IN-SITU METALLOGRAPHY OF A HIGH TEMPERATURE SHIFT CONVERTER

EXAMPLE REPORT

OVERVIEW

Inspection of an ammonia plant high temperature shift converter was performed during a shutdown. The evaluation found, of the six locations evaluated, one panel to exhibit service degradation. Neighbouring material, as close as 2” had not experienced the same degradation suggesting an issue with the degraded panel material. Further PMI was recommended of the panel.

A weld crack found during NDT inspection was found to have been a hot tear having been there since original welding.

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1.0 INTRODUCTION

In-situ metallography was conducted upon a High Temperature Shift Converter (HTS) at six weld locations to assess for service degradation. The converter was made of SA 204B (½ wt% Mo) low alloy steel.

During magnetic particle inspection of the vessel, a crack was found along the lower circumferential seam weld. Evaluation of this weld crack was included.

The following report summarizes the observations obtained.

2.0 EXAMINATION

Through the use of microscopes, examination of the steel can provide information regarding the current material condition and assess if the material had thermally degraded during service. In-situ metallography is a non-destructive method used to perform this examination on-site.

Figure 1 displays the six weld locations evaluated. For the ease of reference, these locations are referred to by their numerical sequence of examination. These locations were prepared by successive grinding and polishing to a 1µm finish. The surface was then etched using 3% nital and examined at 200x magnification. Replications were made and examined under an optical microscope in laboratory conditions.

Figure 2 displays Locations #1 (lower circumferential weld) and #2 (lower pedal weld). Examination of Location #1 found microstructural features typical of the as-

SUMMARY

One lower pedal exhibited potential service degradation. The degradation was the result of either high temperature hydrogen attack (HTHA) or thermal degradation. No cracks, creep voids or micro-fissures were observed. As the neighbouring pedal did not exhibit degradation, this may suggest an issue with the material of the affected pedal. It is recommended that during the next inspection opportunity (a) the lower pedas be PMI’d and (b) monitored by in-situ metallography.

The remainder of the five locations evaluated did not exhibit any signs of service degradation (ie. no HTHA or thermal degradation).

The transverse crack on the lower circumferential weld found by MPI was a hot tear crack formed during welding. The primary tear and numerous other micro-tears were located adjacent a weld start or stop.
manufactured SA 204B steel and weld. Illustrated in Figures 3 and 4, the plate material comprised of ferrite, bainite and some pearlite. No decarburization indicative of hydrogen attack, thermal degradation or cracks/micro-fissures were observed.

Location #2 did show signs of service degradation. One of the pedals adjacent the evaluated weld exhibited a significant reduction of bainite/pearlite. This could have either been from (a) high temperature hydrogen attack or (b) thermal degradation. Note that the weld and opposing side did not exhibit the same microstructural change. Figure 5 compares the structures of the two plates on either side of the pedal weld. The interpretation of this is further discussed in Section 4.0.

Figure 6 displays the transverse crack at Location #3 which had been detected during magnetic particle inspection. Upon grinding and etching, it could be seen that the crack was situated at the end of a weld start or stop. Upon etching, the primary crack was found to contain high temperature oxide and exhibited an intergranular fracture path, typical of a hot tear. Numerous other fine hot tears were located in the vicinity. Therefore, the crack had formed during welding. Figures 7 and 8 display the micro-features of the hot tear crack.

Locations #4 (longitudinal weld), #5 (mid-height circumferential weld) and #6 (inlet tube weld) comprised of microstructural features typical of the as-manufactured condition. No service degradation in the form of high temperature hydrogen attack, cracking or thermal degradation were observed at these locations. Figures 9-11 display Locations #4-6.

