CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

OTTAWA

MINES BRANCH INVESTIGATION REPORT IR 65-106

EXAMINATION OF RIVETS FROM S.S. "MIDLAND PRINCE" BOILER

by

D. E. PARSONS & D. A. MUNRO

PHYSICAL METALLURGY DIVISION

COPY NO. 14

JANUARY 11, 1966

Restricted -- Government Use Only

Mines Branch Investigation Report IR 65-106

EXAMINATION OF RIVETS FROM S.S. "MIDLAND PRINCE" BOILER

by

D. E. Parsons* and D. A. Munro**

SUMMARY OF RESULTS

Examination of cracked rivets from the starboard boiler of the S.S. "Midland Prince" indicated that the cracks had probably started as fatigue cracks in strain-aged 1020 semi-killed steel but that, subsequently, severe attack of the carbide constituent of the steel had occurred.

The evidence of caustic attack in the rivets suggested the possibility that intercrystalline cracking had occurred and that the boiler shell and straps were therefore suspect. A previous examination, prior to repairs, had noted a similar condition in 1960.

Thorough inspection, particularly of the boiler shell, was recommended or, alternatively, replacement of the boiler was also considered.

---

*Senior Scientific Officer and **Technician, Ferrous Metals Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

Three defective rivets, removed from the starboard boiler of the S.S. "Midland Prince" were submitted to the Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys by Mr. H. O. Buchanan, Controller, Steamship Inspection, Department of Transport, Ottawa. The covering letter, Ref. 9400-43 (SMI), November 23, 1965, requested that a metallurgical examination be made on the rivets to determine the cause of cracks observed at the head and shank of each rivet.

The covering letter stated that,

Similar fracturing was experienced on this boiler in 1962 (Mines Branch Investigation Report IR 60-37). At that time rivet and plate sections were examined and evidence of intercrystalline cracking was noted. Subsequently, the boiler was repaired, inspected and returned to service.

Recently, rivet cracking and evidence of cracking of the boiler shell have been reported, suggesting a recurrence or continuation of intercrystalline cracking.

The appearance of the rivet sections is illustrated in Figures 1 to 3 inclusive. Figure 1 illustrates the head of one rivet coated with white deposit. Figure 2 illustrates a second rivet which fractured and also contained a deep crack at the head-shank position. Figure 3 illustrates a third rivet, coated with white deposit, which also contained cracks in the fillet region.

PROCEDURE

Metallurgical examination was carried out as follows:

(1) Chemical analysis of millings from rivet No. 2.

(2) Sectioning of rivets No. 2 and No. 3.

(3) Metallographic examination of branching cracks in the head of rivet No. 2.

(4) Deep etch and sulphur print of ground section obtained by sectioning rivets No. 2 and No. 3 in the longitudinal direction.

The results of chemical analysis are shown in Table 1.

TABLE 1

Results of Chemical Analysis

	C	Mn	Si	S	P
Rivet No. 2	0.21	0.83	0.06	0.025	0.007
AISI 1020	0.18/0.23	.30/.60		.05 max	.04 max

The rivet appears to conform to the chemical composition for AISI 1020 semi-killed steel. This steel, in the semi-killed condition, has been shown to be susceptible to strain-aging in boiler service. Hence, loss of occasional rivet heads is not too unusual, except when complicated by leakage, concentration of caustic and development of intercrystalline stress corrosion cracks.

(2) Sectioning of Rivets No. 2 and No. 3

These rivets were sectioned longitudinally, the surfaces were ground, followed by deep-etching and sulphur printing.

The appearance of deep-etched sections is illustrated in Figure 5. Sulphur prints taken on the same rivets are illustrated in Figure 6.

The appearance of the cracks taken at the tip of the circumferential fillet crack of rivet No. 2 is illustrated in Figures 7, 8 and 9. There is an intercrystalline network of cracks showing evidence of preferential attack of carbide lamellae in the pearlite areas. This type of attack has been reported to be due to the reaction between hot concentrated NaOH and the Fe_3C carbide and is stated(1)(2), to indicate that caustic embrittlement (intercrystalline stress corrosion cracking) may have occurred. Evidence of cracking in the boiler shell plate tends to confirm this observation.

