RTI PAST PERFORMANCE	
RTI Tracking Number:	1307139 Date:7/3/2013
Core Task:	Metallurgical Testing
Analytical Techniques	Metallurgical

REPORT OF ANALYTICAL SERVICES

RTI Lab#: 1307139-001A **Sample Receipt Date: 7/3/2013**

Metallographic observations:

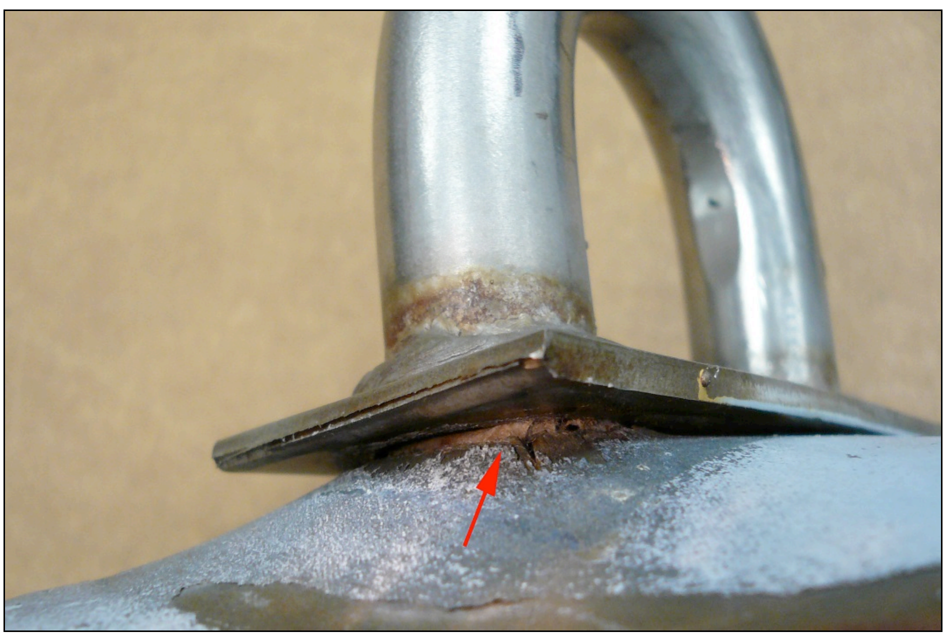
Two (2) failed in service roof anchors were received for analysis (See Fig 1). The target of the analysis was to investigate the nature of the failure by using a variety of the metallographic techniques. It should be noted that the client did not provided engineering drawing and /or service manual for roof anchors. The results of the analyses are provided below.

As-received for analysis. Figure 1. Reduced size.

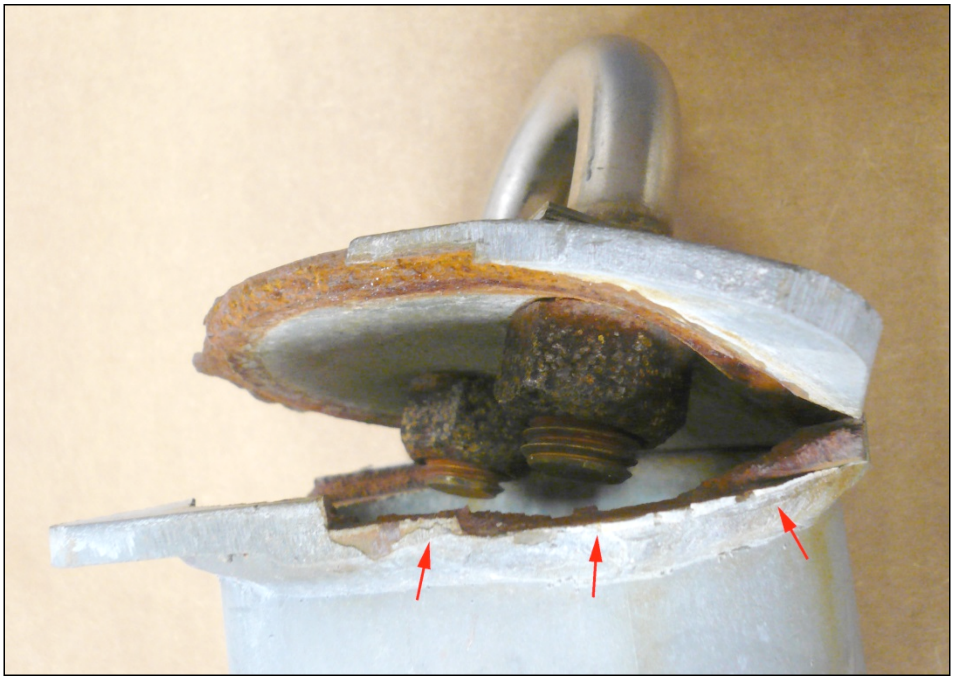
Macro Examination.

