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EXAMINATION OF TWO SAMPLES OF FIRE TUBE FROM A SCOTCH DRY BACK BOILER INSTALLED AT BEACH FOUNDRY LIMITED, OTTAWA, ONTARIO

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Examination of two lengths of boiler tube, containing circumferential grooves adjacent to the rolled ends, was carried out to determine whether grooving was due to mechanical damage or to corrosion.

The presence of iron sulphate and the appearance of the combustion surface showed that corrosion had occurred. The grain flow pattern of the steel was interrupted by the presence of the groove so that either there was no original mechanical damage or it had been removed by subsequent corrosion.

The appearance of the extremely localized groove containing ring marks was not easily explainable on the basis of generalized corrosion attack.

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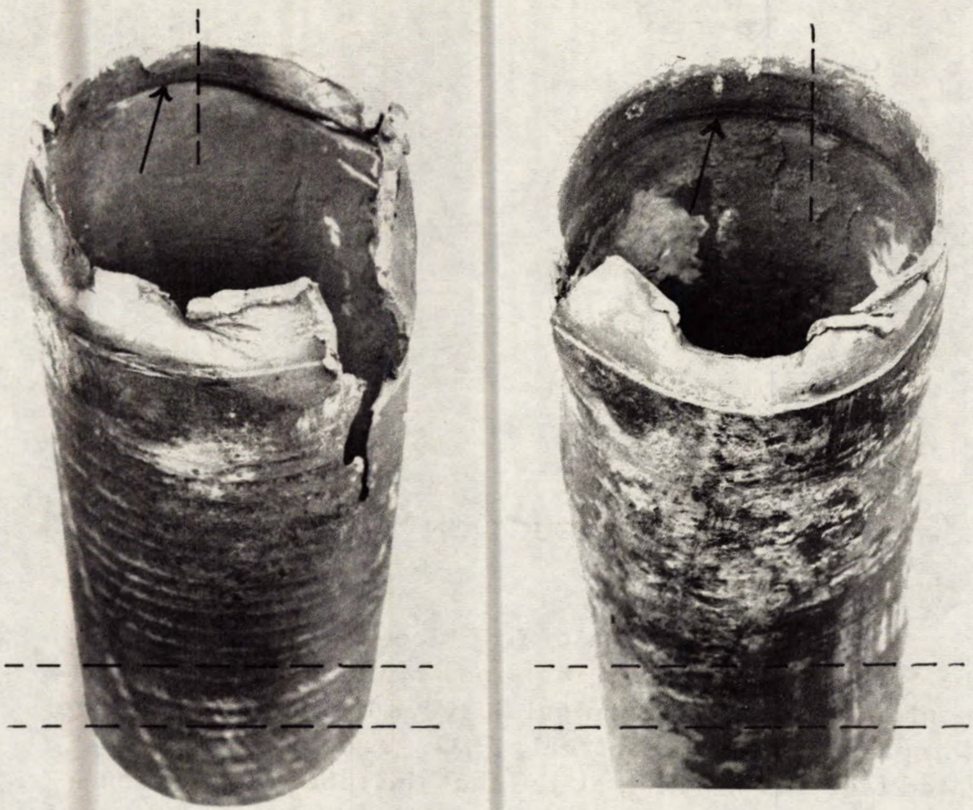
INTRODUCTION

Two samples of fire tube were submitted to the Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys by Dominion Bridge Company Limited, Montreal, P.Q. A covering letter, dated March 29, 1963, stated that the tubes were taken from a Scotch dry back boiler installed at Beach Foundry Limited, Ottawa, Ontario in 1957. The letter also stated that the boiler had been fired using No. 6 Bunker fuel oil and that acid attack was a suspected cause of the localized thinning.

The appearance of the "as-received" samples is shown in Figure 1. The location of each of the circumferential grooves is marked by the arrows.



Approximately Actual Size

Sample A   Sample B

Figure 1. Boiler tubes with circumferential grooves (arrows). The location of longitudinal and transverse sections is illustrated.

VISUAL EXAMINATION

Visual examination of the fire tubes showed the outside surface to be partially covered with tightly-adhering boiler scale. The inside surfaces of the tubes were covered with a loosely-adherent sooty material under which was a white deposit. X-ray diffraction tests showed the white deposit to be $FeSO_4 . H_2O$ (ferric sulphate) and the black substance to be a mixture of $FeSO_4 . H_2O$ and carbon.

