PRJ, Vol. 3 (January 1991); P. 63–67, 13 FIGS, 2 TABLES.

Short Note

THE ATMOSPHERIC CORROSION OF AUSTENITIC STAINLESS STEEL PNEUMATIC TUBING SYSTEM IN AN OFFSHORE ENVIRONMENT

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ظاهرة تآكل وحدات التشغيل من الفولاذ الأستينيتي 316 في بيئة بحرية

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أنابيب وحدات التشغيل قطر 0.25 بوصة من الفولاذ الاستينيتي 316 المستعملة في بيئة بحرية صنفت إلى مجموعتين من حيث المظهر الخارجي لهذه الأنابيب وشدة التآكل. وجد أن معدل التآكل في المجموعة الأولى كان أكثر فاعلية من المجموعة الثانية.
التحليل الكيميائي للعينات أكد أن نوعية المعدن هو الفولاذ الاستينيتي 316. تم معرفة أسباب التآكل واقترحت الحلول المناسبة.

INTRODUCTION

Leaks were reported in the pneumatic stainless steel tubing after about two years in service. The surface of the tubing was exposed to off-shore environment. The tubing system is used for instrumentation purpose. It is reported that the tubing material as per specification is 316 austenitic stainless steel.

OBJECTIVES

(1) To investigate causes for the development of leaks.
(2) To determine chemical composition of the tubing material in order to establish whether the material is according to specificiation.
(3) To examine whether the material used is suitable for the environment encountered.

INVESTIGATION CARRIED OUT

1. Visual observation.
2. Metallographic examination.
3. Chemical composition.

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Visual Observation

Among many tube samples received two of them were different in surface appearance and extent of attack. They were marked as ASTM A213 and TP316. These two samples (here after called set (2)) were dull in colour and were lightly pitted in comparison to set (1) of tubes which were bright in surface appearance and have suffered heavy localised corrosion in the form of crevice and pitting corrosion.

Tubes were exposed to marine atmosphere and degree of localized attack varied in different locations. Tube surfaces were in contact among themselves as well as contacting the surface of holding channels. Presence of pollutants such as traces of H_2S in the platform environment appears to exist.

Metallographic Examination

(A) First Set of Tubes

Macroscopic examination:

Localized attack did not take place over the whole tube surface but was confined to a narrow band in the longitudinal direction as illustrated in Figs. 1, 2. Such morphology results from crevice corrosion. Scattered pits as in Fig. 3 were also seen. Figure 4 shows a ring around a cluster of pits indicating the existence of a deposit over these pit sites, which had come off. Figure 4a reveals the growth of adjacent

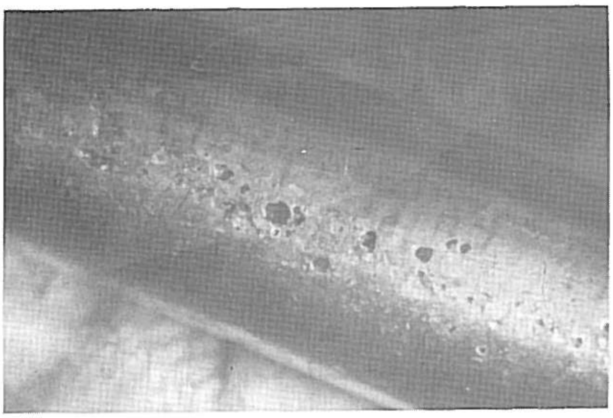


FIG. 1. A band of pits resulting from crevice corrosion × 6.

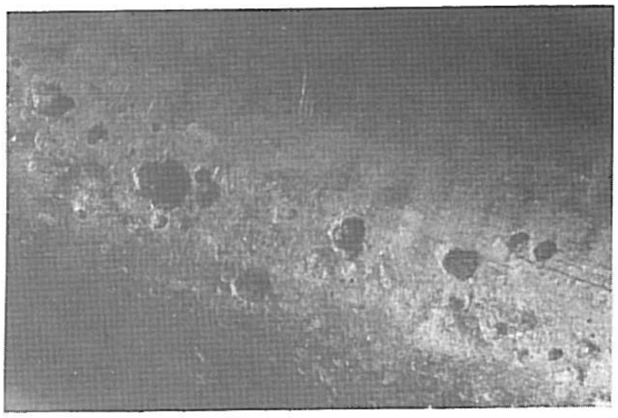


FIG. 2. Another area showing crevice corrosion × 12.

