CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 65-60

# METALLURGICAL EXAMINATION OF BURST BOILER TUBE FROM ELECTRIC REDUCTION COMPANY OF CANADA, LTD.



by

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PHYSICAL METALLURGY DIVISION

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## SUMMARY OF RESULTS

Examination of a burst boiler water tube submitted by Electric Reduction Company Limited, Buckingham, Quebec, showed that rupture was due to extreme thinning of the tube wall. Thinning was apparent on half the circumference of the pipe and for the full length of the sample. The wall thickness in the thinned region was of the order of 0.006 inches.

The seamless pipe was manufactured from silicon-killed carbon steel and appeared to conform to the requirements of ASTM A-106 Grade A "Seamless Carbon Steel Pipe for High Temperature Service".

In service, the pipe had been heated to temperatures considerably higher than 850°F (approximate) allowed for carbon steel. Sub-critical grain coarsening and grain boundary oxidation were observed, and indicated that excessive temperatures of the order of 1100°F were attained.

A heavy water-side scale was observed. This scale by its insulating action may have contributed to overheating.

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## INTRODUCTION

On June 24, 1965, a sample of failed boiler tube and a covering letter were submitted to the Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys by Electric Reduction Company of Canada, Ltd., Buckingham, Quebec. A metallurgical examination of the failed tube was requested to determine the type of tube and the cause of failure.

Figure 1 illustrates the failed tube in the as-received condition. Figure 2 shows the presence of both a thick (water-side) inside scale and a thick (fire-side) outer scale.

## CHEMICAL ANALYSIS

A section of the tube was cut from the original piece and was sand-blasted to remove the scale and dirt. Millings were obtained from this section for chemical analysis. The results are given in Table 1.

TABLE 1

Chemical Analysis of Failed Tube

| Elements Per Cent | | | | | | |
|---|---|---|---|---|---|---|
| C | Mn | Si | S | P | Cr | Mo |
| 0.16 | 0.41 | 0.53 | .029 | .003 | 0.03 | 0.01 |

The tube was manufactured from a plain carbon steel (0.16% Carbon) and appeared to conform to ASTM A-106 Specification "Seamless Carbon - Steel Pipe for High Temperature Service" with respect to chemical composition.

## METALLOGRAPHIC EXAMINATION

Metallographic samples were cut from the tube, mounted in bakelite and were polished for microscopic examination. Figure 3 shows the amount of reduction that has taken place in the wall of the tube. Figure 4 shows the penetration of oxides along the grain boundries of the tube on the outer surface (fire-side) associated with the thick outer scale. Figure 5 also illustrates the amount of reduction in the tube and shows a 0.006 in cross section of the tube at a magnification of 500 diameters. Grain boundary oxides have completely penetrated the wall of the tube in this section. Figure 6 shows the microstructure of the tube approximately six inches from the failure. Complete spheroidization and coalescence of the carbide ($Fe_3C$) has taken place in this region. Figure 7 shows the microstructure near the thin section (approximately 0.006 inches). Sub-critical grain growth has occurred in this region. Grain coarsening and oxide penetration indicate temperatures in excess of those allowed for carbon steel pipe.

## HARDNESS, THICKNESS MEASUREMENTS

Measurements of the wall thickness of the tube were made to determine the amount of reduction that had taken place in this section of tube. The thickest wall section measured was 0.125 inches thick and had a Rockwell B hardness of 69. The wall thickness of the tube at the thinned, burst section was 0.006 inches. This transverse section had a hardness of Rockwell B 50.

## DISCUSSION

The pipe is of seamless grade and appears to conform to the chemical requirements of ASTM A 106 grade A for killed low carbon steel pipe viz:- "Seamless Carbon Steel Pipe for High Temperature Service".

Overheating and severe thinning of the tube wall section by progressive oxidation caused weakening of the wall section prior to rupture. In fact, the tube wall thickness for part of the circumference and the length of the sample was reduced to 0.006 in. The temperature of the tube in service has been of the order of 1100°F. Possibly the presence of a heavy water-side scale or direct flame impingement was the cause of overheating.

## CONCLUSIONS

(1) The pipe was identified as of seamless manufacture from killed low carbon steel and appears to conform to the chemical requirements of ASTM A 106 Grade A -"Seamless Carbon Steel Pipe for High Temperature Service".

(2) Rupture occurred when the strength of the pipe wall was severely reduced by thinning to the order of 0.006 inches and by overheating to the order of 1100°F.

(3) A heavy water-side scale was observed, which may have contributed to overheating of the pipe; alternatively, overheating may have been due to flame impingement.