The most conspicuous feature observed in each sample was a circumferential groove present on the inside tube surface opposite the ridge caused by the sealing process. These grooves were present for about half the circumference of the tubes and were about 3/4 in. from the end of the tube. The grooves also contained two or three ring-like marks, which were faintly visible inside and parallel to the main groove.

The appearance of the circumferential grooves suggests the possibility that these might be due to mechanical damage. This suspicion was increased by the presence of the parallel marks within the grooves. Figure 2, Sample B, shows the appearance of the parallel marks.

SECTIONING

Two transverse sections were cut from each of the tubes at a distance approximately 4 in. from the tube-ends. The remainder of each tube sample was sectioned longitudinally. The longitudinal sections showed the groove-depth of sample A to be slightly greater than that of sample B. The thickness of the transverse and longitudinal sections is shown in Tables 1 and 2, respectively. The longitudinal sections are illustrated in Figure 2.

TABLE 1

Thickness of Transverse Sections at 4 in. Position (in.)

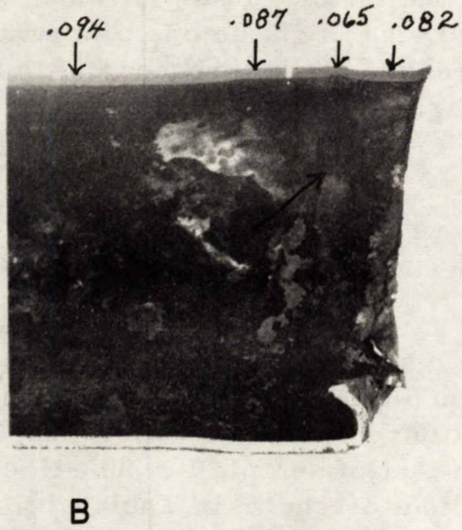
Sample No.	Weld Area	90° from Weld	180° from Weld	270° from Weld	Variation in Wall Thickness
A	0.93	0.95	0.93	0.93	0.002
B	0.92	0.92	0.98	0.97	0.006

TABLE 2

Thickness of Longitudinal Section Measured from Tube-end (in.)

Sample No.	1/4	5/8	1-1/4	3
A	0.081	0.050	0.086	0.095
B	0.082	0.065	0.087	0.094

Maximum reduction of section was observed in sample A. The thickness of this section was reduced to 0.050 in.



Approximately Actual Size

Sample A

Sample B

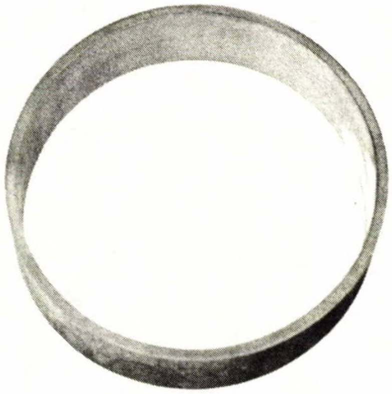
Figure 2. Longitudinal half sections adjacent to tube-end. The sections used for the thickness results, listed in Table 2, are shown at the extreme top left and top right of the pictures for samples A and B, respectively. The parallel ring marks inside the groove are shown in sample B (arrow).

DEEP ETCH TESTS

Transverse sections were deep-etched in 1:1 HCl: water at 71°C-76°C (160°F-170°F) for 10 min. The weld area was revealed and appeared to be an electric resistance butt weld. The inside surface of the tube etched uniformly. Shallow pits were observed on the outside surfaces after deep etching.

The appearance of the deep etched transverse sections cut at a distance of approximately 4 in. from the tube-end is shown in Figure 3.

A



B

Approximately Actual Size

Sample A　　　　Sample B

Figure 3. Deep etched transverse sections, approximately 4 in. from tube-ends. Thickness measurements, shown in Table 1, were taken on these sections. Thinning of these sections is not apparent.

Chemical Composition

Chemical analyses were made on drillings from each of the tubes submitted. The results are shown in Table 3.

