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Stress Corrosion Cracking of a Stainless Steel Vacuum Tower Bottom Line

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ABSTRACT

A refinery experienced an unexpected shutdown due to a power outage linked to an extreme weather condition. The loss of power lasted for 1 week and the utilities were down for a total of 2 weeks. As a consequence of the steam tracing being down for that long, heavy products like the Vacuum Tower Bottom (VTB) solidified in the piping systems. During the unplugging effort, a leak was discovered on a VTB piping circuit constructed of austenitic stainless steel. Therefore, before beginning to restart the unit and the refinery, an investigation had to be carried out to identify the origin and extent of the problem.

The cracking was initiated from the inside and propagated in a short period of time. The failure investigation identified the stress corrosion cracking by chlorides to be the mechanism involved, due to an inappropriate product used during the unplugging of the circuit. The consequences could have been much worse as cracking only affected a limited part of the circuit but could have impacted it entirely which would have resulted in a much higher economic impact for the plant. In circumstances like the one encountered after a major power outage where the resources are stretched in a short timeframe between the different recovery efforts, the need of having guidance for the "unplugging of heavy product lines" is key to ensure the integrity of equipment and the safety of people.

This paper describes the investigation that was performed to identify the corrosion mechanism involved and especially the reason why it took place.

Key words: stress corrosion cracking, stainless steel, unplugging, chlorides

INTRODUCTION

A refinery experienced an unexpected shutdown due to a power outage linked with an extreme weather condition. The loss of power lasted for 1 week and the utilities were down for a total of 2 weeks. As a consequence of the steam tracing being down for that long, heavy products like the Vacuum Tower Bottom (VTB) solidified in the piping systems.

For heat recovery purpose, VTB is used to heat the crude feed in the Atmospheric Crude Unit (ACU). The VTB circuit is spread between the Vacuum Distillation Unit (VDU), the ACU and the Outside Battery Limits piping (OSBL) in between, as presented in figure 1.

During the unplugging effort, a leak was discovered on a VTB piping circuit almost entirely constructed of ASTM A312 TP317L stainless steel (austenitic stainless steel). The stainless steel piping installed 7 years before has only seen one stop during a shutdown which was 3 years before the leak. Hence, before beginning to restart the unit and the refinery, an inspection and failure investigation had to be carried out to identify the origin and extent of the problem. This stand-by situation had some significant economic impact associated.

