Director, Mines Branch

CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 58-23

METALLURGICAL EXAMINATION OF A CRACKED FRONT PLATE FROM A HIGH PRESSURE STEAM BOILER (#5SD, MONCTON, N. B.).

by

D. E. PARSONS

PHYSICAL METALLURGY DIVISION

COPY NO. 16

FEBRUARY 14, 1958

Mines Branch Investigation Report IR 58-23

METALLURGICAL EXAMINATION OF A CRACKED FRONT PLATE FROM A HIGH PRESSURE STEAM BOILER (#5SD, MONCTON, N. B.).

By

D. E. Parsons*

SUMMARY OF RESULTS

Two strips of boiler plate adjacent to a large crack on the front plate were examined prior to major overhaul of the boiler. Corroded microcracks were observed on the water side of the plates, and the main fracture area was severely corroded. It was concluded that the fracture was a result of "corrosion fatigue". It was recommended that if the boiler is to be repaired it should be carefully inspected by non-destructive methods before service.

* Scientific Officer, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Ontario.

CONTENTS

= = = = =

(3 tables, 7 illustrations)

ORIGIN AND PURPOSE OF INVESTIGATION

On January 21, 1958, Wing Commander A. W. Riddell, for Air Officer Commanding, Air Material Command, Royal Canadian Air Force, Department of National Defence, Ottawa, submitted to the Physical Metallurgy Division, for examination, two strips of metal adjacent to a large crack present on the front plate of a Leonard High Pressure steam boiler, #5SD, which had been in service at Moncton, New Brunswick.

In an accompanying letter of that date, reference 62 (SOCE), Wing Commander Riddell stated that the boiler was 16 years old, was rated at 150 psi, and was operating at 100 psi. There was no record of recent hydrostatic tests on this unit. Examination was requested in order that "other areas similarly affected may be detected prior to the commencement of major overhaul".

Enclosed with this letter, for information purposes, were photos of the damaged area, and copies of the Provincial Boiler Investigator's report.

An interim report on the investigation was supplied by letter to Wing Commander Riddell on February 3, 1958.

MATERIAL RECEIVED

The appearance of the cracked plate, viewed from the outside, is illustrated in Figure 1. The appearance of the fracture is illustrated in Figure 2.

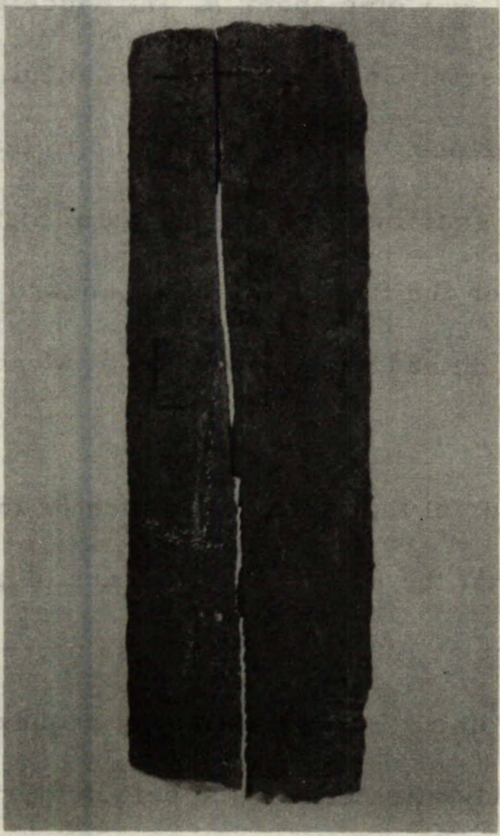


Fig. 1. - Crack in front plate on bend surface (near front circumferential seam).

(Approx. 1/2 actual size)