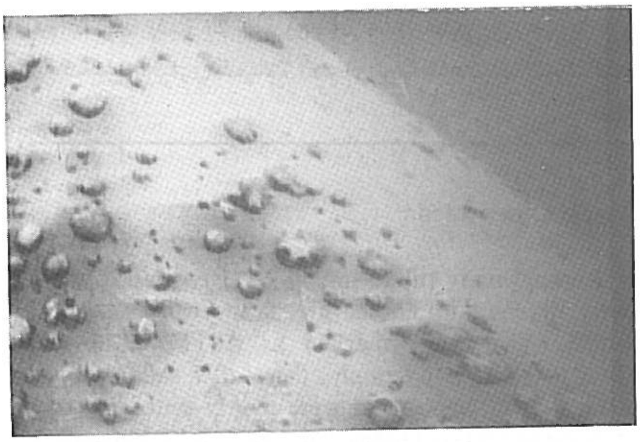


FIG. 3. Scattered pits and particles deposited on tube surface × 64.

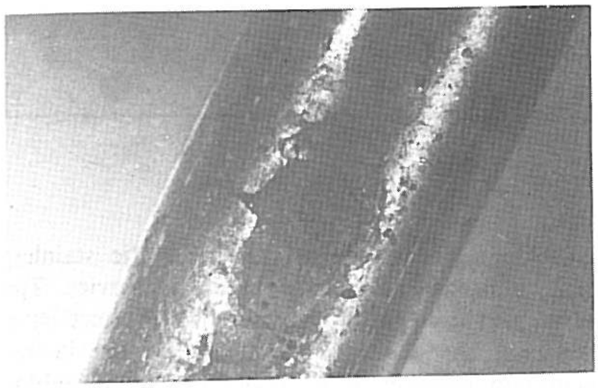


FIG. 4. A ring around a cluster of pits × 6.

FIG. 4a. Growth of adjacent pits leading to a large pit × 12.

pits till they emerged into one another leading to large pits. Figure 5 illustrates pits under the particle deposits on the tube surface.

Microscopic examination:

This was carried out in the transverse section of the pitted region of the tube. Figure 6 shows the undercut appearance of a pit indicating typical chloride attack. The pit has penetrated about 4/5 of the wall thickness. Figure 7 illustrates another morphology (open pit). Figure 8 shows a pit in the cross-section of the tube which penetrated at an angle to the tube surface. Microstructure was examined in the transverse section of the tube. Figure 9 shows that the tube was not seamless, but it was fabricated through fusion welding and the structure of weld was

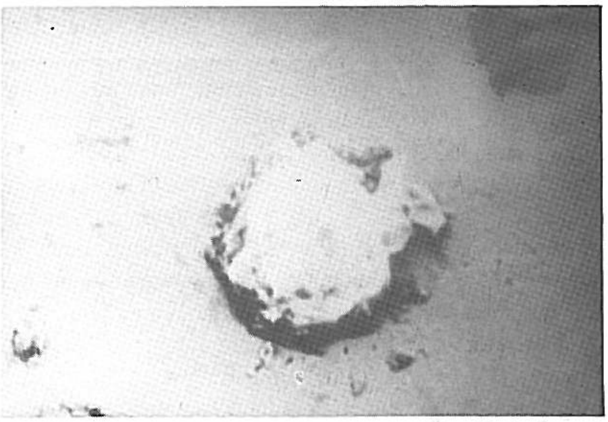


FIG. 5. A pit under the particle deposit × 124.

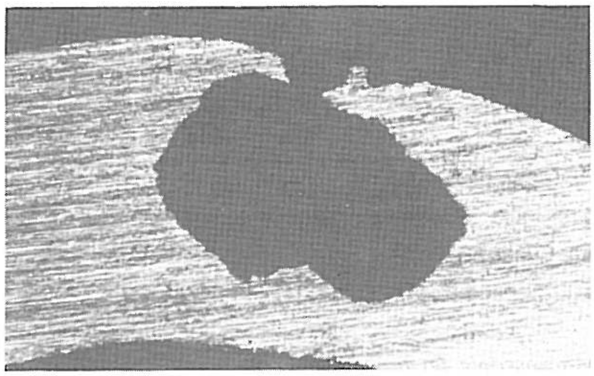


FIG. 6. Under-cut pit typical of chloride attack × 65.

