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OTTAWA April 7th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1383.

Examination of Failed SAE X4130 Aircraft Tubing.

(Copy No. 8.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS

ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Source of Material and Object of Examination:

On April 1st, 1943, Sqdr. Ldr. A. J. Smith, on behalf of Air Commodore A. L. Johnson, for Chief of Air Staff, Department of National Defence for Air, Ottawa, Ontario, submitted for examination two samples of seamless steel tubes. It was stated that such tubes, made from chromium-molybdenum steel of X4130 composition, had been failing in service.

Air Commodore Johnson's request letter for this work (dated March 31st, File No. 902-38-1(AMAE DAI)) asked for tests covering physical and chemical properties.

Chemical Analysis:

Sample drillings taken from the two tubes were analysed. The following results were obtained:

		Specified for SAE X4130 Steel	- F O U N D - (Per cent) Heavy-Walled Tubing	Thin-Walled Tubing
Carbon	-	0.25 - 0.35	0.28	0.28
Manganese	-	0.40 - 0.60	0.53	0.59
Silicon	-	-	0.24	0.23
Phosphorus	-	0.04 max.	0.010	0.009
Sulphur	-	0.05 max.	0.033	0.029
Chromium	-	0.80 - 1.10	0.82	0.82
Molybdenum	-	0.15 - 0.25	0.20	0.20
Nickel	-	-	0.49	0.27
Vanadium	-	-	None detected.	0.025
Copper	-	-	0.07	0.08

Physical Properties:

		Heavy-Walled Tubing	Thin-Walled Tubing
Ultimate stress, p.s.i.	-	115,500	97,300
Yield stress, p.s.i.	-	100,500	90,800
Elongation, per cent in 2 inches		24.0	20.0
Size of tubes, in inches	-	1.505 x 0.092	1.503 x 0.066

Microscopic Examination:

Sections of the tubes were mounted in bakelite, given a metallographic polish, and then examined under the microscope in the unetched condition. Both steels were found to be fairly clean. The steels were then etched in a solution of 2 per cent nitric acid in alcohol and re-examined. Figures 1 and 2 are photomicrographs, at X100 magnification, showing respectively the structure of the heavy-wall and thin-wall tubing. Next to the bakelite (the dark area at the top of the picture in Figure 1) is a broad white band of ferrite, the iron constituent. It will be noted, in Figure 2, that this band is lacking in the thin-walled tube.

Figures 3 and 4 are photomicrographs of the etched

(Microscopic Examination, cont'd) -

steels at X1000 magnification. Figure 3 shows that the structure of the heavy-walled tubing consists of fine pearlite (the iron-iron carbide; dark etching areas) and ferrite (the white etching iron constituent). Figure 4 shows the structure of the steel in the thin-walled tubing to consist of spheroidized carbides (the round globular constituent) and ferrite (the white material).

Discussion of Results:

The steel in the two tubes had the composition of X4130 steel except for the nickel content. The high residual nickel most probably originated from the steel scrap in making the steel, as none of the nickel is lost in the melting operation. The presence of nickel is not considered injurious but it does confer greater hardenability and its presence might lead to cracking in welding.

SAE X4130 steel tubes in the normalized condition should have the following minimum physical properties:

Ultimate stress, p.s.i.	-	95,000
Yield stress, p.s.i.	-	75,000
Elongation, per cent in 2 inches	-	10 to 15

When this steel is welded, the heat of the welding operation will reduce the tensile properties in the zone adjacent to the weld by approximately 10 per cent. This, however, can often be corrected by normalizing with a torch.

The above physicals, however, can be greatly improved by a quench-and-draw heat treatment, but the advantages of this operation would, of course, be destroyed in those areas which are subsequently welded. The physical properties of the tubes examined appear to be satisfactory

(Discussion of Results, cont'd) -

for normalized SAE X4130 steel tubes.

The ferrite at the outer surface of the heavy-walled tubing indicates a bad state of decarburization. The ratio of ferrite to pearlite and the finely lamellar nature of the pearlite show that this tube had been given a normalizing heat treatment, i.e., it was heated above the upper critical range and cooled in air. No decarburization was observed in the thin-walled tubing. The spheroidized structure shown in Figure 4 indicates that it was held for a considerable time at a temperature slightly under the lower critical ranges. Steel in this condition has lower tensile properties than in the normalized condition. This, then, explains the lower ultimate strength of this tube.

The surface decarburization observed in the heavy-walled tubing would not affect materially the static properties of the steel. However, it does affect the fatigue strength, which, under conditions of alternating bending stress, is very largely dependent on the strength of the extreme outer fibres. In a decarburized member this outer material is weak and consequently fatigue-cracks at low loads. This crack acts as a stress concentrator which leads to the subsequent failure of the remainder of the cross-section.

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Figure 1.

X100, etched in
2 per cent nital.

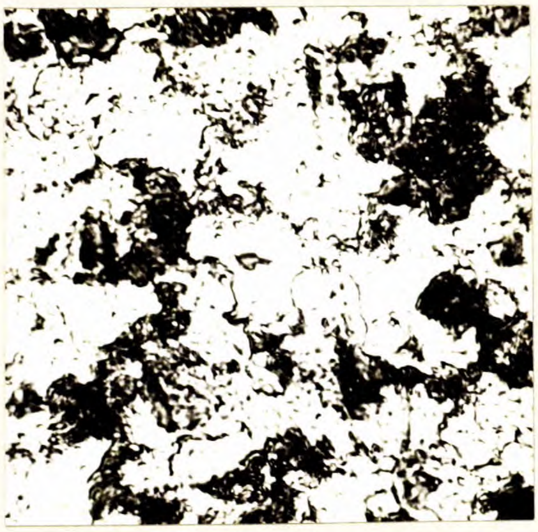
HEAVY-WALLED TUBING.

Figure 2.

X100, etched in
2 per cent nital.

THIN-WALLED TUBING.

Figure 3.



X1000, etched in
2 per cent nital.

HEAVY-WALLED TUBING.

Figure 4.

X1000, etched in
2 per cent nital.

THIN-WALLED TUBING.

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