

## **Laboratory Investigation of Susceptibility of Carbon steel to Amin SCC in Monoethylene Glycol**

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### **ABSTRACT**

High pH (11-11.5) measured in Glycol units due to Monodiethanol amine (MDEA) carryover from sweetening units was a concern as it is generally considered that caustic cracking is possible at these conditions in equipment not subject to post weld heat treatment (PWHT). However, risk of amine stress corrosion cracking (SCC) in glycol rich system is not well studied or documented to define the limits. Monitoring of pH may not be the right integrity operating window (IOW) parameter as it may not reflect the actual risk of Amine SCC. Laboratory testing was performed to determine the susceptibility of welded carbon steel specimens (ASTM A106 Gr.B and ASTM A 516 Gr.70) to amine SCC under field conditions of glycol contactor at 190 °C, in monoethylene glycol (MEG) mixture at pH 11. A blank test at pH 8 was conducted for comparison. The testing indicated that there is no perceptible detrimental impact of the presence of amine in glycol on non-post weld heat treated carbon steel.

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Key words: Amine SCC; Glycol; dehydration; carbon steel

## INTRODUCTION

Carryover of amine from acid gas removal units (AGRU) results in an increase in pH of glycol in many dehydration units that are downstream of AGRU. The pH of the liquid samples from glycol dehydration units were reported to be in the range of 11-11.5 exceeding the integrity operating window of 10.5 which was in place to avoid caustic SCC.

Piping and equipment in the glycol dehydration process units are not subject to PWHT as Amine SCC was not identified as a probable degradation threat. It was not evident if the increase in pH due to amine carryover presented a risk of Amine SCC in carbon steel equipment of glycol process, particularly at higher temperatures like in the reboiler section which operates at about 190 °C. McIntyre et.al reported that caustic cracking was not observed in testing at pH 14 in the glycol solution but there is no similar reported data on amine SCC in glycol medium [1]. In order to further analyse the potential risks associated with the increase in pH from amine carryover and the susceptibility of carbon steel to amine SCC, laboratory testing of the materials of construction of the piping and equipment was considered essential.

The main factors considered when deciding on what test method to proceed with is precision of results and time; as the glycol units have been experiencing this increase in pH for several months and the probability of failure occurring was a concern. Therefore, slow strain rate test was deemed to be suitable for evaluation of susceptibility to amine SCC of CS material; as it provides precise results in a short period of time therefore providing the assurance needed to the company.

## EXPERIMENTAL

All carbon steel pipe and plate specimens were as per ASTM A 106 and A 516 specifications. Elemental compositions of these alloys are provided below

**Table 1**  
**Chemical Composition of ASTM A516 and A106 carbon steel in mass%.**

| Alloy | C        | Si    | Mn          | P    | S     | Al   | Cr  | Cu  | Ni  | Mo   | Nb   | Ti   | V    | Fe  |
|-------|----------|-------|-------------|------|-------|------|-----|-----|-----|------|------|------|------|-----|
| A516  | 0.1-0.22 | 0.6   | 1.0 - 1.7   | 0.03 | 0.03  | 0.02 | 0.3 | 0.3 | 0.3 | 0.08 | 0.01 | 0.03 | 0.02 | Bal |
| A106  | 0.25     | > 0.1 | 0.27 - 0.93 | 0.03 | 0.035 |      | 0.4 | 0.4 | 0.4 | 0.15 |      |      | 0.08 | Bal |

All the specimens were machined as per NACE TM0198 recommendations except that the thread diameter was 8mm. The gage length was 25.4mm and the diameter was 3.45 – 3.48 mm with the cross-sectional area being ~ 9.6 – 9.8 mm<sup>2</sup> as shown in Figure 1. Tensile specimens were machined carefully to achieve near zero stress during grinding. In the case of welded specimens, machining was done such that the welds were at the centre of the gage length. The gauge was grinded to P600 grit finish and all the specimens were checked for quality to ensure that no scratches, markings or rust were observable using optical microscopy or through the naked eye. Tensile specimens were washed with deionized water and dried quickly and degreased ultrasonically in acetone for 15 minutes followed by rinsing in isopropyl alcohol (IPA) for 10 minutes and dried under N<sub>2</sub> flow prior to loading. Slow Strain Rate Testing was adopted to investigate susceptibility to SCC of carbon-steel specimens (also with welds).

