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OTTAWA May 9, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1863.

Metallurgical Examination of a Pitman
Shaft Gear, Twisted in Service.

(Copy No. 10.)

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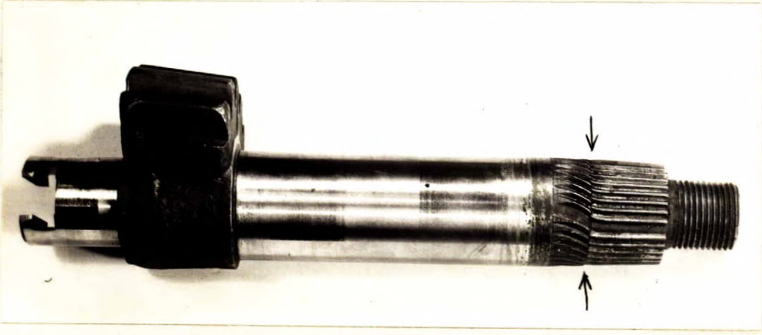
Origin of Material and Object of Investigation:

On March 20, 1945, one Pitman shaft gear which had twisted in service (see Figure 1) was submitted by the Controller General, Inspection Board of United Kingdom and Canada, Ottawa, Ontario, under Analysis Requisition No. O.T. 4341. A drawing, No. 269177, covering the details of the component, was also submitted.

A metallurgical examination to determine cause of failure was requested.

(Origin of Material and Object of Investigation) -

Figure 1.



PITMAN SHAFT GEAR TWISTED IN SERVICE.

(Approximately 1/2 actual size).

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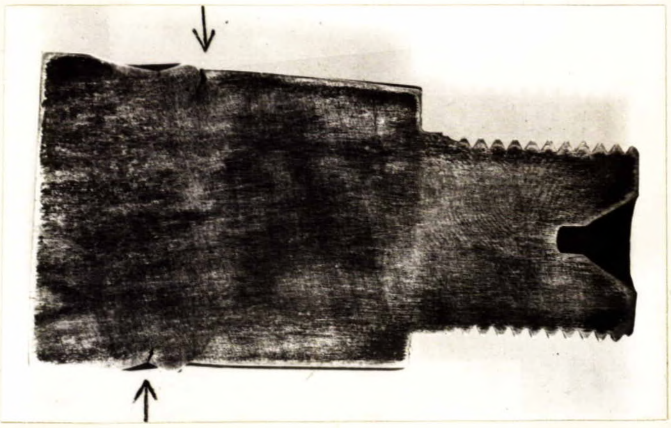
Macroscopic Examination:

Macroscopic examination made on a longitudinal section cut through the shaft revealed cracks extending inward from the surface at the location where twisting had occurred (see Figure 2). These cracks had formed as a result of the twisting of the metal.

Figure 2.



Etchant: 50 per cent HCl solution.

MACRO-EXAMINATION SHOWING CRACKS NEAR SURFACE AT TWISTED AREA.

(Approximately 1½ times actual size).

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Chemical Analysis:

The results of the chemical analysis are compared, in Table I below, with the requirements of General Motors Specification No. 4220, as set forth in Drawing No. 269177.

TABLE I. - Chemical Analysis.

		As Found	Specification, G.M. 4220
		- Per Cent -	
Carbon	-	0.21	0.15-0.25
Manganese	-	0.61	0.30-0.60
Silicon	-	0.26	
Sulphur	-	0.021	0.05 (max.)
Phosphorus	-	0.015	0.04
Nickel	-	1.14	1.0-1.5
Chromium	-	0.40	0.45-0.75
Molybdenum	-	0.16	0.10-0.20
Vanadium	-	Nil.	

Heat Treatment Experiment:

A section of the shaft was heated at 1575° F. for 45 minutes, quenched in oil, and drawn at 300° F. for 45 minutes. Hardness readings were taken before and after heat treating.

Hardness Examination:

Hardness tests made on a section of the shaft before and after heat treatment gave the following results:

TABLE II. - Hardness Readings, Rockwell "C".

		As Received	After Heat Treatment
Centre	-	19	32.5
Surface	-	29	36

Tensile Test:

A tensile test performed on a test piece (0.505 inch in diameter) cut from the shaft in the "as received" condition gave the following results:

TABLE III. - Tensile Test.

Tensile Strength, p.s.i.	0.2 Per Cent Proof Stress, p.s.i.	Elongation, per cent	Reduction in Area, per cent
113,000	76,800	22.0	59.2

Microscopic Examination:

Figures 3, 4 and 5 are photomicrographs taken at X750 magnification. Figure 3 shows the microstructure at the centre, and Figure 4 that near the surface, of the steel as submitted. Figure 5 shows the microstructure resulting from the heat treatment (oil quench from 1575° F., followed by tempering at 300° F.).

Figure 3.

X750, nital etch.

Steel As Received.

MICROSTRUCTURE AT CENTRE.

Note large quantities of ferrite.

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(Microscopic Examination, cont'd) -

Figure 4.

X750, nital etch.

Steel As Received.

MICROSTRUCTURE NEAR SURFACE.

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Figure 5.

X750, nital etch.

MICROSTRUCTURE AFTER HEAT TREATMENT (OIL-QUENCHED FROM 1575° F., AND DRAWN AT 300° F.).

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Discussion and Conclusions:

Chemical analysis revealed that the chemical content of the steel complies satisfactorily with the specifications for G.M. 4220 steel. The chromium content (0.40 per cent) is slightly below the specified minimum (0.45 per cent) but this discrepancy is not regarded as being of prime importance in relation to the failure.

G.M. Drawing No. 269177, submitted with the component, did not include details of the heat treatment. However, in P.M. Lab. Report No. 7032 (February 19, 1944), reporting on a similar failure, it was noted that the specified hardness for the finished component at the serrated end should be 32 to 35 Rockwell "C". Since the hardness of the part as received varied from 19 to 29 Rockwell "C", it was thought that failure had resulted because the part had not been heat-treated to reach the desired strength specified.

Low hardness values could result from either of two causes:

(1) Improper quenching.

(2) Correct quenching, but excessive drawing temperature.

The photomicrograph in Figure 3, which shows the presence of excessive ferrite, would point to improper quenching. It is evident from this photomicrograph that the cooling rate had not been rapid enough to miss the nose of the S-curve, thus resulting in the precipitation of much ferrite.

It was found that oil-quenching from 1575° F., followed by drawing at 300° F., resulted in a hardness varying from 32½ to 36 Rockwell "C", which appears to answer the requirements.

Summarizing, it is thought that the failure had occurred in torsion because of the low strength of the steel, resulting from improper quenching.

Recommendations:

It is recommended that the spline shafts be heat-treated as follows, in order that a hardness range of 32 to 36 Rockwell "C" be achieved throughout the section:

1. Heat at 1575° F. for 1 hour.
2. Quench in oil.
3. Temper at 300° F. for 1 hour.

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AF:LB.