Dr. John Convey, Director, Mines Branch

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EXAMINATION OF A PITTED BOILER TUBE

by

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PHYSICAL METALLURGY DIVISION

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D. E. Parsons* and J. G. Garrison**

SUMMARY OF RESULTS

Examination of a pitted boiler tube submitted by the City of Ottawa Public School Board showed that no defect existed in the material or workmanship of the tube. The steel was identified as conforming to AISI-1008 composition. The tube had been manufactured from a rimming grade of steel.

The appearance of the water surface and of the pits suggested that failure was caused by aggressive feed water or condensate at some stage of boiler operation.

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INTRODUCTION

A length of boiler tube was submitted by Mr. J.C. Ewart, Superintendent of Buildings, City of Ottawa Public School Board, to the Physical Metallurgy Division, Department of Mines and Technical Surveys, with the request that a metallurgical examination be made to establish if pitting of the tube was traceable to any defect in the material or the method of manufacture.

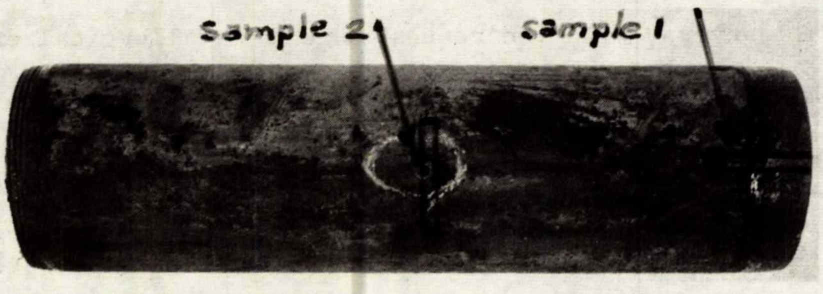
The covering letter, dated March 7, 1960, stated that the length of tube was taken from one of twenty-four tubes, which were replaced because of serious pitting and leaking. The sample submitted contained a pit which had completely penetrated the tube from the water side to the fire side. Information supplied indicated that, after installation, the fire-tube boiler was operated for a period of time before feed water treatment was started.

EXAMINATION

Visual Examination

The length of boiler tube was photographed "as-received" and is illustrated in Figure 1. The deepest pit, which penetrated the tube wall, is outlined by a chalk mark in Figure 1. Numerous other pits were visible on the water surface of the tube. Each pit contained corrosion product. The inside surface of the tube was relatively smooth.

The water side of the tube was covered with black iron oxide and with a discontinuous deposit of boiler scale.

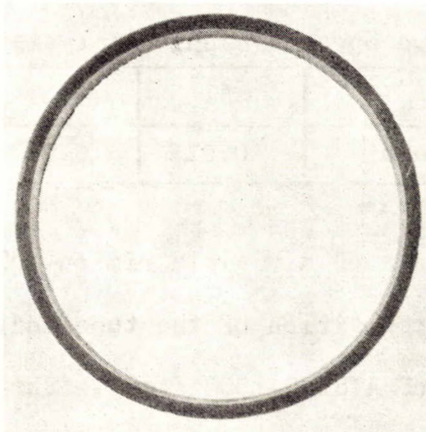


(Approximately 1/3 actual size)

Figure 1. Boiler tube, as-received
The outer surface of the tube (water side) is illustrated.
The inner surface (fire side) was relatively smooth and clean.

Deep-Etched Section

A cross-section of the tube was made and was deep-etched. No defects were observed in this etched ring section (Figure 2) taken adjacent to the pit.



(Approximately 3/4 actual size)

Figure 2. <u>Deep-etched cross section of the boiler tube.</u> The microstructure and cleanness of this section after deep-etching 20 minutes in 1:1 HCL: water at 160°F, appeared normal.

<u>Chemical, Spectrographic and X-Ray Analyses</u>

Chemical analyses and quantitative spectrographic analyses were made on drillings from the tube-wall. The results are shown in Tables 1 and 2.

TABLE 1

Chemical Composition (Per Cent)

Element	C	Mn	Si	S	P	Mo
Boiler Tube	0.08	0.40	0.01	0.028	0.019	0.01
AISI-C-1008	0.10 max.	0.25/0.50		0.050 max.	0.040 max.	

Nickel content was less than 0.01

Vanadium content was less than 0.005

TABLE 2

Quantitative Spectrographic Analysis (Per Cent)

Element	Al	Cr	Cu
Boiler Tube	0.01	0.06	0.05

The presence of a visible rim on polished transverse sections, and the composition of the tube indicate that the tube is a rimming grade of AISI-C-1008 steel. The steel contains small quantities of chromium, copper and aluminum.