3.0 DISCUSSION

One lower pedal exhibited microstructural degradation associated with service. The degradation was either (a) decarburization indicating high temperature hydrogen attack or (b) severe spheroidization from thermal degradation. The microstructure appeared to be more the latter, thermal degradation, however, decarburization indicative of HTHA could not be ruled out. Both of these scenarios seem peculiar considering the neighbouring pedal had not degraded, even though it was less than two inches away from the affected zone. This could suggest some issue with the affected pedal material, potentially a difference in the pedal chemistry. It is advised that PMI be conducted on the bottom pedals during the next opportunity. The evaluated pedal weld was immediately below the top inlet entry and, due to the grinding, should be easy to find.

No cracks, creep voids or micro-fissures were observed on the affected pedal. It is advised that the pedals be closely monitored and in-situ metallography be performed during future inspection opportunities.

The transverse crack at Location #3, on the lower circumferential weld, was a large hot tear formed during welding. Optical examination found the majority of the primary crack to have existed after welding. With the oxide present within the tear, it would suggest this crack had been opened to the surface after welding. Therefore, it was unclear how
this tear had not been observed during previous inspections. Ultimately, the cause of the crack was associated with an issue during manufacture and not with service degradation.

No service degradation or issues were observed at the remaining four locations evaluated.

4.0 CONCLUSIONS

The evaluation found one lower pedal evaluated to exhibit service degradation. The degradation was either the result of high temperature hydrogen attack or thermal degradation. In either case, no cracks, creep voids or micro-fissures had formed. The neighbouring pedal, only two inches away, did not exhibit any notable deterioration. Assuming the neighbouring vicinities experienced relatively similar operating conditions, this may suggest an issue with the material of the affected pedal. It is recommended that during the next inspection opportunity (a) the lower pedals be PMI’d and (b) monitored by in-situ metallography.

The remainder of the five locations evaluated did not exhibit any signs of service degradation (ie. no HTHA or thermal degradation).

The transverse crack at Location #3 on the lower circumferential weld was a hot tear crack formed during welding. The primary tear and numerous other micro-tears were located adjacent a weld start or stop.
Figure 1: Schematic displaying the locations evaluated by in-situ metallography and hardness testing on the HTS.
Figure 2: Photographs displaying the locations of the (1) lower circumferential weld and (2) a pedal weld.
Figure 3: Micrographs from the replica taken at Location #1 (lower circumferential weld) of the top edge of the weld. The base metal, heat affected zone and weld metal were typical of the as-manufactured condition. No evidence of HTHA, cracks or thermal degradation was observed.
Figure 4: Micrographs from the replica taken on the bottom portion of Location #1, of the lower circumferential weld on the pedal side. No evidence of HTHA, cracks or thermal degradation was observed.
Figure 5: Micrographs of the replica taken from Location #2 of a lower pedal weld. The base microstructure on one of the two pedal welds was not consistent with SA 204B steel. This indicated service degradation during service from either HTHA or, more likely thermal degradation. No cracks or micro-fissures were present. It is recommended that this pedal be subjected to PMI and closely monitored during future shut-downs.
Figure 6: Photographs displaying the crack at Location #3 which had been detected by magnetic particle inspection. After grinding and etching, it was found that the crack had initiated at a weld start or stop.
Figure 7: Micrographs from the replica of Location #3 displaying numerous hot tear cracks at the edge of the weld start/top. The hot tears were filled with high temperature oxide. These tears, and the majority of the crack, had formed during welding.
Figure 8: Micrographs displaying one end of the crack at Location #3. The crack comprised of oxides near the end, suggesting the majority of the crack at this plane had existed after welding. Numerous, sub-surface hot-tears were also within the vicinity. No evidence of HTHA or service degradation was observed.
Figure 9: Micrographs of the replication taken from Location #4, a longitudinal weld on the bottom portion of the converter. No evidence of HTHA, cracks or thermal degradation was observed.
Figure 10: Micrographs of the replication taken from Location #5, the mid-height circumferential weld. No evidence of HTHA, cracks or thermal degradation was observed.
Figure 11: Micrographs of the replication taken from Location #6 at the inlet region. No evidence of HTHA, cracks or thermal degradation was observed.