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MINES BRANCH INVESTIGATION REPORT IR 63-65

EXAMINATION OF BOILER TUBE FROM CAMP GAGETOWN, N. B.

by

C. M. WEBSTER & D. E. PARSONS

PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Examination of a 12 inch length of boiler tube has been carried out to determine the cause of excessive loss of metal from the exposed combustion surface of the tube. Wastage of metal from this surface was due to a combination of erosion and flue gas corrosion. The tube wall thickness of the sample examined was reduced to 0.050 inch from an initial thickness of 0.17 inch in a brief period of service.

Pitting corrosion was observed on the inside (water) surface of the tube and was attributed to the aggressive character of the boiler water.

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INTRODUCTION

A 12 inch length of boiler tube was submitted to the Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Ontario, by Mr. J. L. Sisk, Chief Boiler Inspector, Department of Labour, Province of New Brunswick, for metallurgical examination. The covering letter stated that the tube sample had been removed from a high temperature, high pressure hot water boiler operated at Camp Gagetown, N.B. The boiler was fired with pulverized coal and operated at a maximum water temperature of 350°F with a maximum outside surface temperature of the tube of 400°F. The design and construction of the boiler is such that half the circumference of the affected tubes is exposed to the hot gases, the remaining portion being buried in furnace refractory.

VISUAL EXAMINATION

The sample, as-received, was approximately 12 inches long and comprised two pieces of $1\frac{1}{2}$ inch tubing welded together as a straight length and part of a curved section. For identification purposes the straight length is referred to as Sample A and the curved end as Sample B. Figure 1 illustrates the appearance of Samples A and B in the "as-received" condition.

The outside surface of the tubes for the most part had a dull, rusty appearance with numerous, randomly-distributed patches of white deposit on the fire side of the tube. X-ray diffraction tests showed this deposit to contain two phases, $FeSO_4H_2O$ and $Fe_2(SO_4)_3H_2O$. The inside surface was covered with a dull black, porous-type scale, having a random dispersal of rust spots throughout.

An end view examination showed severe wall-thinning on the exposed portion of the tubes, which had reduced the outside pipe diameter without affecting the inside pipe diameter. Measurements of the wall thickness were taken on both ends, starting at the thinnest area and travelling in a clockwise direction. Results of these measurements are given in Table 1.

TABLE 1

Wall Thickness Measurements (in inches)

Sample No.	Thinnest Area	90°	180°	270°
A	0.054 *	0.121	0.171	0.168
B	0.049 *	0.088	0.162	0.153

* - Tube wall almost penetrated.

DEEP ETCH TEST

Transverse ring sections, taken from each end of the sample, were deep-etched in 1:1 H.Cl and water at 160°F-170°F for 15 minutes. Sample A etched uniformly, whereas Sample B contained a light etching area extending from the centre of the wall to the outer surface. The fire side of Sample B (thinned side) etched uniformly, with no indication of the light etching material.

Examination of the longitudinal surfaces of the rings showed uniform attack on the outside and considerable pitting on the inside. Figure 2 shows a transverse view of the ring sections. The pitted inner surface is shown in Figure 3.

CHEMICAL ANALYSIS

Drillings were taken from Sections A and B for chemical analysis. The Mines Branch results are given in Table 2.

TABLE 2

Chemical Composition (Per Cent)

Sample No.	C	Mn	Si	S	P	★ Cu	★ Ni	★ Al
A	0.13	0.55	0.08	0.030	0.022	0.073	0.060	0.056
B	0.11	0.41	0.07	0.033	0.012	0.26	0.17	0.013

★ Spectrographic Analysis

The tubes appear to be of seamless manufacture from semi-killed carbon steel.

MICROSCOPIC EXAMINATION

Transverse and longitudinal microsections were examined. No abnormalities in the amount or distribution of non-metallic inclusions were observed. The etched structure showed Sample A to have a grain size of less than ASTM No. 8 with scattered areas of enlarged grains (ASTM No. 5) throughout. Sample B has a mixed grain size (ASTM 5 to 7) somewhat larger than A. The longitudinal microstructures of A and B are shown in Figure 4.

Examination of the inside and outside surfaces in section showed severe pitting and traces of intergranular attack on the water side, (inside surface). The fire side (outside surface at the thinned portion) was eroded and showed a pitting type of attack believed to be due to flue gas corrosion. Figure 5 illustrates the appearance of both surfaces at a thinned region in Sample B. The difference in the type of attack observed is shown in Figure 6.

DISCUSSION

Examination of the sample submitted did not reveal any metallurgical abnormalities. The deposit of $FeSO_4.H_2O$ (ferrous sulphate) found on the fire side of the tube is evidence of sulphuric acid attack. The severe and rapid wall-thinning of the exposed surface (fire side) of the tube progressed from the outer surface inwards and was caused by a combination of flue gas corrosion and erosion.

Pitting and some intergranular attack by the feed water was noted on the inside surface of the tubes suggesting that the feed water was also corrosive.

CONCLUSIONS

1. No metallurgical abnormalities were detected except for some variation of the "as-manufactured" grain size of the two lengths of tube.

2. The severe thinning of the fire side of the tubes progressed from the outer surface to the inside surface and was attributed to erosion and flue gas corrosion.

3. Pitting and grain boundary attack were noted on the inside surface (water side) of the boiler tubes, suggesting that the boiler feed water was aggressive with respect to carbon steel tubing.