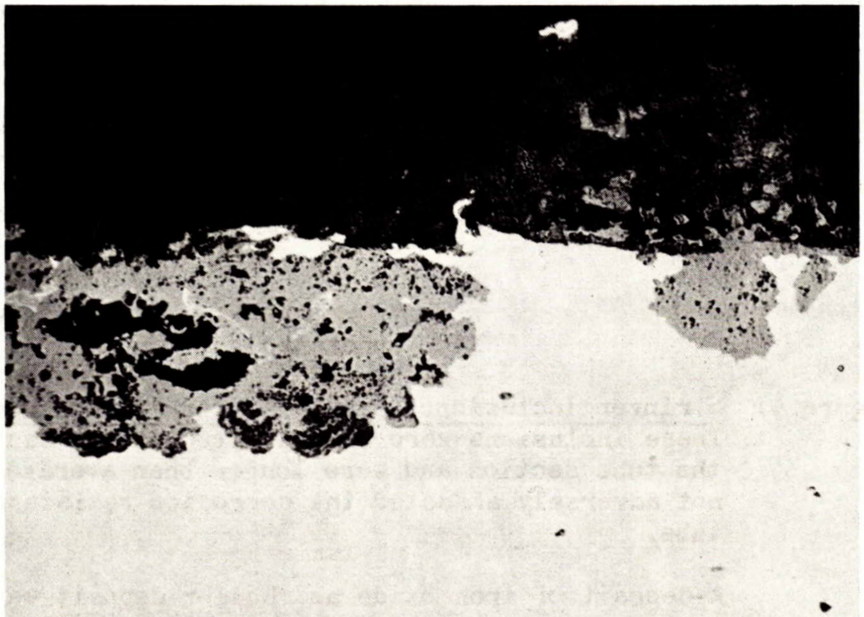
The steel appears to meet the chemical requirements for Grade A, Electric-Resistance-Welded Low-Carbon Steel Boiler Tubes as outlined in ASTM A-178-55T.

X-Ray Analysis of Scale

A sample of the black oxide was taken at the end of the tube free from boiler water deposit (Figure 1, right) and was examined by Debye-Scherrer X-ray diffraction analysis. The black constituent was identified as Fe_3O_4 containing particles of alpha iron, but it was not possible to establish whether this constituent was original mill scale formed during rolling or normalizing or scale formed by the action of hot steam on the iron surface.

METALLOGRAPHY

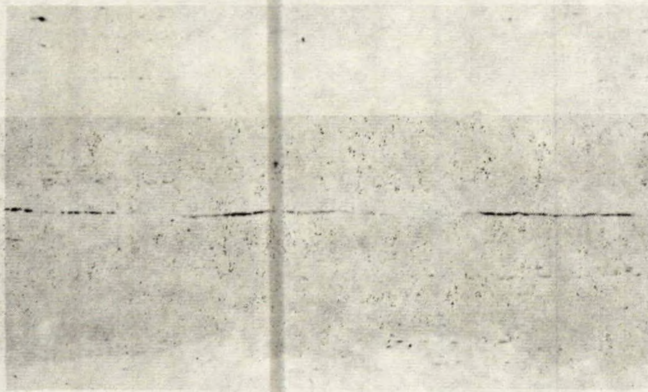
Two samples were obtained from the tube at the positions marked in Figure 1. Examination of these samples showed numerous corrosion pits on the water side of the tube which were filled with corrosion product as shown in Figure 3. The fire side of the tube was not affected by corrosion.



X500 unnetched

Figure 3. Water side of the tube, sample 1, longitudinal section
Numerous pits were observed on this surface. One pit penetrated the tube, several penetrated about 1/3 the wall thickness. The pits were filled with corrosion product.

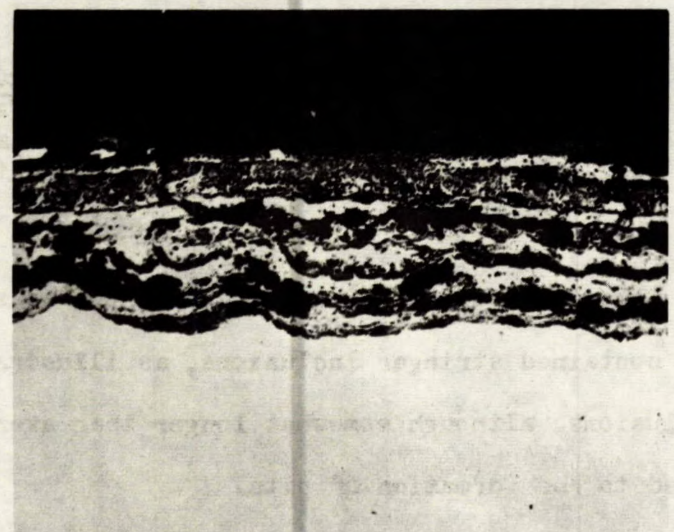
The longitudinal microspecimen shown as sample 1, Figure 1, contained stringer inclusions, as illustrated in Figure 4. These inclusions, although somewhat longer than average, had not contributed to the formation of pits.



X100 unetched

Figure 4. Stringer inclusions, sample 1, longitudinal section
These inclusions were concentrated at the centre of the tube section and were longer than average but had not adversely affected the corrosion resistance of the tube.

