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CORROSION FAILURE ANALYSIS OF CORRUGATED N10276 AND STAINLESS STEEL FLEX HOSES

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ABSTRACT

Flex hoses constructed from corrosion resistant alloys (CRAs) are commonly used to supply fuel gas to heat recovery steam generators (HRSGs) in plants. Due to their availability and relatively low cost, 304L/316L stainless steels (SS) are commonly used in flex hoses in these applications. However, due to the harsh nature of the fuel gases and the associated high temperatures, the service life of 304L SS is often shorter than desired. In particular, longitudinal welds in these hoses become susceptible to corrosion that can eventually lead to leakage.

This paper describes the failure analysis of a 3-inch (76-mm) 304L SS corrugated flex hose that developed leaks along its longitudinal weld. It was subsequently replaced by a N10276 hose, which remained in the same service for approximately 1 year before being retrieved for examination. The failure analysis included visual examination, photography and macrophotography, sectioning, analysis of deposits and corrosion products, quantitative chemical analysis, metallography, scanning electron microscopy, and energy dispersive x-ray spectroscopy. A metallurgical analysis of the weld microstructure was also performed for both materials.

The analyses showed that the 304L SS flex hose ruptured along its longitudinal weld due to excessive corrosion caused by high concentrations of chloride. By contrast, no evident pits or corrosion formed on the inside surface of the N10276 corrugated hose, indicating that N10276 provides good corrosion resistance in fuel gas service.

Keywords: 316L stainless steel, N10276, welds, flexible hose.

INTRODUCTION

Flexible metal hoses, especially corrugated hoses, are commonly used in applications where corrosion resistance, pressure rating, and flexibility are key requirements. By selecting the proper material, corrugated hoses can be designed to withstand high pressures and provide maximum leak tightness.^[1–3] The hose's flexibility is achieved by the elastic behavior of the corrugation profile.

Corrugated hoses are commonly used in refinery applications, with 304L/316L SS materials often used due to their availability and relatively low cost. These alloys contain nickel and other elements to increase their chemical resistance.^[4]

A failure investigation was performed on 304L and N10276 (Alloy C-276) flex hoses^[5–6] that were used to supply fuel gas to the heat recovery steam generator (HRSG) in a plant. Results of the analyses are summarized in this paper.

FAILURE ANALYSIS

304L Stainless Steel Flex Hose

A leak developed in a 3-inch (76-mm) diameter SS flex hose following an unspecified length of service supplying fuel gas to an HRSG. The failed flex hose is shown in Figure 1. Discoloration of the outer braided jacket was evident and indicated either the location of the leak or external contamination of the hose. Identification markings on one of the flanges indicated NPS 3, 150-pound, ASME SA-182, Type 304/304L SS.



Figure 1: Leaking fuel gas 304L flex hose as received for analysis. Numbered scale divisions are inches/cm.

Figure 2 shows the inside surface of the corrugated inner tube of the hose as viewed through one of the flanges. A region of deposits and/or corrosion products was observed.

A portion of the braided external jacket was removed from the hose by sectioning, which exposed the leak site. The leak was determined to be the result of a rupture that followed the longitudinal weld of the corrugated inner tube of the hose (Figure 3).