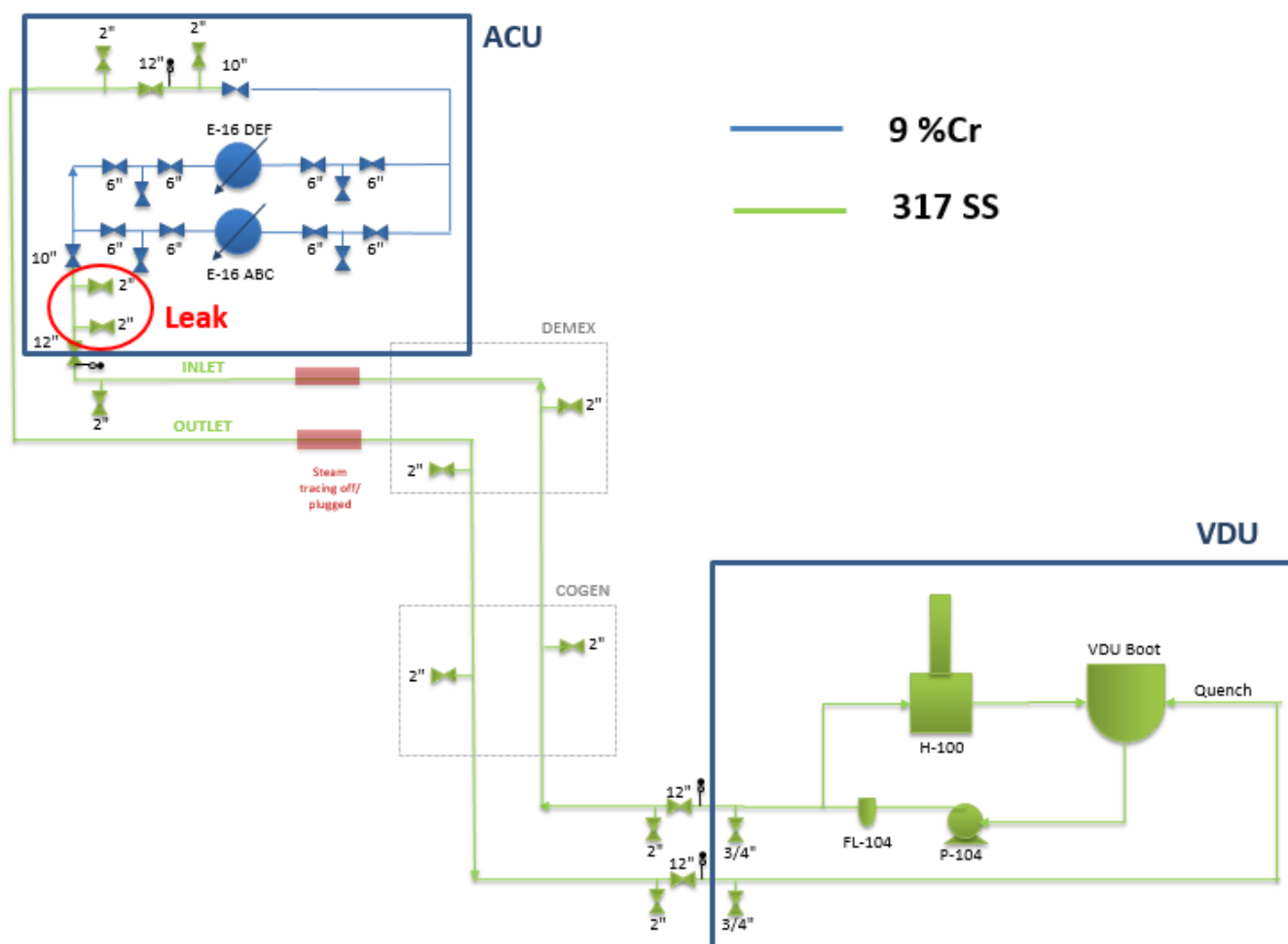


Figure 1: ACU and VDU VTB loop

INSPECTION

The visual inspection localized the leak near a circumferential weld between a 12" piping and an elbow. The crack was adjacent to the steam tracing tubing. A Penetrant Testing (PT) was done on the Outside Diameter (OD) in order to identify the exact location of the leak. Multiple crack like indications were found. The cracks were oriented longitudinally on the piping side of the weld and were relatively close to the bottom of the horizontal run of piping. It was not possible to determine if the cracks were originated from the ID or the OD. The inspection department did not recommend installing an engineered clamp or a welded leak enclosure because of the presence of cracks.

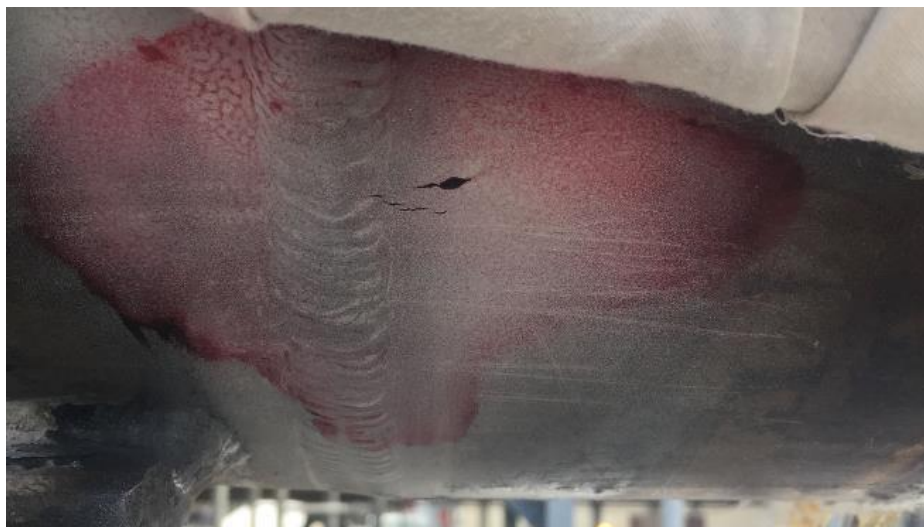


Figure 2: Cracking highlighted by PT (cracking occurred next to the steam tracing tubing)

A full volumetric inspection with advanced (Non-Destructive Testing) NDT was performed on the weld seam and expanded to several adjacent piping welds to determine if it was an isolated event or more widespread. The inspection NDT used were "UT shear wave" and "Phased Array" (figure 3). The first results showed additional cracking indications on adjacent welds, therefore, a much more extensive inspection campaign was carried out on all the concerned piping circuit.

