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Failure Analysis of an 8-inch Urban Gas Distribution Steel Pipeline

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Abstract

The use of carbon steel is conventional for the transmission and distribution of treated natural gas. In order to control the internal corrosion of the gas transfer pipelines, the moisture content is removed in dehydration unit. In addition, the amount of CO_2 gas is limited to less than 2%. In this study, the cause of the failure of an 8-inch gas distribution pipeline is investigated. The pipeline was not in service for two years and then it was in operation for 6 years before the failure. Microscopic examinations, as well as chemical analyzes such as EDS and XRD, were used to determine the possible mechanisms of damage. In addition, the NORSOK CO_2 corrosion model was used to determine the corrosion rate in operating conditions. The results showed that corrosion caused by carbon dioxide is the most likely cause of internal corrosion of the pipeline and the occurrence of the leakage.

Keywords: CO_2 Corrosion, Failure Analysis, Carbon Steel, Natural Gas, Pipeline.

Introduction

Considering the relatively high corrosion rate of carbon steel in the environment, mitigation methods should be considered to prevent corrosion of steel pipelines. Such methods include coating and cathodic protection to control external surface corrosion and removing moisture and corrosive gases to prevent internal corrosion [1]. The presence of corrosive gases, such as CO_2, can lead to internal corrosion and failure of the pipelines [2]. Another corrosion mechanism which may cause corrosion of the gas pipelines is microbial corrosion [1]. Microorganisms do not directly damage the metal. Instead, products derived from their activity exacerbate certain types of corrosion, such as pitting corrosion, crevice corrosion, and under deposit corrosion [3, 4]. In this study, the cause of the corrosion of an

8-inch gas distribution pipeline was investigated.

Experimental Procedure

In order to investigate the microstructure of the pipe material and to ensure the absence of microstructural defects, especially in the perforated area, samples of the tube were made at a cross-section near the perforation site. The chemical composition of the pipe material was determined using Spark Atomic Emission Spectrometry according to ASTM E415-14 [5]. In order to determine the nature of the deposits formed on the inner surfaces of the pipe, these surfaces were evaluated in near-hole areas by using a scanning electron microscope (SEM) equipped with Field Emission Gun (FEG) and Energy Separation Spectroscopy (EDS). In addition, X-ray diffraction technique (XRD) was used to determine the main compounds present in the precipitate formed on the inner surface of the pipe.

Discussion and Results

The results of the 8-inch tubular chemical analysis are presented in Table 1. As can be seen from the results, the chemical composition of the pipe material conforms to API 5L Gr.B [6].

Figure 1 shows the hole created in the 8-inch tube. As can be seen, there are no corrosion effects on the external surface, and internal corrosion has been occurred. Figure 2 (a) shows the inner surface of the 8 inch pipe around the hole created. As can be seen, there are signs of localized corrosion, but only at one location, the hole has been created. In Figure 2 (b), the deposits formed on the inner surface of the pipe are shown. No significant tubercles were observed on the inner surface, especially in the lower position of the tube. The presence of such tubercles is an indication of the occurrence of microbial corrosion [7, 8].

Table 1: Chemical composition of the pipe material and API 5L-PSL1 Gr.B requirement.

Elements	C	Mn	P	S	V+Nb	V+Nb+Ti	Fe
Pipe material	0.11	0.82	0.014	0.010	0.009	0.018	Bal.
API 5L-PSL1 Gr.B	0.26 max	1.2 max	0.030 max	0.030 max	0.06 max	0.15 max	Bal.

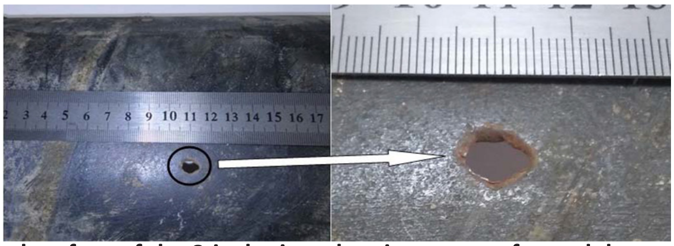

Figure 1: The external surface of the 8-inch pipe, the pipe was perforated due to internal corrosion.

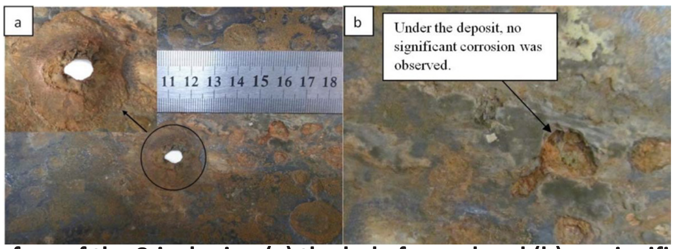

Figure 2: The internal surface of the 8-inch pipe (a) the hole formed and (b) no significant corrosion occurred under the deposit.

The results of the deposit analysis using the EDS analyzer are shown in Table 2, and the image of the points examined is shown in Figure 3.

Conclusion

The causes of failure in the tubes of a boiler were studied by various microscopic and analytical techniques. Based on the results of chemical analysis, the chemical composition of the pipe material conforms to API 5L Gr.B standard. The failure of the 8-inch pipe was due to corrosion from the internal surface. Due to the fact that the chemical analysis of deposits on the inner surface of the pipe did not show significant amount of sulfur, and due to the absence of small and deep pits, the probability of failure due to microbial corrosion caused by SRB microorganisms is very weak. The presence of iron carbonate compounds in the deposit shows the most likely cause of the failure is CO_2 corrosion.

Table 2: Chemical analysis at different points shown in Fig. 3.

Location \ Element (Wt.%)	C	Al	O	S	Mn	Ca	Fe	Si
(Figure 3) A	17.63	0.25	39.89	2.51	0.24	0.33	38.77	0.38
(Figure 3) B	10.30	0.13	41.31	3.31	0.51	0.10	44.08	0.26
(Figure 3) C	5.89	0.18	2.21	0.19	0.57	0.06	90.61	0.29

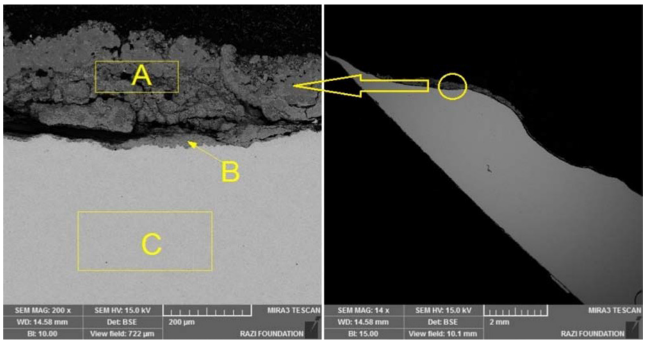

Figure 3: SEM image of the hole cross-section and EDS analysis locations.

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