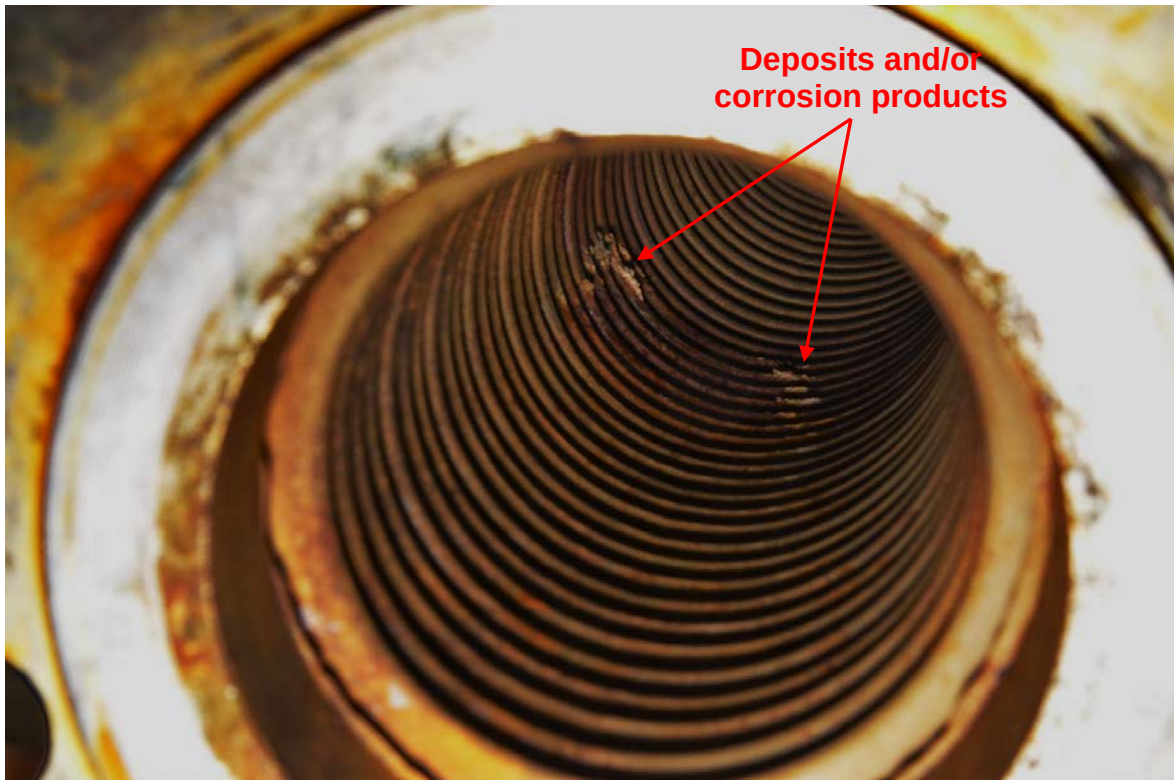


Figure 2: Inside surface of the corrugated 304L flex hose inner tube. Deposits and/or corrosion products were observed.

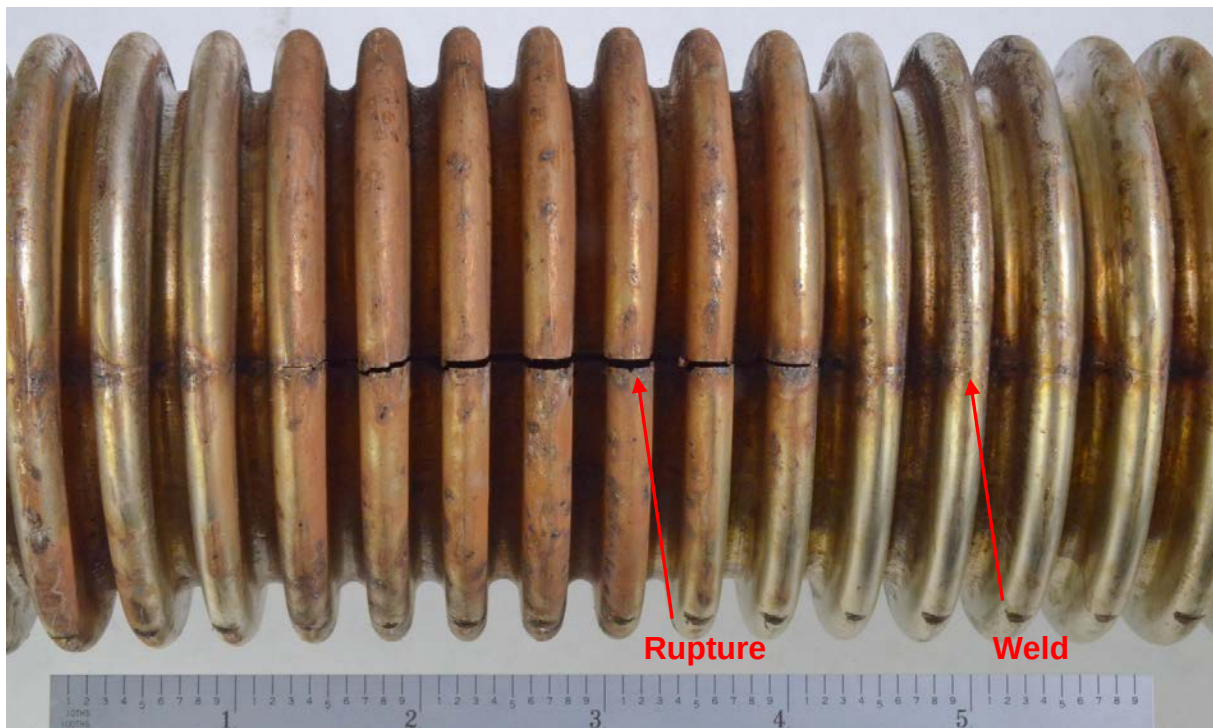


Figure 3: External surface of the corrugated 304L inner tube after removal of the braided outer jacket. Rupture followed the longitudinal weld of the corrugated tube. Major numbered scale divisions are inches.