The evidence of caustic attack is illustrated in Figures 8 and 9, and in this sense appears to be identical to the condition previously observed in 1960 and described in Mines Branch Investigation Report IR 60-37.

X1

Figure 1. Head and Fracture Surface, Rivet Sample No. 1. This rivet head and fracture surface were coated with white deposit.

X2

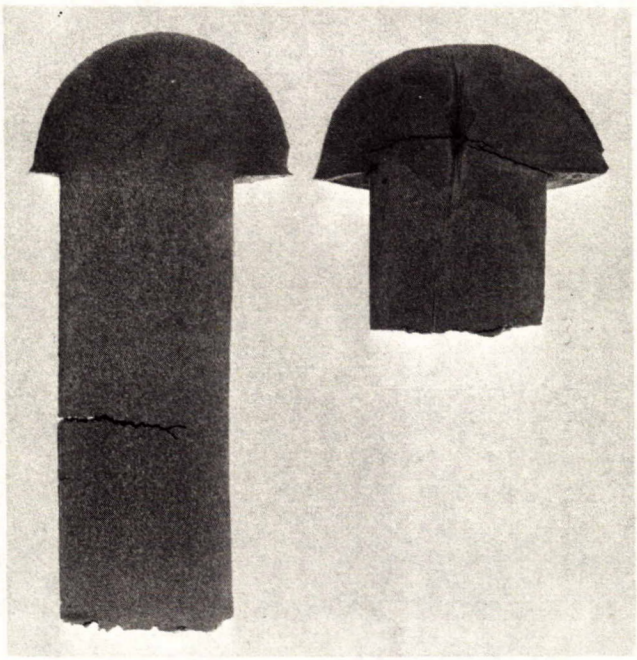
Figure 2. Illustrates Head and Shank, Rivet Sample No. 2. In addition to the fracture a deep circumferential crack is present in the fillet between the shank and the head.

X2

Figure 3. Illustrates Fracture Surface, Rivet No. 2, same as Figure 2.
Fracture of this rivet shows no evidence of deformation and appears to be irregular or intergranular and has the appearance of having occurred in a relatively brittle manner.

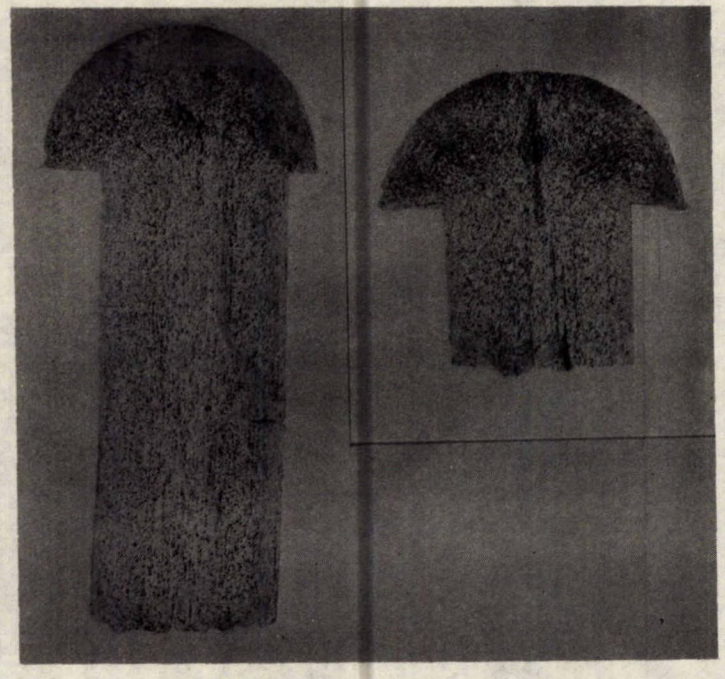
Actual Size

Figure 4. Illustrates the Appearance of Cracked Rivet No. 3. In addition to the large crack, smaller circumferential cracks are present at the head shank fillet.