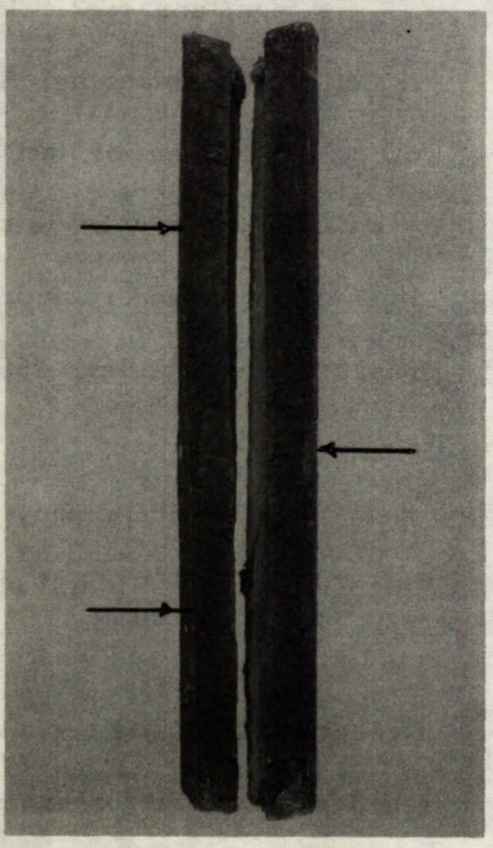


Fig. 2. - Crack surfaces. The steam surfaces are illustrated at the centre; the outer surfaces are shown (arrows).

(Approx. 1/2 actual size)

INVESTIGATIVE PROCEDURE

Metallurgical examination was carried out as follows:

(1) Visual inspection of fracture surface and inspection using fluorescent magnetic particles.

(2) Chemical and spectrographic analysis of the plate.

(3) Hounsfield tensometer, and Charpy V notch impact test.

(4) Hardness tests and metallographic examination.

o o

1. Visual Inspection of Fracture Surface.

The fracture surface consisted of two parts. About four-fifths of the fracture adjacent to the steam side of the plate had a ragged appearance and showed evidence of laminations in its deepest part. The remaining one-fifth of the fracture next to the outside surface appeared to be of the 45° shear type and showed evidence of deformation.

The appearance of the fracture suggested that the crack developed from the steam side and progressed slowly through four-fifths of the metal section, where it was interrupted by an inclusion stringer. Corrosion occurred at this lamination for a time. Then the reduced section bulged and failed in shear, leaving a deformed 45° lip for one-fifth of the section adjacent to the outer surface.

2. Chemical and Spectrographic Analysis.

Sample	C	Mn	Si	S	P	Ni	Cu	Cr	Mo	Al*
	%									
Front plate	0.22	0.37	0.03	0.038	0.015	0.08	0.30	0.06	0.07	0.01
AISI 1020	0.18 /0.23	0.30 /0.60		0.050 max	0.040 max					

*Spectrographic analysis.

The steel analysis conforms to the requirements of type AISI 1020 steel, and the chemical composition of the steel appeared satisfactory for "semi-killed" steel.

Flame photometer results on small samples gave results of 0.1% and 0.3% sodium ion in tight and thick boiler deposits respectively.

3. Mechanical Test Results*

	U.T.S., psi	Yield Point, psi	Elongation %	Red. of Area, %
Bar #1	70,800	49,900	32.0	53.0
Bar #2	66,000	40,100	38.0	59.0

*Hounsfield miniature tensile test bars.

The tensile ductility of the plate appeared satisfactory.

Charpy V-notch Impact Results.

	80°F	0°F
Bars #1	6 ft-lb	2 ft-lb
Bars #2	10ft-lb	3 ft-lb

The results of the Charpy V-notch impact tests indicate that the 15 ft-lb transition temperature of this plate was higher than 80°F.

At 80°F the fracture surfaces appeared to be about 90% cleavage (brittle) and 10% shear (ductile).

4. <u>Hardness Tests and Metallographic Examination.</u>

Measurement of the Brinell hardness in the bend region adjacent to the crack was made on surfaces polished to eliminate the curvature. The average hardness on the steam side was 159, whereas the average hardness at the outside of the bent plate was 165.

Metallographic examination of microsections cut transversely through the fracture showed the presence of corrosion pits and microcracks at the steam surface. The main fracture was transgranular but showed evidence of pitting corrosion, especially in the vicinity of the inclusion stringer which interrupted the fracture about 1/8 inch from the outside surface.

Transcrystalline, corroded microcracks were observed at the steam surface which were parallel to the main fracture. Possibly a similar crack acted as an origin for the main fracture.

The appearance of three sections through the crack is illustrated in Figures 3, 4 and 5.

Figures 6 and 7 illustrate the appearance of a typical microcrack on the water side of the plate. (If the plate had not fractured at the bend, microcracks similar to those shown in Figure 6 could have propagated under the influence of residual stress and applied cyclic stress.)