TABLE 3

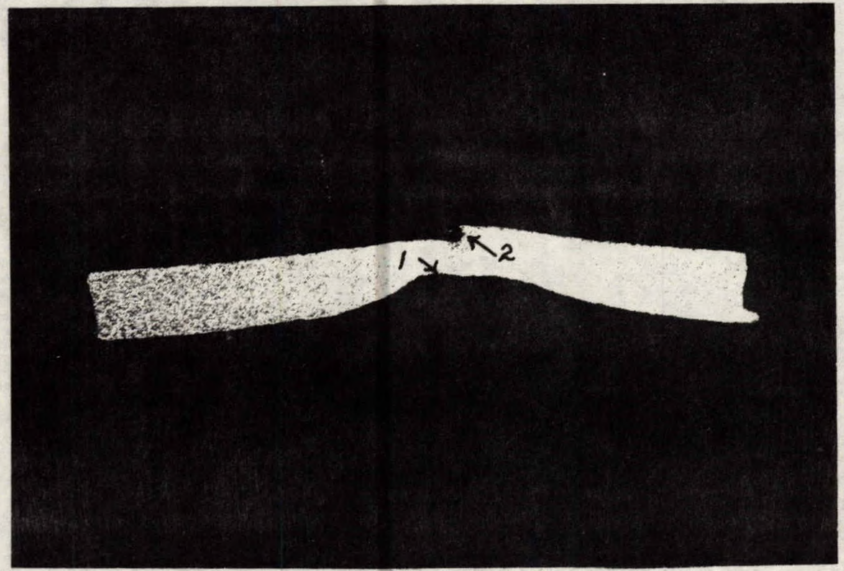
Chemical Composition of Samples A and B (Per Cent)

Sample No.	C	Mn	Si	S	P	Cu
A	0.05	0.31	0.01	0.028	0.006	
B	0.07	0.39	0.01	0.039	0.006	

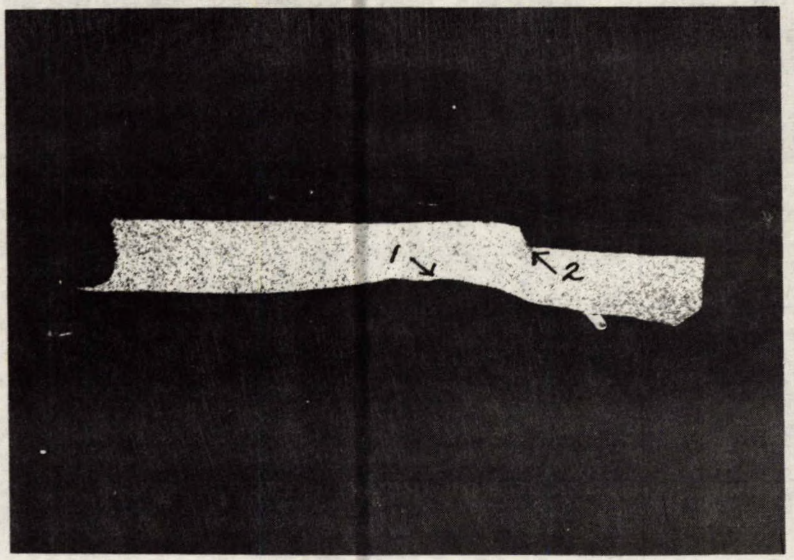
The analysis and the appearance of deep etched sections tends to classify the tubing as low carbon steel manufactured by electric resistance welding.

METALLOGRAPHIC EXAMINATION

The appearance of longitudinal sections through the grooves in samples A and B is shown in Figure 4(a) and (b), respectively. The grooves in each section are marked (arrows 1). The shoulder caused by the sealing ridge is marked (arrows 2).