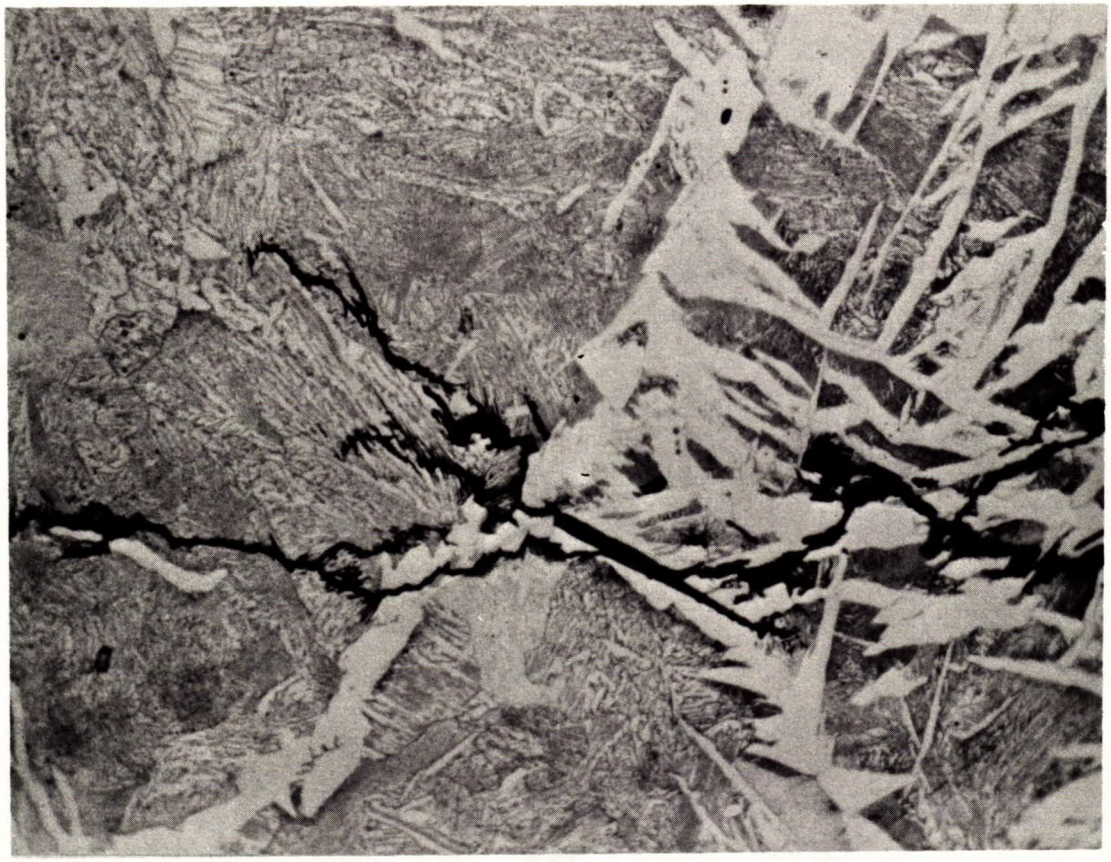
X 1/2

Figure 5. Deep-Etched Sections,
Rivet No. 3 (left),
Rivet No. 2 (right).