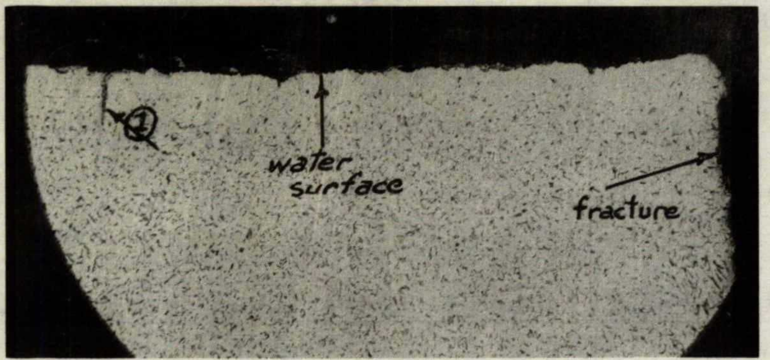


Fig. 3. - Water side of plate (top). Fracture at extreme right. A corroded microcrack, 0.012 in. in depth, parallel to the fracture, is illustrated at the water surface (arrow ①). X33.

Fig. 4. - Appearance of fracture at 4/5 section distance. The fracture has been interrupted by a sulphide stringer and corrosion (arrows) has occurred on the fracture surface and along the stringer. X33.

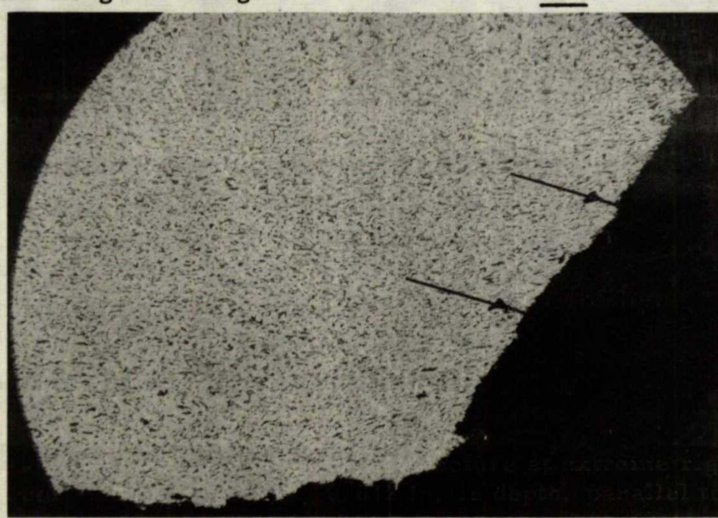
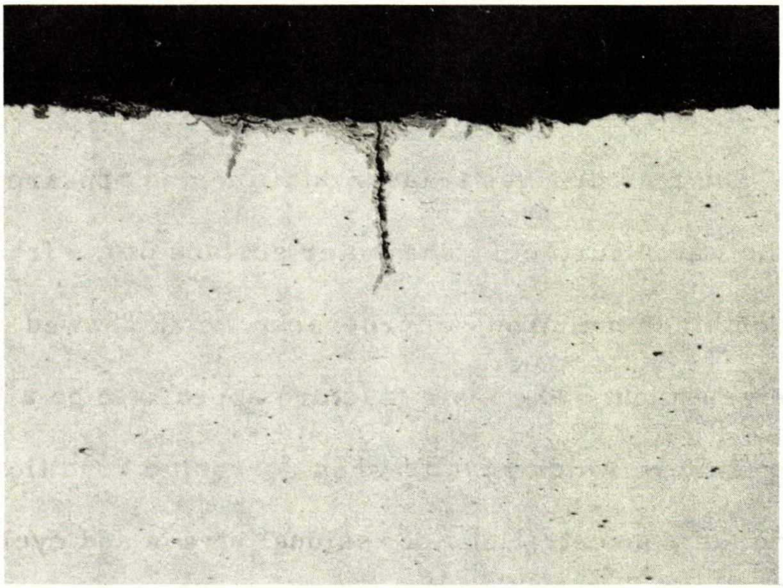


