

Corrosivity Assessment of Three New Gas Transmission Lines

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ABSTRACT

The purpose of this study was to perform lab analysis to assess the corrosivity of fluids transported through three transmission lines from Gas Compression Plants (GCPs) to Gas Plants (GPs), where CO₂ varies from 44 to 55 mol%, and H₂S varies from 9 to 40 mol%. The study consisted of four parts: 1) corrosion rate prediction using corrosion modeling; 2) uniform corrosion measurements in liquid and gas phases; 3) pitting corrosion measurements in liquid and gas phases; and 4) gas phase corrosion measurements. The highest corrosion rate measured under simulated field conditions was 144 mpy which is much less than the 1500 mpy obtained by running corrosion prediction modeling (CPM). The highest water film average wall shear stress estimated by CPM for the three lines was 14 Pa. The highest corrosion rate value, i.e. 144 mpy, was measured at a wall shear stress of 29 Pa assuming a worst-case scenario. Pitting attacks were observed under one test conditions in the tests left running for a period of 14 days. The results show that sweet corrosion rates in the liquid phase are comparable or higher than sour corrosion rates, while in the gas phase sour corrosion rates are higher than their sweet counterparts. Unlike CO₂, the presence of H₂S appears to facilitate wetting of the steel surface in the gas phase. Gas phase corrosion was studied at low velocities to avoid any water splashing. The highest measured corrosion rate value in the gas phase was 52 mpy.

Key words: corrosivity assessment, gas transmission lines, rotating cage

INTRODUCTION

The design packages for the construction of three new gas transmission lines are being optimized. These transmission lines will transport gas from Gas Compression Plants (GCPs) to Gas Plants (GPs). The gas compositions of these transmission lines have been benchmarked against existing gas services in the company and found no identical or similar conditions. Corrosion prediction modeling estimated very high corrosion rates (>1500 mpy) by feeding applicable operating scenarios. Therefore, it was necessary to confirm predicted corrosion rates through lab testing in order to ensure suitable material selection with adequate corrosion mitigation options. The aim of this study was to assess the corrosivity of the transported fluids in the three gas transmission lines in terms of general corrosion, pitting corrosion, and top-of-the-line corrosion (TLC).

Knowledge of the transmission line skin temperature is required to simulate TLC. Normally, TLC is driven by an abrupt drop in external temperature leading to water condensation selectively on top of the line.¹⁻³ Runs by OLGA flow modeling predict the fluid temperature to fluctuate between 140°F at the inlet of the pipeline to ~105°F at the outlet of the pipeline; a portion is shown in Figure 1. The direct skin temperature was assumed to be equal to the fluid temperature. The employed heat transfer model assumes a soil temperature of 60°F and a low flowrate case of 227 MMSCFD.

The presence of organic acids would aggravate TLC.⁴⁻⁶ According to the field personnel, however, organic acids are not expected to present. Since the direct skin temperature was assumed to be equal to the fluid temperature and since there are no organic acids present in the stream, the study focused on gas phase corrosion rather than TLC only. The difference is that in the case of gas phase corrosion all internal surfaces exposed to the gas are considered rather than top of the line only. Therefore, we elected to use gas phase corrosion to refer to the whole surface exposed to the gas phase attack including top of the line.

The absence of dissolved solids and bacteria, which were confirmed by the proponent, eliminated the need to study for scaling and microbiologically-influenced-corrosion (MIC). The laboratory study therefore consists of four parts: 1) corrosion rate prediction using corrosion modeling;⁷ 2) uniform corrosion in liquid and gas phase; 3) pitting corrosion in liquid and gas phase; and 4) gas phase corrosion.

EXPERIMENTAL PROCEDURE

The objective of this study was to assess the corrosivity of the gas transmission lines which was predicted by corrosion modeling to be extremely high (> 1500 mpy). This was conducted by performing both corrosion prediction modeling and laboratory tests simulating the conditions in these three lines. In this study, corrosion modeling was performed using Multicorp 5.5⁸. In developing the laboratory test matrix, the Process Flow Diagrams (PFDs) and the Heat and Mass Balance (H&MB) reports were reviewed for the service conditions of the three lines projected for years 2024 through 2043. The three lines are arbitrarily labeled as GTL-AA, GTL-BB, and GTL-CC. Three types of corrosion attacks were investigated, namely, uniform corrosion, pitting corrosion, and top-of-the-line-corrosion (TLC). To address the different corrosion attacks, in total eighteen (18) laboratory test conditions were developed. The test matrix includes service conditions for the three gas transmission lines along with corresponding virtual lines containing CO₂ only.

In all tests, deionized water was used as the test solution representing condensate water. The volume of the solution was 600 mL except for the gas phase corrosion tests where the volume was 500 mL. The autoclave dead volume is about 1000 mL. To study both uniform and non-uniform attacks, the tests were run over relatively short and long periods of time. For uniform corrosion, the tests were run for 18 hours to avoid artificial retardation of corrosion rates due to formation of corrosion products which is attributed to the limited amount of test solution in the laboratory set-up. For non-uniform corrosion, tests were run for 14 days to allow pits to form and populate. Moreover, corrosion rates in both liquid and gas phases were measured in all tests.

