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OTTAWA March 18th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1372.

Examination of Broken Steel Tie Rods.

(Copy No. 4.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS
ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

OTTAWA March 18th, 1943.

REPORT

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ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1372.

Examination of Broken Steel Tie Rods.

Source of Material and Object of Investigation:

On March 8th, 1943, Mr. G. A. Lindsay, Engineer-in-charge, General Engineering Branch, Department of Transport, Ottawa, Ontario, submitted two samples of broken tie rods for examination. It was stated that two self-supporting antennae towers had collapsed as a result of the failure of these tie rods. It was desired to check the composition, physical properties, and structure of the steel used.

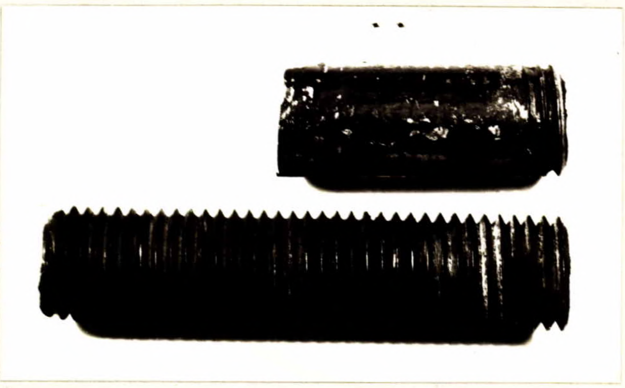
Chemical Analysis:

		Per cent
Carbon	-	0.82
Manganese	-	0.71
Silicon	-	0.16
Phosphorus	-	0.020
Sulphur	-	0.051

Macro-Examination:

Figures 1 and 2 are two photographs showing fractures in the threaded and unthreaded sections of the bars respectively. It will be observed, in Figure 2, that a piece of the metal split off the bar on the inside of the bend. Figure 3 shows the coarsely crystalline nature of the fracture of the broken tie rod shown in Figure 1. The fracture of the bars was of the non-duplex type.

Figure 1.



Approximately ¾ size.

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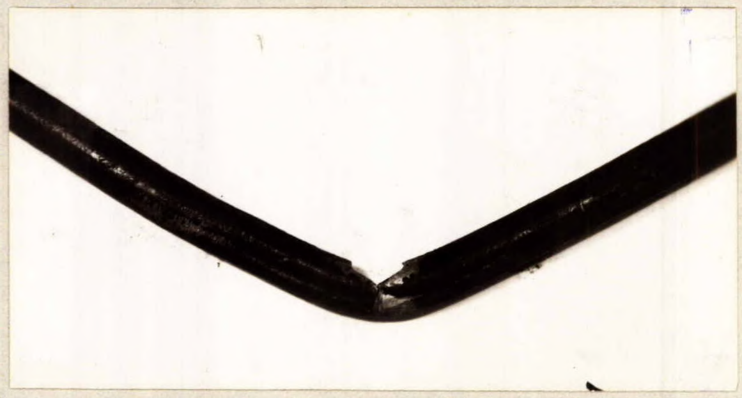
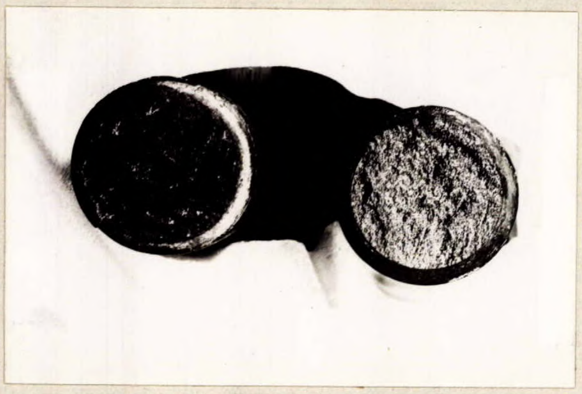
(Macro-Examination, cont'd) -

Figure 2.



Approximately $\frac{1}{4}$ size.

Figure 3.



Approximately to size.

Heat Treatment:

One of the bars was normalized at 1650° F., hardened in oil at 1475° F., and drawn at 1100° F., in order to determine what properties could be obtained. The results of physical tests on the "as received" and "after heat treatment" bars are given below:

Physical Properties		As Received	After Heat Treatment
Ultimate strength, p.s.i.	-	134,750	142,700
Yield " , p.s.i.	-	71,600*	86,400
Elongation, per cent in 2 inches	-	13.5	18.0
Reduction in area, per cent	-	22.5	23.0
Brinell (3,000-kg. load)	-	277	285
Elastic limit, p.s.i.	-	60,000	
Izod impact, ft./lb.	-	6	6

* 0.2 per cent proof stress.

Microscopic Examination:

A section of one of the steel bars was given a metallographic examination and examined under the microscope in the unetched condition. The steel was found to be fairly clean. After etching in a solution of 2 per cent nitric acid in alcohol, the steel was re-examined. Figure 4 is a photomigrograph, at X1000 magnification, showing the structure to be similar to that of an annealed SAE 1080 steel. The structure consists of fairly coarse pearlite (the dark etching constituent), and ferrite (the white constituent).

Figure 4.

X1000, etched in 2 per cent nital.

Discussion of Results:

The material used in making these tie rods was found to have the composition of SAE 1080 steel. The non-duplex nature of the fractures indicates that they had been produced by impact stresses, the fracture being practically identical to that of the izod test bar. The steel had the required ultimate strength, namely 120,000 p.s.i. However, it did not have the specified yield strength of 85,000 p.s.i. The low elastic properties of the steel examined does not leave much margin of safety since the stress in the bolts under design load was stated to be about 58,000 p.s.i.

The coarse pearlitic structure of the steel indicates that it was given an anneal heat treatment, i.e., it was cooled slowly through the critical range.

Heat treatment tests carried out in these laboratories on the steel improved all the physical properties of the steel, with the exception of the izod impact values.

It is concluded, from the results of these physical tests on the "as received" and heat-treated" bars, that this high-carbon steel should not have been used in the construction of these towers, as the impact properties are too low.

It is recommended that a steel of SAE 1045 composition be used. This steel, when normalized at 1650° F. hardened at 1,475 to 1,525° F. in water and drawn at 900° F. should have approximately the following physical properties:

Ultimate strength, p.s.i.	-	130,000
Yield " , p.s.i.	-	98,000
Reduction in area, per cent	-	45
Elongation, per cent in 2 inches	-	16
Izod impact, ft./lb.	-	50

In case it is felt that the service requires a steel with high fatigue strength as well as high impact properties, a nickel steel of SAE 2330 composition, or a chromium-nickel

(Discussion of Results, cont'd) -

steel of SAE 3135 composition, is suggested. After suitable heat treatment the average physical properties obtained with these steels are as follows:

Ultimate strength, p.s.i.	-	140,000
Yield " , p.s.i.	-	110,000
Elongation, per cent in 2 inches	-	16.0
Reduction in area, per cent	-	55

Brinell hardness ranges of 228 to 269, 241 to 286, or 269 to 321, are usually specified, depending upon requirements.

Where extreme sub-zero temperatures are encountered a nickel steel is recommended, as the impact properties of these steels are considerably better under low temperature conditions.

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