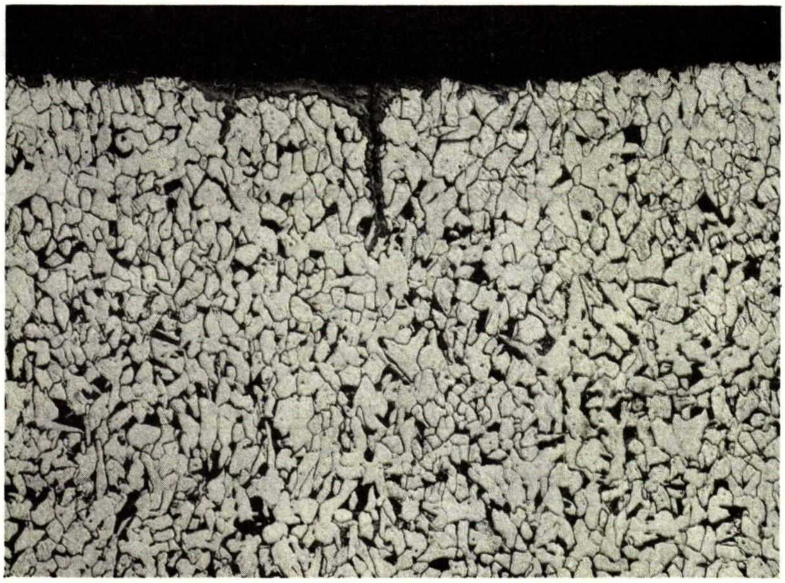
Fig. 5. - Appearance of shear fracture (arrows) present for 1/5 of the section at the outside plate surface. In this shear zone, plastic deformation of metal was observed (arrows). X33.



X100, unetched.

Fig. 6. - Water side of boiler, front plate.

This section, transverse to the main fracture, illustrates the corroded surface and shows a typical microcrack parallel to the main fracture. Several similar microcracks were detected in the small sample of front plate submitted for examination.



X100, etched in 2% nital.

Fig. 7. - Water side of boiler, front plate.

The same field as shown in Figure 6 is shown in the etched condition. The microcrack is transcrystalline and shows evidence of corrosive attack.

DISCUSSION

The fracture was transcrystalline and appeared to develop from the water surface. The water surface of the fractured front plate contained numerous microcracks which showed evidence of corrosive attack. The main fracture appears to be a "corrosion-fatigue" failure which results when corrosive conditions exist in the presence of concentrations of residual stress and cyclic applied stress.

Failure probably started at a microcrack and progressed, thereby relieving the stress so that other adjacent microcracks did not propagate. In other areas, where residual and applied stresses have not been relieved by cracking, deeper cracks may be present on the steam side of this plate. Residual stress and strain-ageing evidenced by the hardness gradient through the "semi-killed" plate, may have been factors contributing to localization of the crack in the bend region of the plate.

Severe pitting was present at the steam surface and on the fracture surface, suggesting that, as recently as at the time of the bulge, corrosive conditions existed within the boiler and that, consequently, the condition of the water-steam side of this plate beneath the boiler scale is doubtful. This steam surface contains corrosion pits, which in some places have become microcracks. These pits, in the presence of concentrated residual and applied stress in a corrosive wet environment, would be expected to propagate.

The writer knows of no satisfactory method of removing all the pits, since, if the surface is ground or cleaned up, the tips of some of these surface defects may be left. After cleaning, the deeper pits and microcracks could be located by magnaflux, but the shallower ones would remain to propagate at an unknown rate under the influence of stress and a corrosive environment.

Evidence obtained from an examination of the front plate cannot be sufficient to permit definite conclusions to be drawn concerning the condition of the remainder of the boiler. However, one can assume that similar conditions possibly exist throughout, and in the interests of safety, the entire boiler should be suspect with respect to corrosion on the inner side.

CONCLUSIONS

1. The fracture was characteristic of transcrystalline "corrosion fatigue".

2. The water side of the boiler had suffered corrosive attack and microcracks had developed parallel to the main fracture.

3. Magnetic particle inspections will detect the deeper cracks. Other corrosion sites may propagate at an unknown rate subsequent to inspection, under the influence of stress and a corrosive environment.

RECOMMENDATIONS

1. If the boiler is repaired, consideration should be given to inspection for cracks by the magnetic particle method.

2. If the boiler is repaired, consideration should be given to

a hydrostatic test and to a stress relief treatment prior to service. (Stress-relief of the boiler plate bend regions and control of the feed water to avoid corrosive conditions would be expected to minimize the possibility of failure.)

o o o o o
o o o

DEP:(PES):VB