To conduct these experiments, high-pressure / high-temperature (HPHT) rotating cage systems were used. One-liter autoclave reactors were used to conduct the short- and long-term corrosion tests under simulated dynamic field conditions. A typical autoclave reactor is shown in Figure 2. Also shown is a rotating cage apparatus used to generate controlled dynamic (flow) conditions inside the reactor. A typical rotating cage used to measure corrosion rates in both liquid and gas phases is shown in Figure 3. The reactors and the rotating cage assembly are constructed from Hastelloy C-276. Carbon steel coupons, CS1018, were used in these autoclave tests. Table 1 gives a typical chemical composition of

these coupons. The carbon steel coupons were degreased and cleaned before and after testing in accordance with ASTM G 1¹⁰.

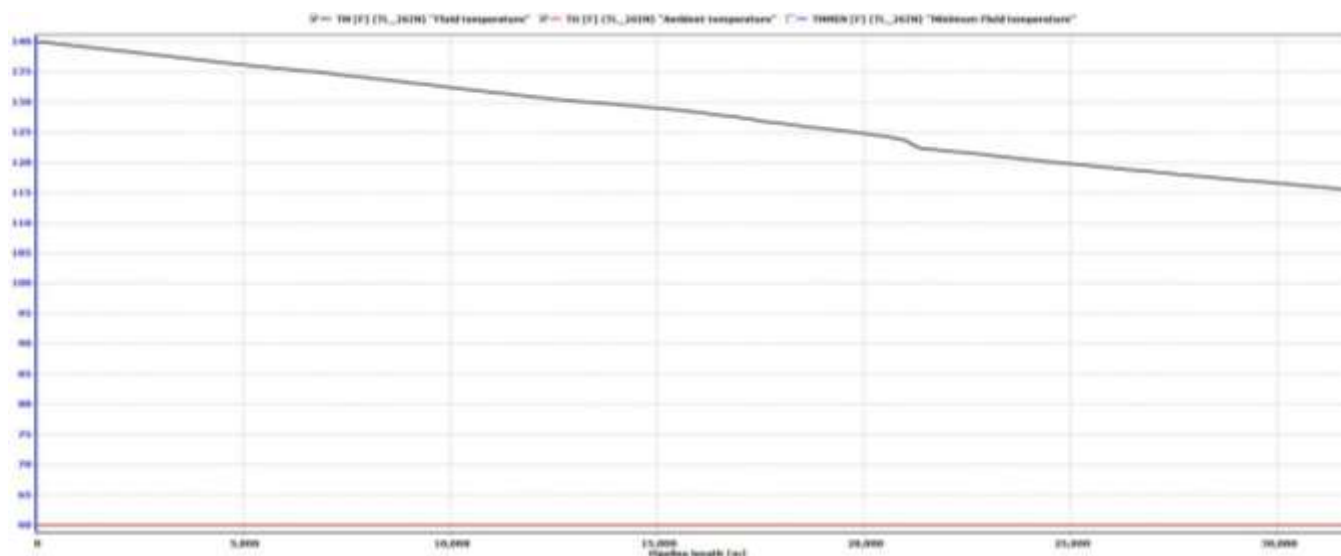


Figure 1: The fluid temperature fluctuates at GTL-AA between 140°F at the inlet of the pipeline to ~105°F at the outlet of the pipeline (not shown). The direct skin temperature was assumed to be equal to the fluid temperature. The employed heat transfer model assumes a soil temperature of 60°F and a low flowrate case of 227 MMSCFD.⁹

Test coupons were installed into the rotating cages after cleaning and weighting. For each test, an assembly consisting of top and bottom rotating cages was used with each cage containing two test coupons. The whole assembly was then mounted into the autoclave. The test solution, i.e. deionized water, was purged with nitrogen gas for two hours to remove dissolved oxygen. The test solution was then transferred into the autoclave vessel. The vessel was closed and all necessary connections were made ready to start the test. The autoclave was heated to the desired temperature 140°F (60°C). The shaft rotation was set at the desired rotation speed. The gases were introduced to the reactor chamber. First H₂S was introduced until the required pressure was achieved followed by CO₂ to arrive at the final total pressure. The rotating cage assembly was left in the autoclave reactor for either 18 hours or 14 days and then was removed. The corrosion rates were calculated by taking the weights of the cleaned coupons before and after exposure.

The following empirical equations were used to estimate the highest average, τ_{mean} , and instantaneous, τ_{95} , wall shear stresses on the surface of the rotating coupons¹¹:

$$\tau_{mean} = \alpha \times RPM^{\gamma} \times \eta^{\lambda} \quad (1)$$

$$\tau_{95} = \beta \times RPM^{\gamma} \times \eta^{\lambda} \quad (2)$$

Where,

- τ_{mean} = Maximum average wall shear stress (Pa)
- τ_{95} = Maximum instantaneous wall shear stress (Pa)
- $\alpha, \beta, \gamma, \lambda$ = Empirical constants determined experimentally
- RPM = Speed of the rotating cage in revolution per minute
- η = Hydrodynamic viscosity (mPa.s)

The hydrodynamic viscosity, η , of distilled water at 140°F/60°C is equal to $466.5 \times 10^{-6} \text{ Pa.s}^{12}$. Table 2 gives the two different rotating cage wall shear stresses for the three different rotation speeds by substituting the values of η and RPM into Eq.'s 1 and 2.