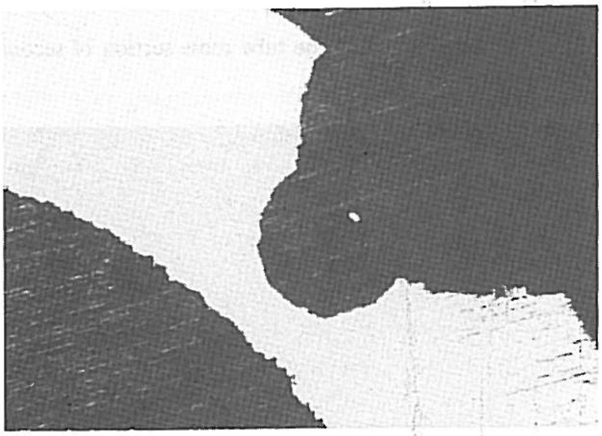


FIG. 7. An open pit × 65.

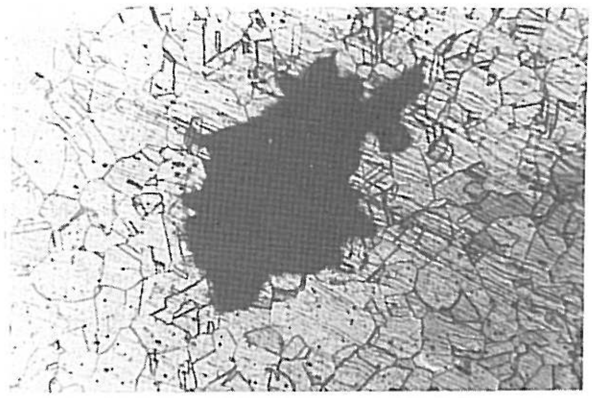


FIG. 8. A pit in the tube cross section × 260.

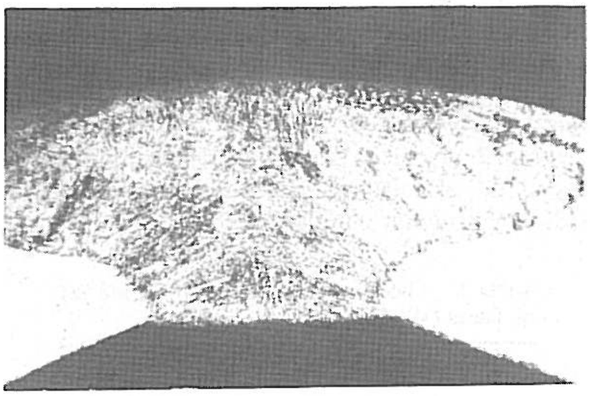


FIG. 9. Fusion weld having dendrite structure × 65.

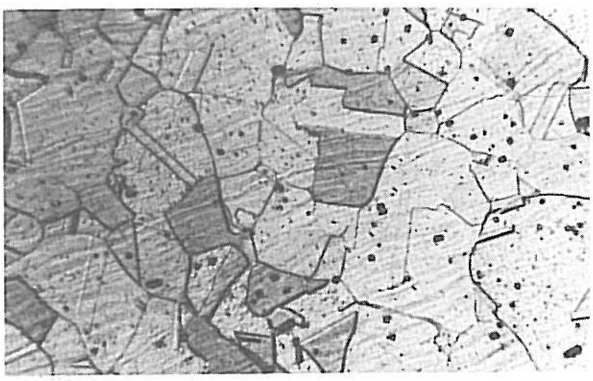


FIG. 10. Microstructure showing grain structure, annealing twins, second phase precipitates and deformation markings × 520.

dendritic. The structure of the base metal as seen in Fig. 10 consists of equiaxed grains, annealing twins, second phase particles and tube has been subjected to slight cold deformation as evident from the presence of deformation markings due to slip.

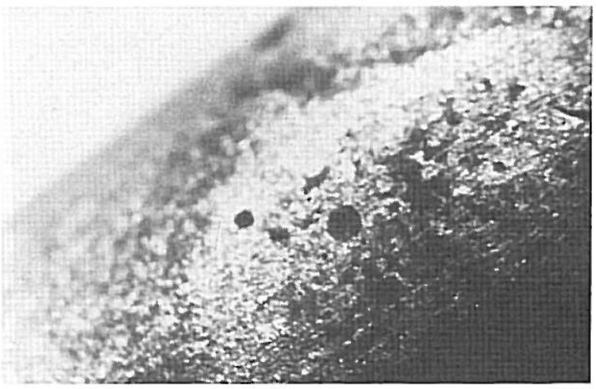
Chemical Composition:
Table 1 gives the chemical composition of the first set of tube material which corresponds to AISI 316 austenitic stainless steel.