The coverage done and the results found for the VTB loop were the following ones:

- 100% welds inside ACU battery limit (ISBL): 60% of the austenitic stainless welds showed indications but nothing found on the 9%Cr piping part. Some of the indications found were proved-up after destructive examinations.
- 20% welds inside VDU battery limit: 0% cracking indications – 100% austenitic stainless steel.
- 10% welds OSBL piping: 0% cracking indications – 100% austenitic stainless steel.

Inspection scope limitation:

A 100% coverage of all the welds would have been a huge scope impacting the refinery restart schedule. The restart of the refinery was on hold, waiting for the outcome of the investigation. 10% of the OSBL welds already represented a considerable scope as the ACU and the VDU were not close from each other. The coverage done and the absence of indications both on the OSBL and the VDU ISBL was deemed enough in terms of risk management to justify stopping the inspection. At that time, it was suspected that the degradation was only limited at the ACU ISBL piping.

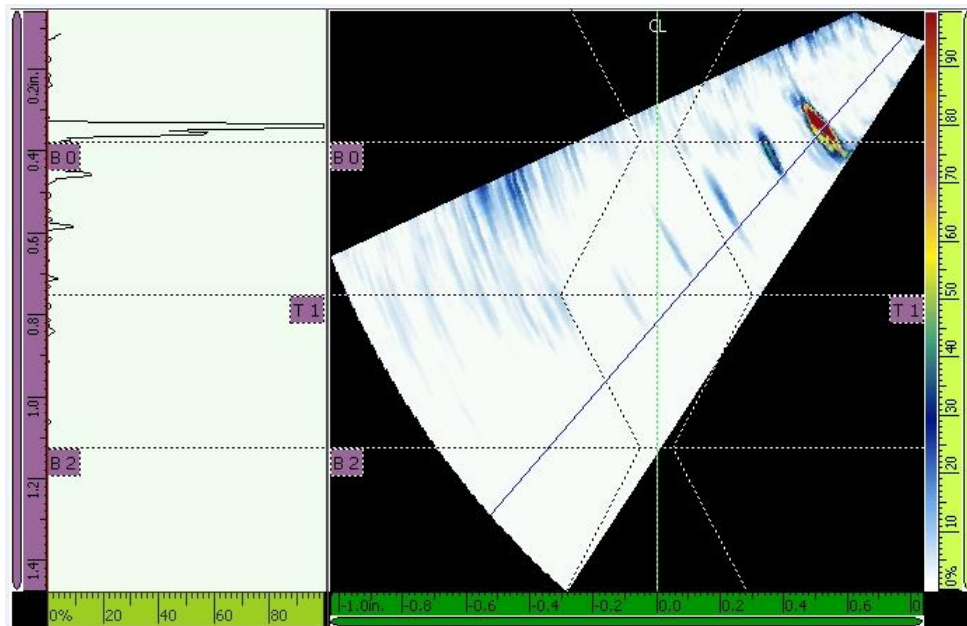


Figure 3: Phased Array scan showing an indication

The main takeaways of this inspection were that “no” cracking was found outside ACU battery limits and that the cracking only concerned the 317 stainless steel.

FAILURE INVESTIGATION

Several corrosion mechanisms could have led to the stress corrosion cracking of the 317 stainless steel:

- ID stress corrosion cracking by chlorides^{1,2,3}
- OD stress corrosion cracking by chlorides Under Insulation (CUI) due to the rain event and poor insulation,
- ID stress corrosion cracking by caustic^{4,5}.

NDT results and macroscopic observations:

The absence of NDT indications on the 9%Cr was pushing to rule out the “ID stress corrosion cracking by caustic” hypothesis which should have affected both metallurgies (ferritic and austenitic structures) at this temperature even though the 9%Cr welds were heat treated.

To investigate further, the piping spool containing the cracks was cut out and split for investigation. The ID observations highlighted (figures 4 & 5):

- Larger cracks on the ID than on the OD → damaged initiated from the ID,
- Presence of pitting → characteristic of the presence of: “chlorides and free water” for austenitic stainless steels like the 317, but also of stagnant conditions.