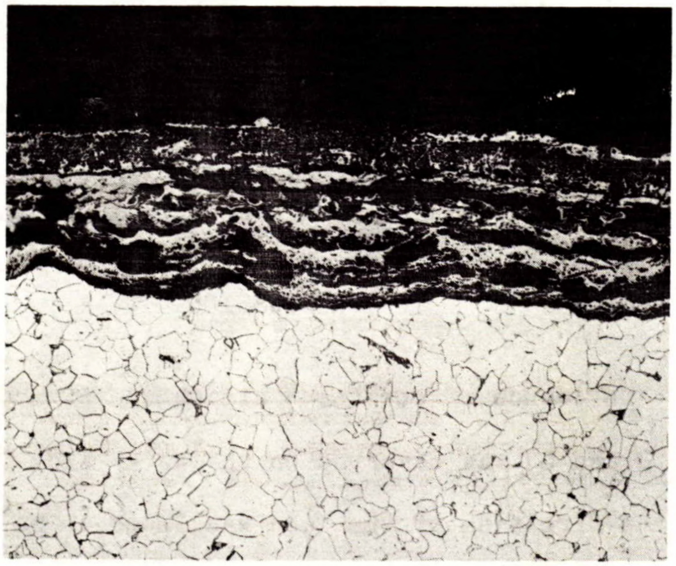
A deposit of iron oxide and boiler deposit was observed, in layers, on the water side of the tube, as shown in Figure 5.



X100 unetched

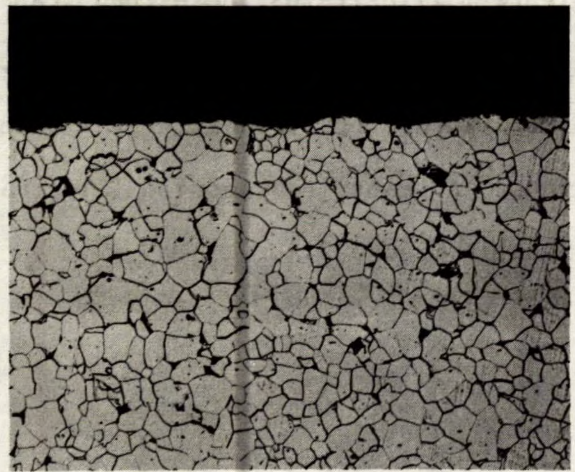
Figure 5. Scale deposit in layers on the water surface of the tube. Sample 2, transverse section.
The scale deposit appears thicker than normal. Its appearance suggests that scale has formed over a period of time and that it has not been effectively removed by feed water treatment.

Figure 6 illustrates the etched transverse microstructure of sample 2. The ferrite grain size is small, corresponding to ASTM No. 7. No evidence of overheating was observed on the fire side of the tube. A transverse section illustrating the fire side surface is shown in Figure 7.



X100 etched in 2% nital

Figure 6. Sample 2, transverse section. Same area as Figure 5. The steel microstructure is typical of AISI-1008 steel having a fine ferrite grain size corresponding to ASTM No. 7.



X100 etched in 2% nital

Figure 7. Sample 2, transverse section. Fire side surface of tube. The steel surface on the fire side was clean and, except for the perforation, was free from pitting. No evidence of local overheating was observed.

DISCUSSION

Evidence of corrosive attack and of accumulation of scale (Figures 3 and 5) was observed on the water side of the boiler tube, whereas the fire side of the tube was found to be clean and free from corrosive attack. No decarburization, grain growth or evidence of local overheating of the tube was observed.

The material composition amd microstructure were satisfactory for grade A, low carbon electric-resistance-welded boiler tube (ASTM A-178-55T) and, although the steel contained long stringer inclusions, these had not contributed to failure by pitting corrosion.

The presence of the heavy, layered deposit of scale suggests attack of the steel surface, possibly by aggressive feed water or condensate prior to commencement of feed water control (alkalinity and oxygen content). The presence of the heavy scale deposit also shows that feed water treatment has not been effective in cleaning and maintaining a clean tube surface.

Possibly, failure of similar boiler tubes could best be prevented by cleaning of the tubes prior to installation and by commencement of feed water treatment immediately after installation (1). Care should also be taken to avoid corrosion of the boiler during lay-up periods, for example, in the presence of acid condensate. During installation, care should be taken to avoid galvanic cells which can be formed by contact of dissimilar metals (copper and steel) in the presence of an electrolyte.

SUMMARY

1. The material conformed to ASTM A-178-55T for grade A, low-carbon electric-resistance-welded steel boiler tubing with respect to chemical composition.

2. No material or manufacturing defect was observed, although the surface condition of the tubes after installation could not be judged at this time.

3. Failure appeared to be typical of pitting corrosion which is often observed in similar tubes, probably as a consequence of inadequate feed water treatment and control at some stage of boiler operation [1].

4. Present feed water treatment does not appear to be effective in eliminating the scale deposit on the tube surface.

CONCLUSION

The tube failed by pitting corrosion rather than because of any material or manufacturing defect.

Reference

1. "The Corrosion of Pipes" by Frank N. Speller.
Blast Furnace and Steel Plant 28, 885-888 (September 1940).