RECOMMENDATIONS

(1) Consideration and review of combustion conditions with respect to reduction of fuel sulphur content, alteration of combustion conditions and use of protective baffles might advance the possibility of increasing tube life.

(2) Consideration might be given to use of tubes offering more resistance to erosion and to wastage due to sulphuric acid attack.

(3) Consideration of the short tube life obtained in this boiler indicates a hazard of dangerous thinning of tubes in relatively short periods of time (1-2 years). Routine safety inspection appears to be necessary.

(4) Possibly thinning might be alleviated to some extent by review of maintenance and cleaning procedures.

(5) The tendency to corrosion on the water side of the tubes should be minimized.

DEP/gm

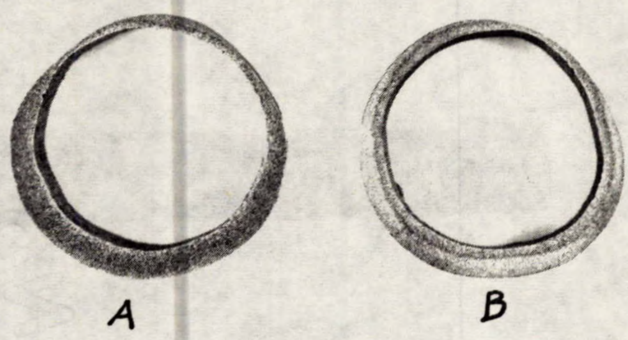
(a)
(approximately 1/3 actual size)

This surface of tube was buried in, and protected by furnace refractory.

(b)
(approximately 1/3 actual size)

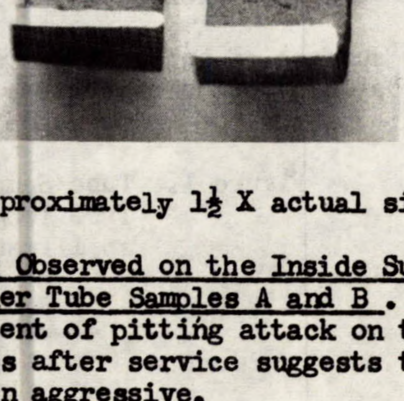
This surface of tube was exposed to erosion and flue-gas corrosion by combustion gases.
Note:- patches of white deposit on exposed surface.

Figure 1. Tube Sample "As-Received". Tube lengths A and B were butt-welded as illustrated.



(approximately actual size)

Figure 2. <u>Deep-Etched Transverse Sections through Thinned Region of Samples A and B</u>.
A light etching area is visible on the transverse section through Sample B. This effect was attributed to segregation and to the non-uniform grain size. Uniform etching was obtained in pipe section A but, despite the uniform grain size and freedom from segregation, thinning of the wall section occurred to the same extent as in Sample B.



(approximately $1\frac{1}{2}$ X actual size)

Figure 3. <u>Pitting Observed on the Inside Surface (water side) of Boiler Tube Samples A and B</u>.
The extent of pitting attack on the inside tube surfaces after service suggests that the feed water has been aggressive.

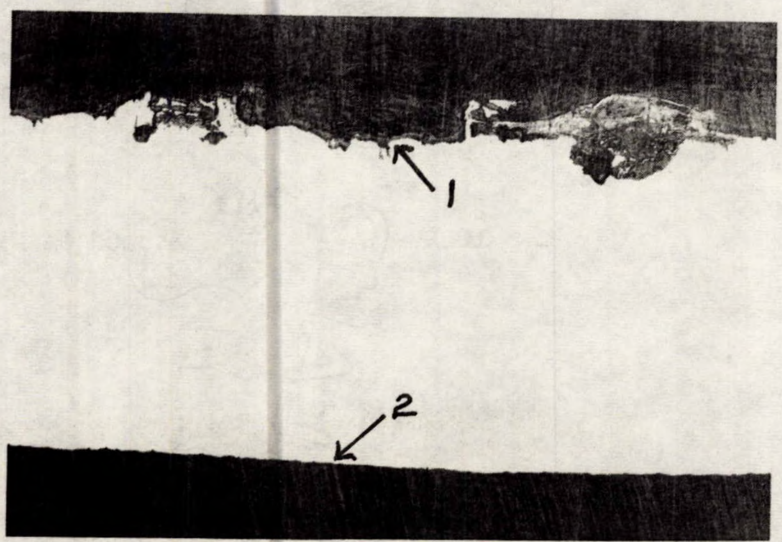
(a)

100X Etched 6% Nital

(b)

100X Etched 6% Nital

Figure 4. Longitudinal Sections, Sample A - (a); Sample B - (b). Both steels have equi-axed microstructures and lamellar pearlite - No spheroidization of carbide was observed. The "as-manufactured" grain size of both steels is non-uniform. The variation in grain size is more conspicuous in Sample B. (The mixed grain size is attributed to manufacturing practice and does not correlate with thinning or with service temperature).



50X Unetched

Figure 5. Pitting and Grain Boundary Attack on the Inside Surface of Sample B: (Arrow 1). Compared to Shallow Pitting Observed on the Outside (fire side) Surface (Arrow 2).

(a)

500X Unetched

(b)

500X Unetched

Figure 6. Sample B. Thinned Section - Water Surface (a) Combustion Surface (b).
(a) Deposits and grain boundary oxidation from feed water.
(b) Shallow pitting caused by flue gas corrosion and erosion.