2Table 1. Chemical Composition of First Set of Tubes (Wt. %)

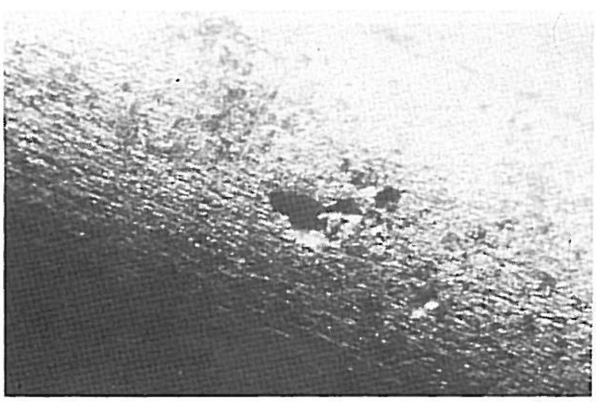
Cr	Ni	Mo	Mn	C
18.5	12.2	2.74	1.71	0.04

(B) Second Set of Tubes

Macroscopic Examination:
Mild pitting was observed on tubing surface as illustrated in Fig. (11a,b) and had random distribution.



a.



b.

FIG. 11a,b. Show pits in the tube surface of second set of tubes × 6.

Microscopic Examination:
Many cross-sections were examined and only a few shallow pits were seen. Figure 12 shows the undercut pit which penetrated only 1/20 of the wall thickness. Unlike first set of tubing second set of tubing was seamless.

Microstructure consists of equiaxad grain structure showing twining and presence of second phase particles as seen in Fig. 13; quantity being much less than that detected in the first set of tubes.

FIG. 12. Shallow pit in the tube cross section of second set of tubes × 130.

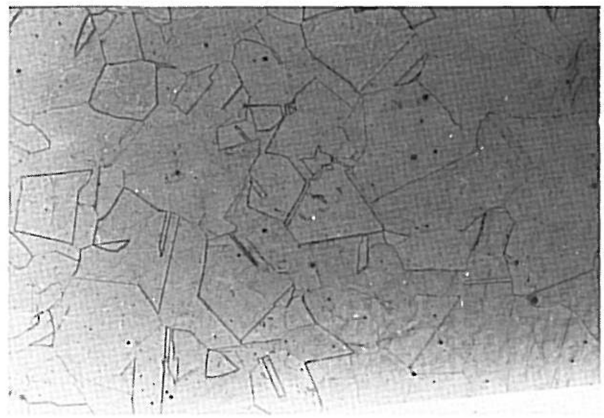


FIG. 13. Microstructure showing less quantity of second phase precipitates × 400.

Chemical Composition:
Table 2 gives the chemical composition of the second set of tube material which corresponds to AISI 316 austenitic stainless steel.

Table 2. Chemical Composition of Second Set of Tubes (Wt. %)

Cr	Ni	Mo	Mn	C
19.1	13.1	2.3	1.2	0.051

DISCUSSION

The present study reveals that the first set of bright tubing, AISI 316 austenitic stainless steel, shows poor resistance to crevice and pitting corrosion in the marine atmosphere, while the second set, also AISI 316 austenitic stainless steel, was also susceptible to pitting corrosion but the extent of pitting was far less.

Localisation of crevice attack to one side of the tubes suggests that the tubes remained in contact with other tubes/holding channels. This contact areas remain shielded from the supply of oxygen creating differential aeration corrosion cells. Salt deposited on the tube surface from marine atmosphere accelerates corrosion activity in corrosion cell [1], causing local break-down of passive film leading to crevice and pitting corrosion.

The difference in behaviour of the two sets of tubes may be due to surface treatment given to the second set of tubing imparting more resistance to pitting corrosion. Further, presence of higher amount of second phase particles as seen in the micro-structure of first set of tubing increases pit initiation [2].

CONCLUDING REMARKS

It is known that 316 austenitic stainless steel does not possess adequate resistance to crevice and pitting corrosion in stagnant chloride bearing aqueous environment. This is also the case in the present study also where tubing surfaces are exposed to marine environment in which a stagnant film of chloride bearing aqueous environment forms on the tube surfaces.

REFERENCES

[1] Mattsson E., 1982, Material Performance; Vol. 21, No 1.
[2] Smialowskal Z.S., 1986, Pitting Corrosion of Metals: NACE, Houston, p. 93.