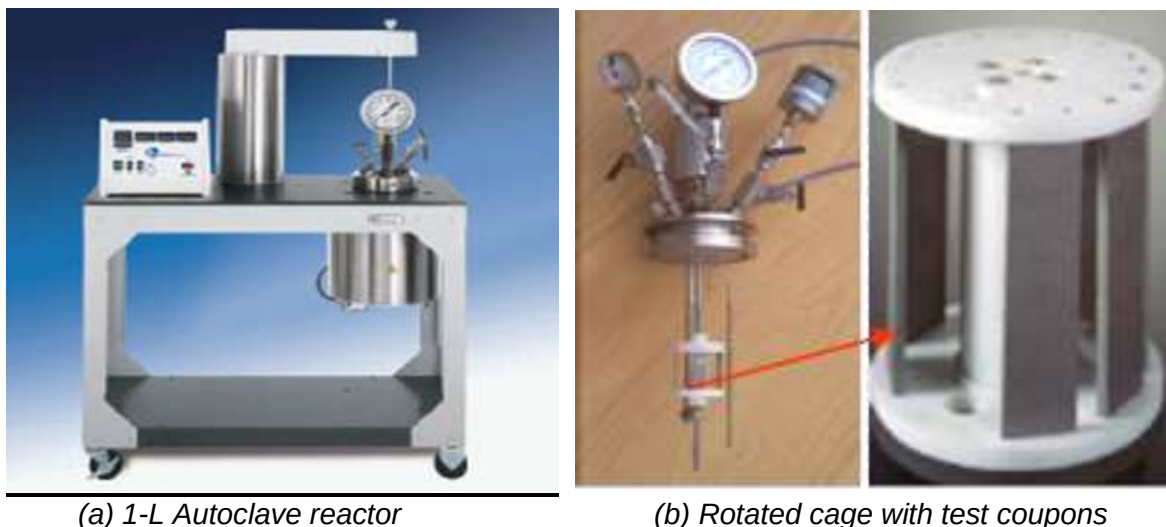


Figure 2: Photographs of the autoclave setup (a) and the rotated cage with test coupons (b).

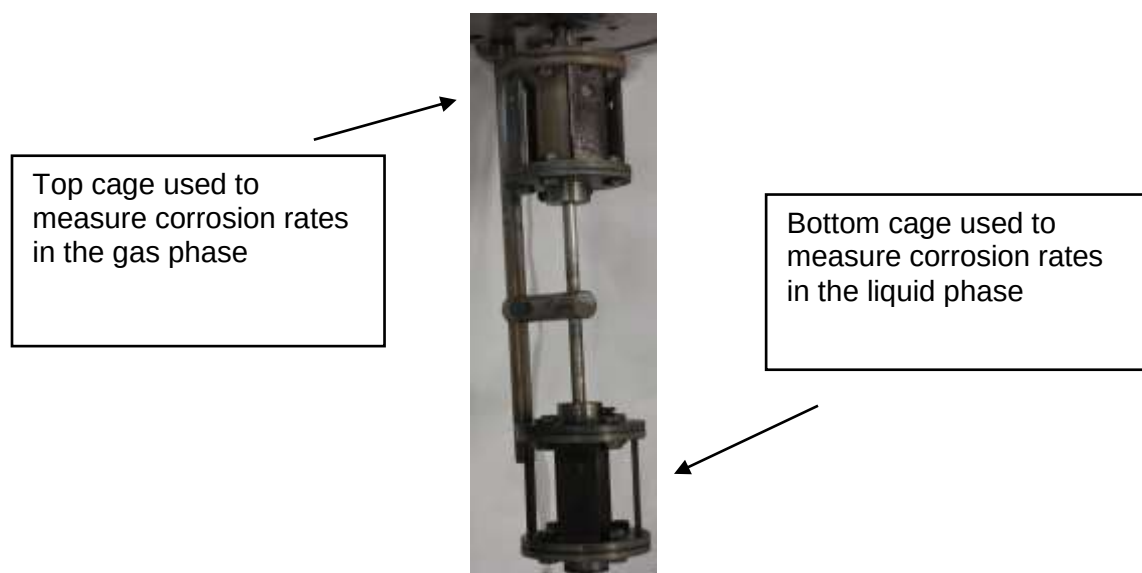


Figure 3: Photograph of a typical rotated cage assembly used to measure corrosion rates in both gas (top) and liquid (bottom) phases.

Table 1
Test Coupons CS1018 Data

UNS	G10180
Density (g/cm ³)	7.87
Element	Content (%)
Manganese, Mn	0.60-0.90
Carbon, C	0.15-0.20
Sulfur, S	0.05 (max)
Phosphorous, P	0.04 (max)
Iron, Fe	Balance