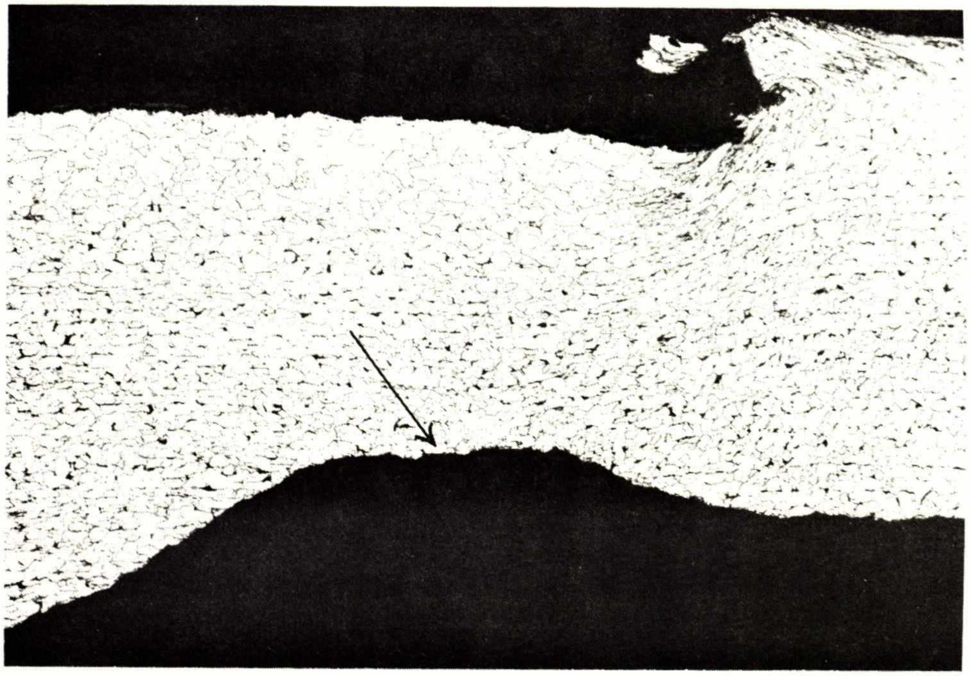
(a) X4
Sample A - Longitudinal Section



(b) X4
Sample B - Longitudinal Section

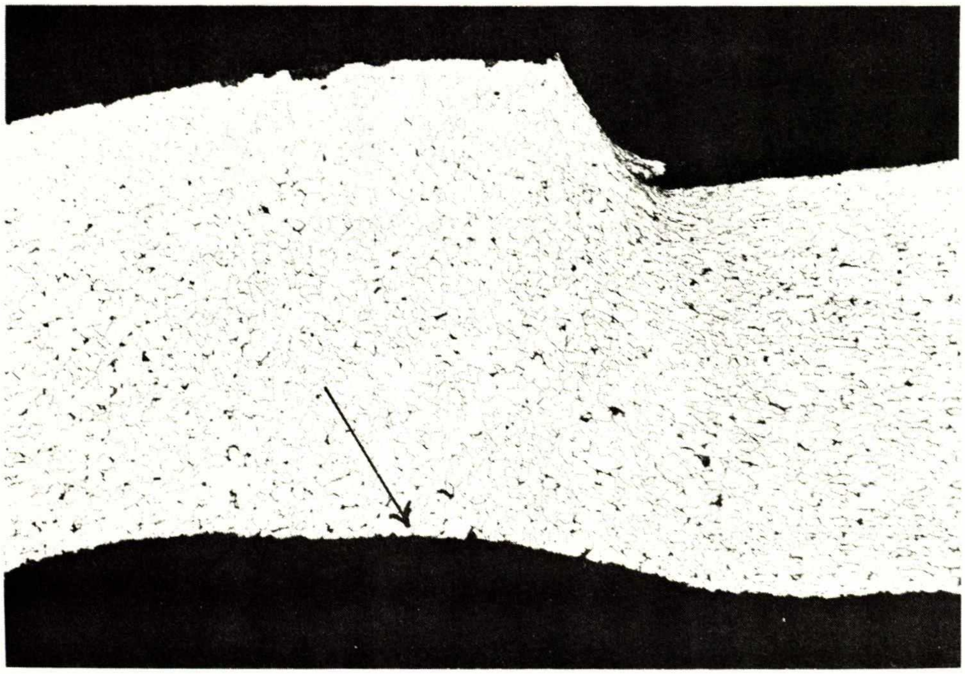
Figure 4. Longitudinal section through grooves, samples A and B. Note: Grooves on inside surface arrow 1, sealing ridge arrow 2.

The microstructure observed in longitudinal sections through the grooves is illustrated in Figure 5 (a) and (b) for samples A and B, respectively.