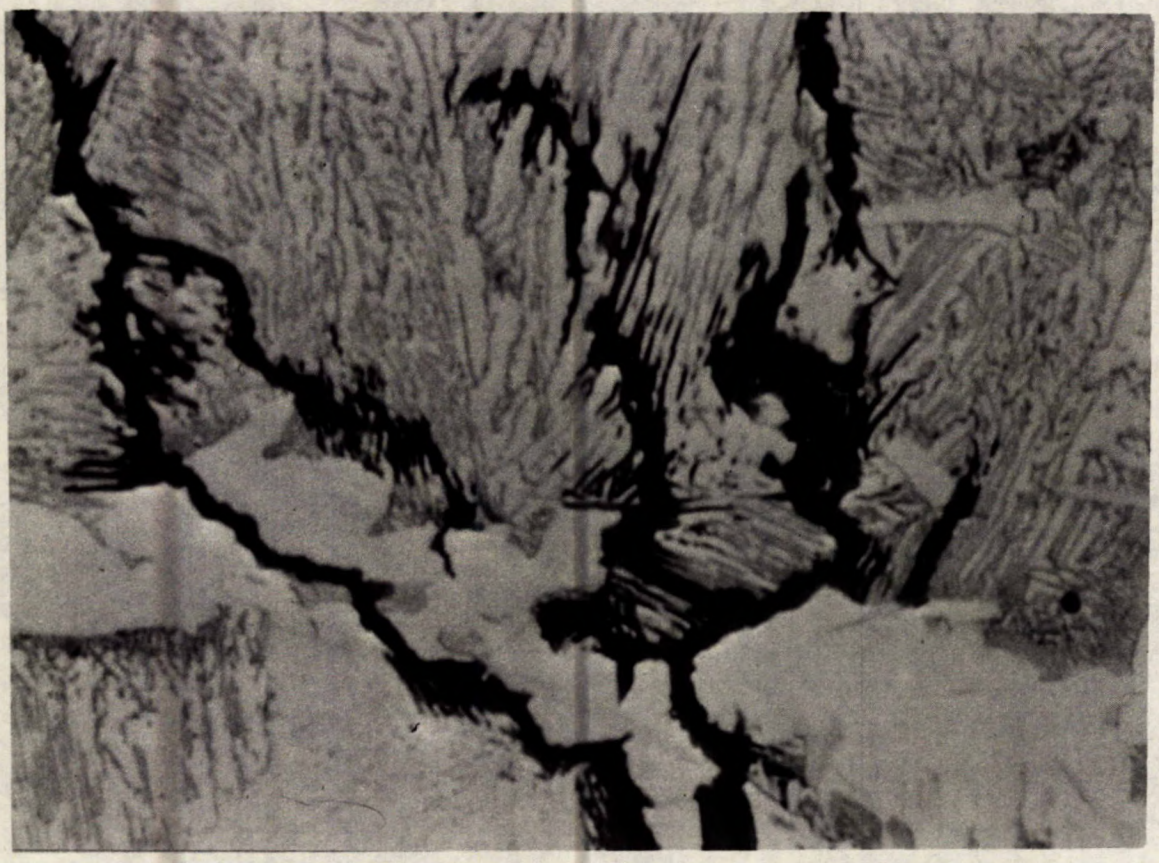
X 1/2

Figure 6. Sulphur Prints,
Rivet No. 3 (left),
Rivet No. 2 (right).



