentration of stress), the use of a rolled thread rather than a cut thread is recommended, if possible. Surface shotblasting would also improve fatigue strength. Indeed, it is quite possible that this treatment might make serviceable the bolts now in use, provided that these were first shown to be crack-free by a magnaflux inspection.

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