(a) X35

Etched 2% nital

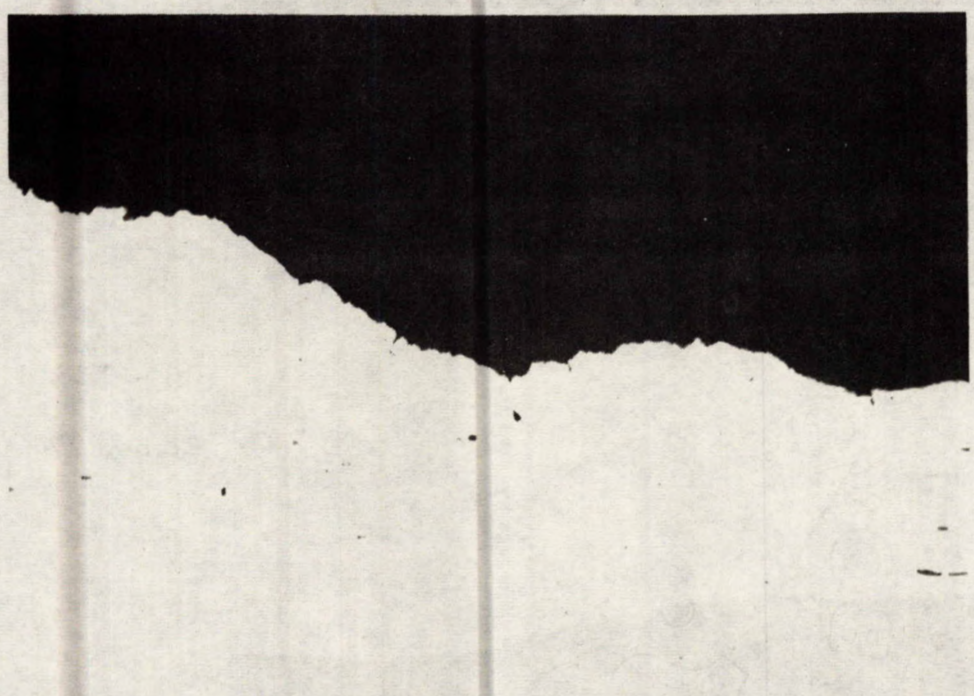


(b) X35

Etched 2% nital

Figure 5. Same areas as Figure 4. Longitudinal sections, samples A and B. Cold-worked metal is visible at the outer surface adjacent to the sealing ridge, but is not conspicuous in the region of the grooves (arrows).