**Table 2**  
**Test Matrix for SSRT testing**

| Test (NACE TM0198)             | Alloys types      | Electrolyte                                       |
|--------------------------------|-------------------|---------------------------------------------------|
| SSRT (4 x 10 <sup>-6</sup> /s) | 2 CS -A516 & A106 | 99% TEG + 1% Water (pH adjusted to 11.2)          |
|                                |                   | 99% TEG + 1% Water (pH not adjusted, measured ~8) |
|                                |                   |                                                   |

|                               |                               |                                                   |
|-------------------------------|-------------------------------|---------------------------------------------------|
| SSRT ( $4 \times 10^{-6}/s$ ) | 2 CS -A516 & A106 (with weld) | 99% TEG + 1% Water (pH adjusted to 11.2)          |
|                               |                               | 99% TEG + 1% Water (pH not adjusted, measured ~8) |
|                               |                               |                                                   |

A strain rate of  $4 \times 10^{-6}/s$  or a constant extension rate (CERT) of  $1 \times 10^{-4}$  mm/s was chosen such that it would account for the effect of strain and the time of exposure to the glycol media at 190° C. This strain rate was chosen in accordance to NACE TM0198 testing recommendation. In addition, this was also based on achieving a balance between the exposure time to account for the efforts of corrosion and the overall duration testing. The Glycol-water solution was made by mixing 99 vol.% of Triethylene Glycol (TEG) and 1 vol. % of de-ionized (DI) water. The pH of this mixture was ~ 8.0. Monodiethanol amine (MDEA) was added to increase the pH ~ 11.2 for testing at elevated pH. It is to be noted here since the water content was quite low in the mixture, at least 10 vol.% of MDEA was required to increase the pH to ~ 11.2.

A 2.2-liter Hastelloy autoclave, connected to a 10,000 lbf tensile machine (Figure 2) from CORTEST Instruments<sup>†</sup>, was used for Slow Strain Rate Testing (SSRT) of carbon steel exposed to Glycol media. Test data (stress vs elongation) was collected every 20 seconds during the test. Prior to conducting SSRT experiments, the autoclave was thoroughly cleaned, and pressure tested to ensure leak free experimentation at elevated temperature and pressures.

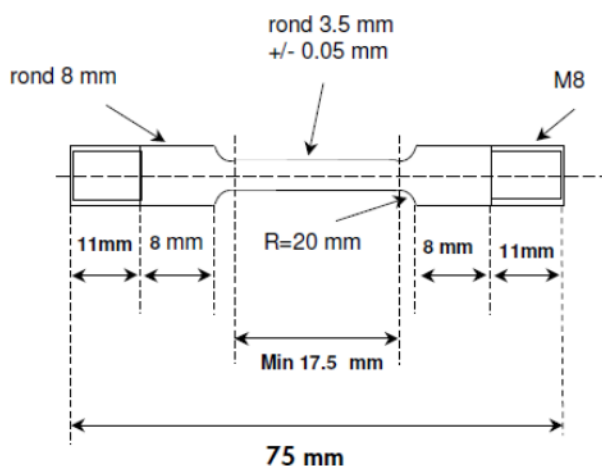


**Figure 1: Schematic of Tensile specimens as per NACE TM0198 used for SSRT**

The prepared Glycol-water mixture was transferred into the autoclave and de-aerated by N<sub>2</sub> purging for at least 2 hours prior to the start of the experiment. After de-aeration, the specimen was inserted through the fixture inside the autoclave and was again purged with N<sub>2</sub> prior to heating. Heating was through an external heater jacket. Once the temperature reached 190°C, the specimen was preloaded to 45 N/mm<sup>2</sup> at a higher CERT of  $3.5 \times 10^{-4}$  mm/s after which the SSRT commenced with a CERT of  $1 \times 10^{-4}$  mm/s. Pressure of 5-6 bars N<sub>2</sub> was maintained in the autoclave to prevent evaporation of water. Baseline testing of both these alloys (with welds) were done in air at room temperature and 190°C under N<sub>2</sub> atmosphere. For these baseline tests under N<sub>2</sub> environment, the thermocouple position was adjusted to sense the temperature on the surface of the specimen. Although testing the specimen under pure glycol (as an inert media) was considered, it was decided to use N<sub>2</sub> at temperature for baseline experiments. All specimens were tested until fracture. Then the autoclave was cooled and depressurized after which the tensile specimen was removed and cleaned in acetone ultrasonically and stored in a dry area for cross-sectional examination. The tensile specimens were visually observed for presence of macro scratches or nicks prior to testing and were discarded if any were present. All SSRT tests with specimens containing welds were done in triplicates and the parent metal specimens in duplicates to confirm repeatability of results.