The inner tube was further sectioned to expose the fracture surfaces of the rupture, as well as the internal surface of the tube. Figure 4 shows the mating surfaces of the rupture and the region of heaviest deposits and/or corrosion products on the inside surface of the corrugated tube.

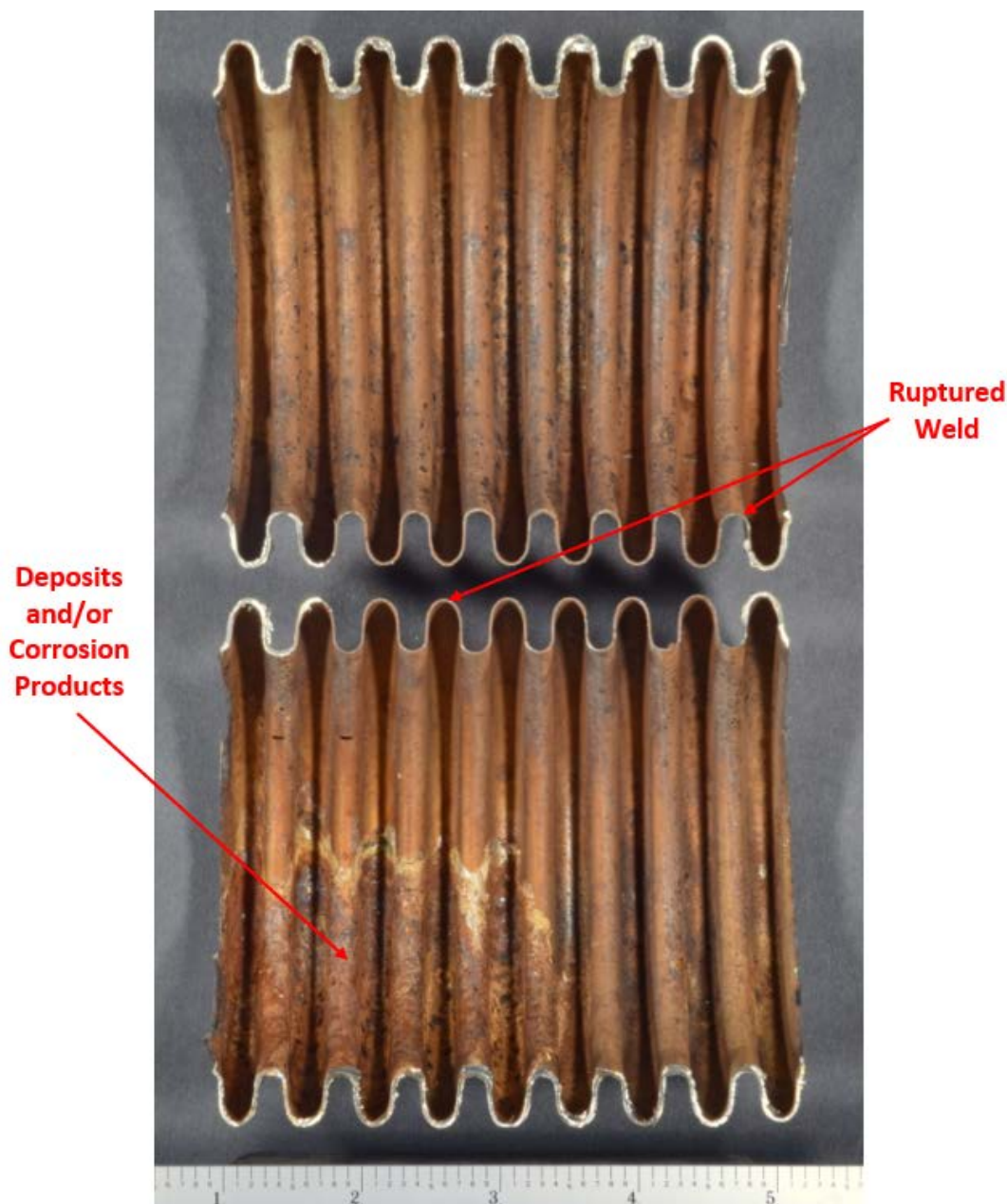


Figure 4: Inside surface of the corrugated 304L inner tube at leak site. The ruptured longitudinal weld is brown compared to the shiny metallic appearance of sectioned corrugations. Major numbered scale divisions are inches.

At higher magnification, Figure 5 shows that the rupture preferentially followed the fusion lines of the longitudinal weld. Corrosion pitting was observed on the interior surface of the corrugated inner tube (Figure 6).