## RECOMMENDATIONS

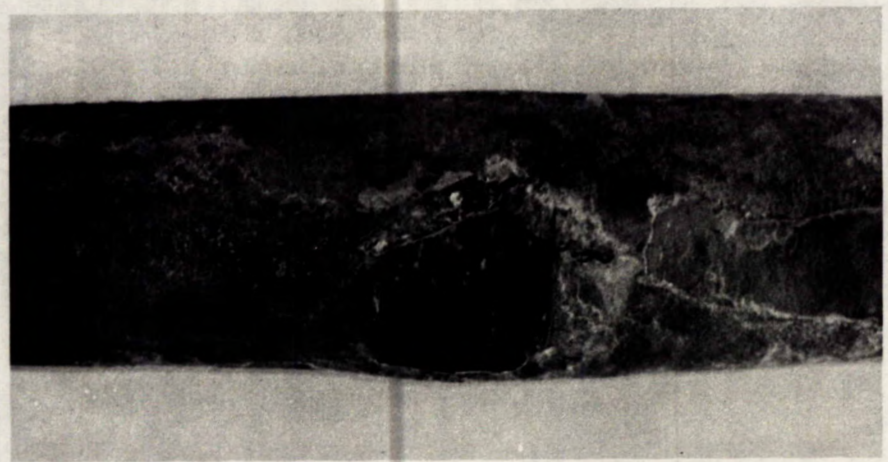
(1) Consult with the boiler manufacturer concerning proper repair of the boiler.

(2) Consider whether changes in the method of firing and of water treatment or boiler cleaning practice are necessary.

DEP:DAM:lc

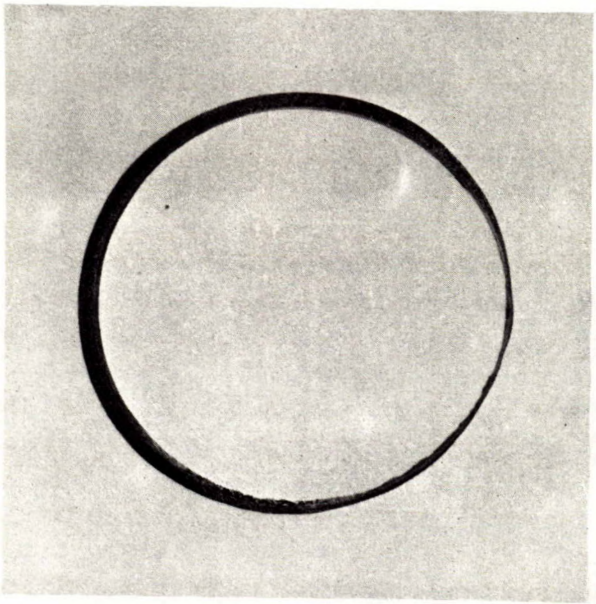
As-received    1/3 actual size

Figure 1 - Failed section of tube in the as-received condition.



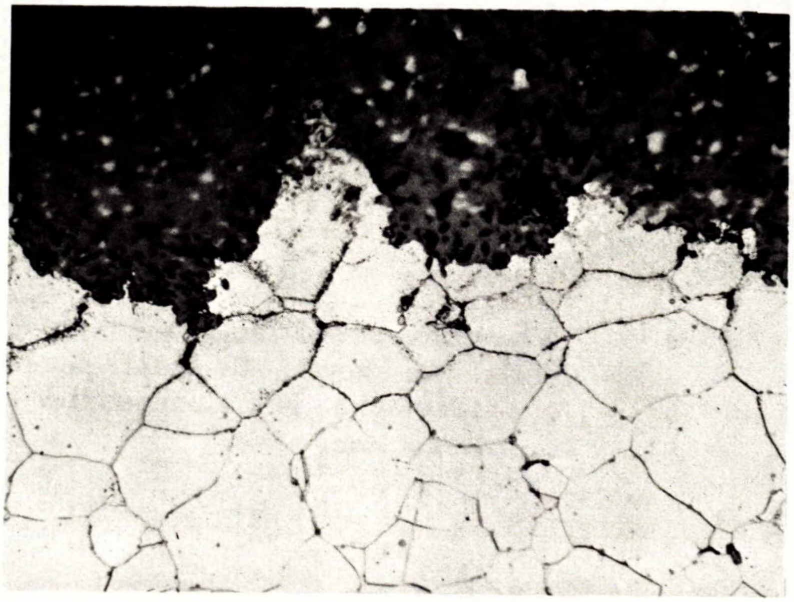
As-received    1/2 actual size

Figure 2 - Heavy scale deposits on the outside (fire-side) and heavy white scale on the inside (water-side) of the tube.