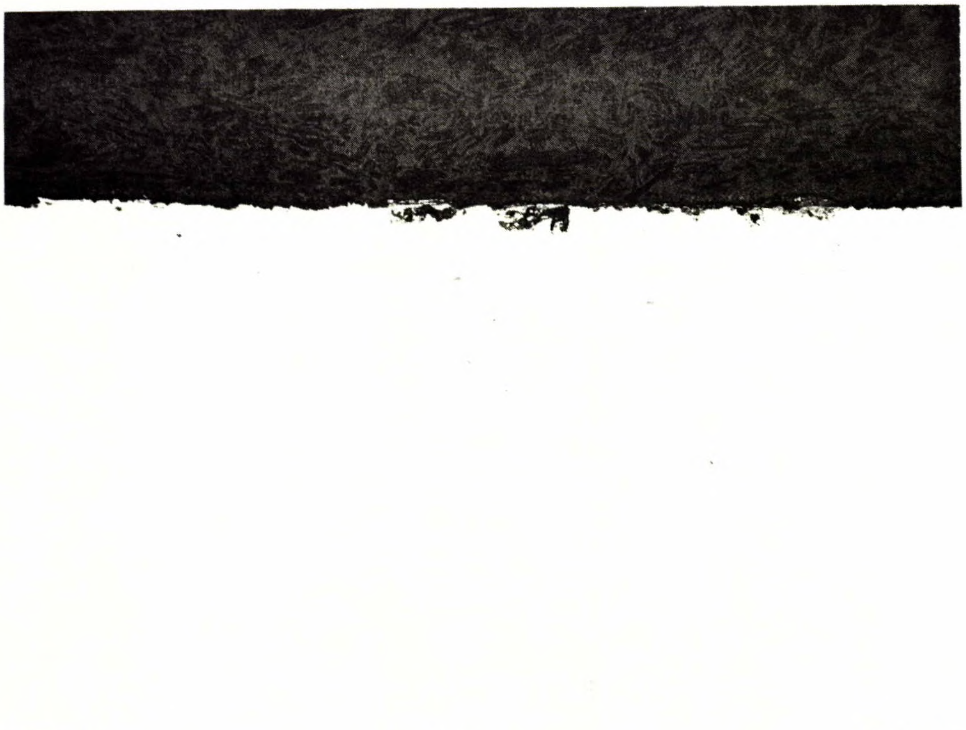
Unetched (a) X100



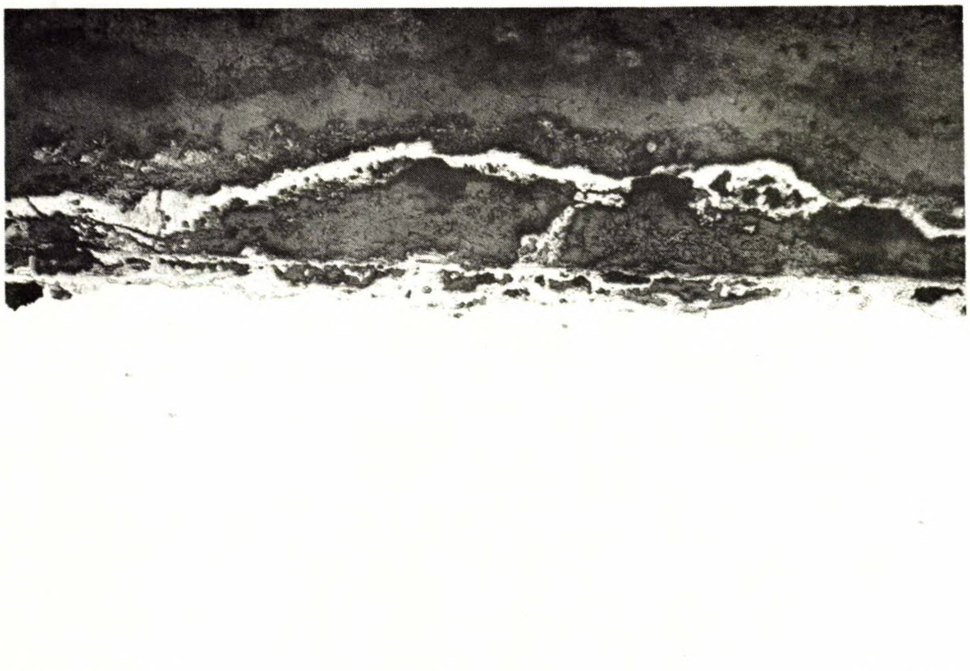
Unetched (b) X500

Figure 6. Sample A. Inside tube surface. Generalized pitting and grain boundary attack ascribed to sulphuric acid are visible in Figure 6 (b).

The appearance of the (water side) outside surface scale in sample A is illustrated in Figure 7 (a) and (b).



Unetched (a) X100



Unetched (b) X500

Figure 7. Scale and pitting on (water side) outside surface, sample A. The extent of scale deposition and pitting are illustrated.

SUMMARY AND DISCUSSION

The presence of $FeSO_4 . H_2O$ on the inside surface (fire side) confirms the suspicion that sulphuric acid attack has occurred. The shallow pits on the outside surface (water side) may be due to corrosion by the boiler feed water.

Examination of the tube microstructure, in the region of the grooves, does not show any signs of severe deformation that would be expected as a consequence of mechanical damage. Rather, the extension of the grooves through the flow lines suggests only a corrosion attack in this region.

It might be noted, however, that the possibility exists that mechanical damage had occurred at some early stage in the history of the tube but had subsequently been obscured by the corrosion.

The circumferential grooves are present at the change in section corresponding to the sealing area and approximately opposite the severely cold-worked ridge formed by the roll-sealing operation.

CONCLUSIONS

1. The circumferential grooves, present on the fire-side of the boiler tubes submitted, showed obvious signs of corrosive attack by sulphuric acid from the combustion gases.

2. There was no sign of cold-working in the vicinity of the grooves. Localized corrosion was concentrated on the fire side opposite the severely cold-worked metal at the change in sections caused by the sealing ridge. While evidence of mechanical damage was not apparent, the extent of corrosion since fabrication and the original section thickness were unknown.

3. No reason was found for the unusual and localized pattern in which corrosion occurred - possibly this can be related to peculiarities of manufacture or operation of the boiler.

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