ABSTRACT

A Saudi Aramco Gas processing Plant commissioned in 1980 to process wet sour gas streams and produce dry sweet sales gas in addition Natural Gas Liquid (NGL). A detailed assessment study was conducted in this plant pertaining to Hydrogen Induced Cracking (HIC). Corrosion loops were established for the sour environment and revealed that HIC is one of the potential damage mechanisms that could affect the sour gas system. HIC is susceptible to be presented in the sour gas system because of the following criteria:

- Hydrogen sulfide (H$_2$S) concentration is ranging from 2-41 mol% which equivalent to 20,000-410,000 ppm of H$_2$S.
- Piping and vessels were fabricated by non HIC resistant material.
- Present of element sulfur in the streams.
- Temperature ranging from 120-280 $^\circ$F.
- Present of free water in the fluid stream.

INTRODUCTION

Hydrogen atoms are generated by corrosion reaction of H$_2$S and Fe in present of free water. The hydrogen atoms, which have the smallest atomic elements are diffuses into steel and traps in mill laminations or voids. Then, every two atoms combine together to form hydrogen molecular. As per the below the reaction in present of water:

\[
\begin{align*}
\text{H}_2\text{S} & \quad \rightarrow \quad 2\text{H}^+ + \text{S}_2^- \\
\text{Fe} + 2\text{H}^+ & \quad \rightarrow \quad \text{Fe}^{++} + 2\text{H}^0 \\
2\text{H}^0 & \quad \rightarrow \quad \text{H}_2
\end{align*}
\]

The trapped molecular hydrogen in the mill laminations or voids will have high internal pressure which will cause hydrogen blistering or cracking. For illustration, see Figure #1 to illustrate the reaction. And Figure #2 to illustrate the diffusion mechanism of hydrogen in the mill laminations or voids. Figure #3 an actual internal hydrogen blistering. Figure #4 an actual external hydrogen blistering.

The mechanism of HIC is similar to that for hydrogen blistering. If two or more adjacent blisters are close enough so that the crack tips are overlap, a series of stepwise cracks
(SWC) will be developed. In this stage, a potential dangerous situation which could lead to rapture and gas leak. As shown in Figure # 5 and Figure #6.

Figure #1

Figure #2

Figure #3
ASSESSMENT METHODOLOGY:
A detailed assessment study was conducted in plant pertaining to HIC. This assessment includes:

- The potential location of HIC damage in the system.
• Conduct comprehensive survey in the system.
• Assess the survey result.

All sour piping and vessels which have potential of HIC damage were identified. And a comprehensive survey was conducted for both piping and vessels. The techniques that used for the survey is advanced ultrasonic examination (P-scan ultrasonic mapping), which is used to detect corrosion, laminations, inclusions, HIC/blistering and any defect between the outer surface and the internal surface. The survey result revealed present of different damages such as

• Internal and external hydrogen blistering.
• HIC
• SWC

Inspection Techniques and Interpretation:

There were 140 pipe spools that were identified with HIC in the Plant facilities using ultrasonic on-stream inspection (OSI). The objective of this survey was to inspect, and identify severely effect plant piping to avoid occurrence of any catastrophic failure that could result from HIC/SWC damage.

Special techniques develop by Saudi Aramco utilizing Advanced ultrasonic systems (Advanced Ultrasonic inspection & Phased Array systems), to detect and confirm step-wise cracking. The results revealed Indications of HIC/blisters, categorized as moderate to severe and SWC have been recorded for many pieces of piping spools.

Based on the result of this assessment, significant cost savings through production loss avoidance was realized. Potential short term repair measures, including replacing the sever pipe spools with SWC, and extend the service life of the moderate affected piping until the next scheduled test and inspection T&I.
RECOMMENDATIONS
The assessment recommendations revealed the following:

Piping:
- A replacement program was established to replace the severely affected piping sections. In addition, planning to replace all the piping with HIC resistant material that meets international standard specifications for wet sour applications.
- Close monitoring for identified HIC damage to identify the crack growth rate.
Vessels:
- Isolate from operation any vessels that have severe HIC damage.
- Close monitoring for any identified HIC damage to identify the crack growth rate.

CONCLUSION
In conclusion, there are different type damage mechanisms for each process streams. It depends mainly to the process stream material and process parameters (temperature, pressure and compositions). Identification of potential damage type assists to determine the appropriate non-destructive test (NDT) type. Advanced ultrasonic inspection techniques have been successfully detected HIC and SWC. Long and short term replacement program for the HIC resistant pipe or vessels were established to avoid unscheduled shout down.

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