Approx. actual size

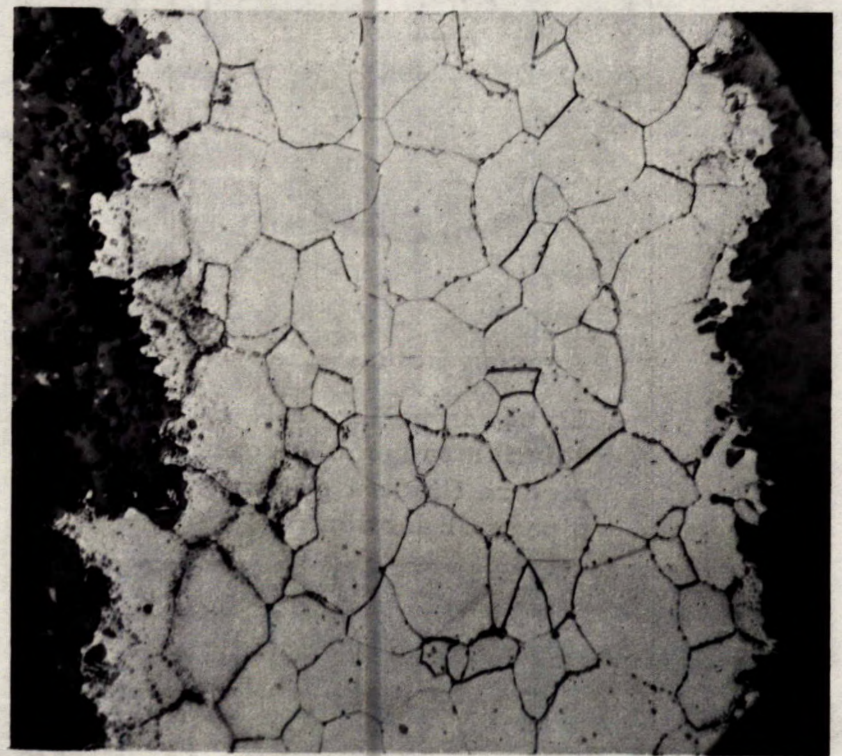
Figure 3 - Etched in boiling 1:1, HCl:$H_2O$ solution to remove scale. The picture illustrates thinning of the pipe wall section.



X500 2% nital etch

Figure 4 - Grain boundary penetration of oxides and the presence of heavy scale on the fire-side of the tube is illustrated.

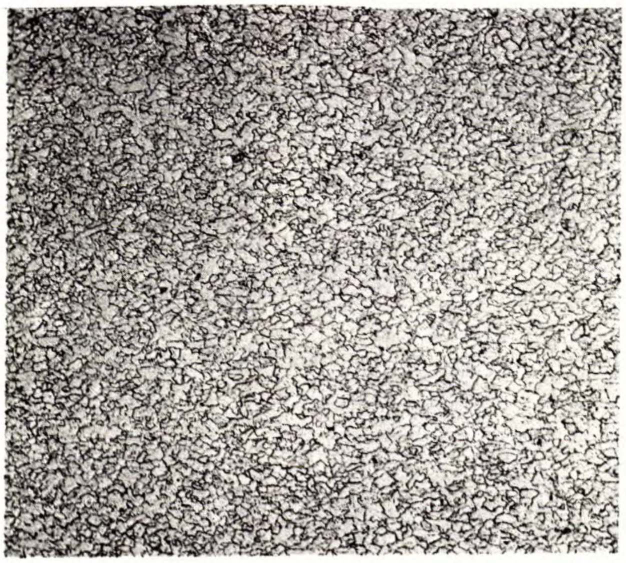
Fireside



Waterside

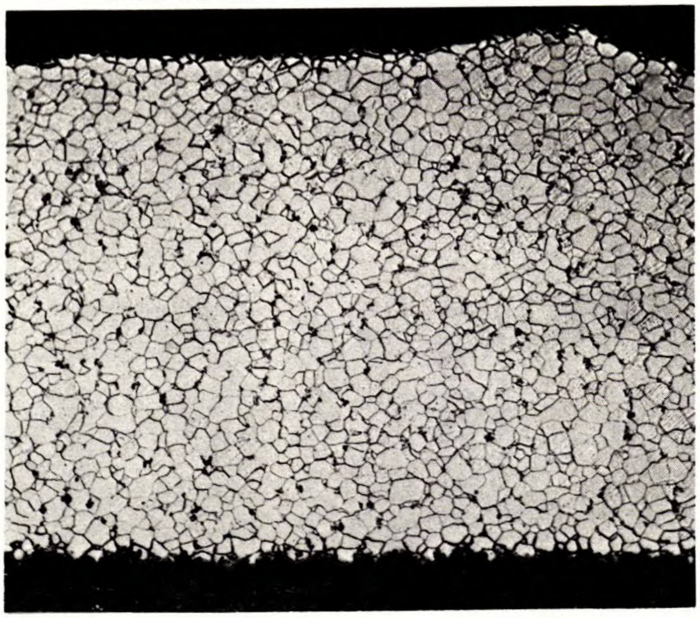
X500 2% nital etch

Figure 5 - The thinnest section of the pipe near the failure is shown. Complete penetration of oxides at the grain boundaries is visible in this section.



X100 2% nital etch

Figure 6 - Spheroidization and coalescence of carbide ($Fe_3C$) in this section of the tube remote from the failure, indicates high operating temperatures. Hardness - $R_b$ 69 in this section.



X100 2% nital etch

Figure 7 - Microstructure of the pipe adjacent to the rupture. Decarburization and grain coarsening are visible. Hardness - $R_b$ 50 in this section.