FAILURE ANALYSIS OF HYDROTESTED ASTM A519 CARBON STEEL TUBE

EXAMPLE REPORT

OVERVIEW & OUTCOME

Steel tubing purchased overseas and distributed by a Steel Distributor had failed during pressure testing by a client manufacturer. Due to the time sensitive nature of the situation, analysis was conducted locally to provide immediate answers.

Analysis found that the tubes comprised of seam defects which resulted in tube failure at low pressures. Therefore, the problem was a quality issue initiating at the steel producer. This material lot was deemed unfit for service.

Also found during the investigation was that the client manufacturer had performed a braze heat treatment which reduced the material strength below the specified ASTM A519 requirements. The client manufacturer was made aware of this and they decided to purchase a different material condition to accommodate their process.

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FAILURE ANALYSIS OF HYDROTESTED ASTM A519 CARBON STEEL TUBE

SUMMARY

The failure of an ASTM A519 tube during hydrostatic pressure testing was the result of a seam protruding through the majority of the tube wall thickness. The seam was the result of foreign material entrapped within the steel during the steelmaking process. This material was deemed unfit for the intended application.

1.0 INTRODUCTION

A Steel Distributor submitted a failed, cold drawn 1” OD ASTM A519 1026 steel tube for analysis. Upon delivery to the client manufacturer, the tube had been cut to length, cleaned, brazed at 2020°F and zinc plated. Subsequently, the tube failed during hydrostatic pressure testing at 200psi. The pass rating for this pressure test was 7000psi.

2.0 EXAMINATION

2.1 Visual / Macroscopic Examination

Figure 2 displays the crack found on Tube Sample #1 which had resulted in failure during pressure testing. The through-crack was located at mid-length of the tube and was measured to be approximately three inches long. The through-crack had slightly opened. No deformation or necking had occurred. Neighbouring, fine cracks were observed adjacent the through-crack.

A series of cracks were present opposite the through-crack. Figure 3 displays the cracks on the opposite side of the tube as the through-crack.

Both sets of cracks were cut and opened for examination of the fracture surfaces. Examination of the through-crack found the majority of the surface to have been zinc coated. Therefore, these features had pre-existed the galvanizing process. No macroscopic fracture features were observed due to the zinc coating on the fracture. Figure 4 displays the through-crack fracture surface.

The fracture surface opposite the through-crack is displayed in Figure 5. The crack had extended just beyond half the wall thickness. The entirety of the feature surface had also been covered in zinc.
2.2 SEM Examination

The cracks on the Failed Tube were prepared and examined by a scanning electron microscope (SEM). Examination and energy dispersive spectroscopy (EDS) analysis confirmed the surfaces had been covered in zinc (Figure 6). Amongst the zinc, particles were found which EDS analysis found to consist predominantly of silicon, calcium and oxygen (Figure 7). Lesser amounts of sodium, aluminium, titanium, potassium and manganese were also present. These elements were typical of entrained mould powder from the casting process. Therefore, these features had been seam defects formed by the presence of unwanted material caught into the steel during casting.

3.3 Optical Examination

Transverse cross-sections were taken through the main crack, the edge of the through-crack, adjacent the through-crack and at a remote location. A remote, longitudinal cross-section was also taken. Optical microscopy found seam defects to have been filled with zinc from the galvanizing process (Figure 8). The opaque entrained mould powder material was visible within the seam defect.

Also of note, the manufacturer had effectively annealed the tube material during the 2020°F brazing operation. ASTM A519 is ordered in the cold drawn condition which is critical for obtaining the specified mechanical properties (Figure 9). During the brazing operation, the applied temperatures annealed out the cold worked structure, expected to reduce the strength and hardness.

3.0 CONCLUSIONS

Failure during pressure testing was the result of a quality issue with the tube material. The failed tube comprised of seam defects from the presence of entrained material in the steel. The seam defect significantly reduced the effective wall thickness of the tube, resulting in tube failure at low pressures. The entire material lot would be at risk of having these defects and it is recommended the supplier consider the lot unfit for service.

Seam flaws are the result of unwanted material becoming entrapped in the steel during casting. The composition of the entrained complex silicate material indicated it may have been entrained mould powder used during the steelmaking/casting processes. It is recommended that the material producer further investigate the origins of the entrained material.

Although not a significant contributor to failure, it should also be noted that the 2020°F heat treatment during the brazing operation had annealed out the cold-worked structure from the as-supplied condition. This would significantly reduce the tube strength and the steel can no longer be expected to conform to the ASTM A519 mechanical requirements. It is advised that the client manufacturer be aware that the material strength may no longer meet their design criteria due to their processing.
Figure 1: Photograph displaying the Failed Tube submitted for analysis.

Figure 2: Photographs displaying the crack resulting in leaking on Failed Tube (failed during pressure testing) and an adjacent crack. Further examination would find these to be seam defects which extended through the majority of the tube wall thickness.
Figure 3: Photograph displaying cracks, later identified as seam defects, on the opposite side as the crack displayed in Figure 2.
Figure 4: Photograph displaying the opened surface of the through-crack. The crack surface had been zinc plated.

Figure 5: Photograph displaying the opened crack surface of the crack opposite the through-crack on the Failed Tube (crack displayed in Figure 3). The crack depth was just beyond half of the wall thickness. The crack surface had been covered with zinc and therefore, the crack had pre-existed the coating process.
Figure 6: SEM images and an EDS spectrum of the through-crack fracture surface. The majority of the fracture surface had been covered by zinc. 20kV.
Figure 7: SEM images displaying particles of entrained material on the crack surface. EDS analysis of the entrained material found it to comprise of elements typical of mould powder from casting. 20kV.
Figure 8: Micrographs of the edge of the through-crack. The crack had been filled with zinc. Some regions of the crack consisted of entrained material, consistent with the mould powder detected by EDS analysis. Therefore, these features were seam defects, formed by the presence of entrained material caught in the steel during casting. As-polished condition.
Figure 9: Micrographs displaying (a,b) the cold worked structure of the as-supplied material for ASTM A519, 1026 steel. (c,d) The microstructure of the Failed Tube had annealed out the cold worked structure which would result in a reduction in strength. Etched using 3% nital.