IN-SITU METALLOGRAPHY OF LINEAR INDICATIONS ON HEATER TUBES

EXAMPLE REPORT

Modified from Original Report

OVERVIEW & OUTCOME

This work was completed within 24 hours.

In-situ metallography found that the heater tube NDT indications were not cracks yet rather, material flaws that had been there since original manufacture twenty years before. These flaws had not been a problem during service. The refinery removed the flaws by light grinding.

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IN-SITU METALLOGRAPHY OF LINEAR INDICATIONS ON HEATER TUBES

SUMMARY

During shutdown, planned inspection of a heater found numerous linear, crack-like indications on several tubes. This heater was critical path and its operation needed to run the plant. Steel Image was requested to non-destructively evaluate these features and determine their nature. The tubes had been installed in 1996 and comprised of ASTM A312 TP321 seamless stainless steel tube.

Figure 1 displays examples of the linear features on Tubes #21 and #22. Each of these sites were prepared for in-situ metallography by grinding and then polishing to a 1µm finish. Replicas of the features were made in the as-polished and after electrolytically etching using 10% oxalic acid.

Optical examination of the replications from each site found the tubes’ core material to be in good condition. Each site comprised of equiaxed austenite (Figure 2). No detrimental phases, such as sensitization or sigma phase, were present. No features were observed that would have increased the tubes’ susceptibility to cracking or corrosion.

Figure 3 displays the linear indication present on Tube #21 after preparation. Examination by in-situ metallography found the irregular morphology of the feature to be consistent with an entrained material flaw (i.e. large inclusion, Figure 4). The linear feature was not a crack yet rather a material flaw that had been present since original manufacture of the tube. No cracks had initiated from the material flaw.

Figures 5 and 6 display a similar material flaw on Tube #22. Whereas the features was originally continuous, light grinding had caused the feature to become intermittent. This could suggest that the feature was relatively shallow and had been nearly ground out. In-situ metallography found this feature to also be consistent with material entrained into the steel (Figure 7). No cracks were observed to have initiated from the intermittent entrained material.

CONCLUSIONS

The linear indications present on Tubes #21 and #22 comprised of entrained material flaws (i.e. large, complex inclusions). Such foreign material is most often embedded into the steel during casting yet, sometimes can be introduced during tube forming. In either case, these linear flaws had been present on the original tubes. The type of material entrained into the steel cannot be determined by non-destructive techniques.

No cracks had initiated from these flaws during the past twenty-two years of service. Therefore, these flaws had been benign at the operating conditions experienced. Unless the operating pressure/stress were increased, it was likely that these flaws would not present a significant reliability risk under similar loading/operating conditions as the historical service.

The core material/microstructure of the tubes had not degraded during service. No features were observed that would have increased the tubes’ susceptibility to cracking or corrosion.
Figure 1: Photographs displaying the linear, crack-like features found by the refinery inspection group on (a) Tube #21 and (b) Tube #22.
Figure 2: Micrographs displaying the core structure of Tube #21 adjacent the linear indication. No concerns with the microstructure were observed. No significant sensitization (carbide formation) or sigma phase had occurred. No degradation was observed that would have increased the tube’s susceptibility to cracking or corrosion. Images taken from replications, electrolytically etched on-site using 10% oxalic acid.
Figure 3: Photographs displaying the linear indication on Tube #21 in the (a) as-found condition, (b) after grinding and (c) after complete preparation.
Figure 4: Micrographs displaying the top of the feature along Tube #21. Its irregular morphology was a material flaw comprising of foreign material entrained into the steel. This flaw had been introduced during casting at steelmaking. No cracks had formed from the material flaw. Images taken from replications, electrolytically etched using 10% oxalic acid.
Figure 5: Photographs displaying a similar linear indication on Tube #22.
Figure 6: Photograph displaying the feature on Tube #22 after light grinding. Whereas the features was originally continuous, light grinding had caused the feature to become intermittent. This could suggest that the feature was relatively shallow and had been nearly ground out. In either case, the intermittent nature of the feature was consistent with a material flaw, not a crack.
Figure 7:  Micrographs of several of the intermittent lengths of the linear indication along Tube #22. These features were consistent with entrained material flaws that had been present within the original tube material. No cracks had formed from the material flaw. Images taken from replications, electrolytically etched using 10% oxalic acid.