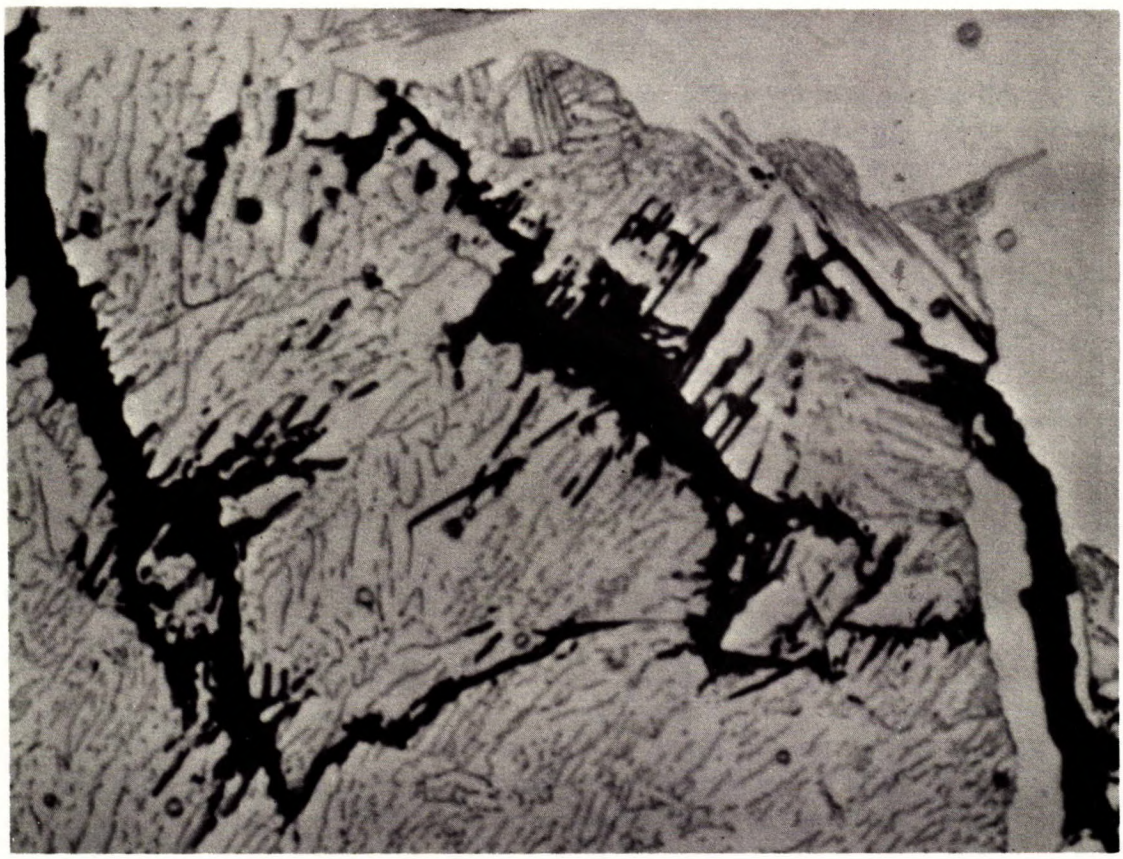
X500

Figure 7. Part of Circumferential Crack, Head of No. 2 Rivet. This crack is not completely intercrystalline but does have numerous branches, suggesting that it may have started as a fatigue crack in the fillet (due to strain-aging) but that caustic attack occurred subsequently.



X2000 - Etched 2% Nital

Figure 8. Appearance of Crack Network and Attack of Fe_3C Lamellae in the Head of Rivet Sample No. 2.
Attack and oxidation of carbide lamellae is visible. This effect has only been reported due to the action of hot concentrated NaOH.



X2000 - Etched 2% Nital

Figure 9. Rivet Sample No. 2. Crack Network and Evidence of Caustic Attack.

DISCUSSION

The appearance and location of the cracks suggests that these started in strain-aged metal as fatigue cracks and, in fact, are partly intercrystalline and partly transcrystalline. However, subsequent to formation of the original crack there is evidence of caustic attack that appears to have caused extension of the cracks and arouses suspicion that "caustic" intercrystalline attack may have occurred throughout the boiler. Reports of the presence of cracks in the boiler shell plate and the history of this boiler tend to confirm this observation.

CONCLUSION

1. The cracks probably started as fatigue cracks in strain-aged metal but, subsequently, there is clear evidence of severe caustic attack.

2. The presence of caustic attack associated with rivets has been regarded by boiler insurance companies as evidence of a dangerous condition of "caustic" stress corrosion cracking in boilers.

RECOMMENDATION

1. The remainder of the boiler should receive thorough inspection for evidence of cracking in boiler shell plates and straps.

REFERENCES

1. "Caustic Cracking in Steam Boilers" - British Engine, Boiler and Electrical Insurance Co. Ltd., Manchester, Technical Report, Vol. I, pp. 9-59, text page 55 (1952).

2. "Examination of Boiler Rivets from the S.S. "Midland Prince"" - Mines Branch Investigation Report IR 60-37, Department of Mines and Technical Surveys, Ottawa, Canada (March 28, 1960).

DEP/DAM/bb