Macro examination, both visual and under a low power microscope has revealed a series of conditions as follows:

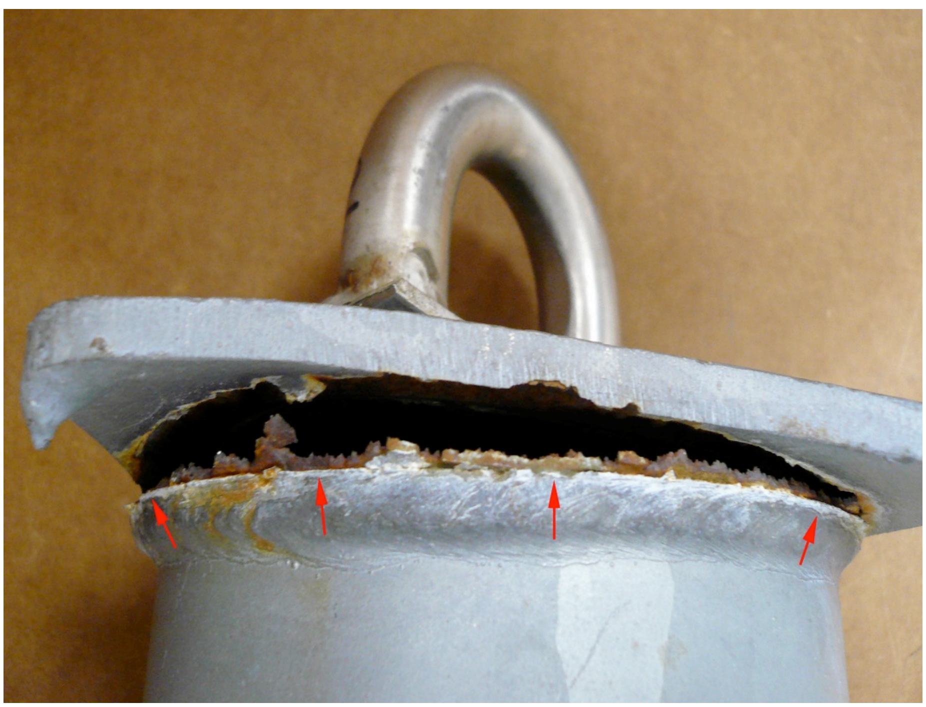
1. It is important to note that the entire fracture surface of both samples was obliterated due to heavy corrosion. However, there are number of secondary features that relate to the failure.
2. Both roof anchors appear to experience angular tension loading (most likely cycle loading – which is evident in the fractured steps throughout the failed welded region) for some period of time. The fracture occurred at the opposite side from the tension load (see fig1).
3. The angular tensile load was so severe that cause plastic deformation of the round top plate and yielding of the U-bolt holes (see fig. 2). It should be pointed out that, the plastic deformation of the U-bolt holes unsealed the inner chamber of the roof anchor and exposed to the external environment.
4. The evidence of the severe corrosion of the nuts in the inner threaded portion of the U-bolts in compressing to the rest of the inner surfaces of the roof anchor confirms original entrance of the condensate (see fig. 3 and fig. 5).
5. In both samples condensate also precipitated at the circumference at the root portion of the weld between tube and top round plate (see fig.5) and ceased crevice corrosion.
6. The circumferential crack also originated at the root portion of the weld and propagate in steps (indication of the cycle loading) toward the weld face (see fig.6).
7. The final catastrophic fracture occurred between circumferential weld interface and top round plate (see fig. 3 & fig.4).



As-received for analysis. Figure 2. Enlarged size
Red arrow points to the failed region.

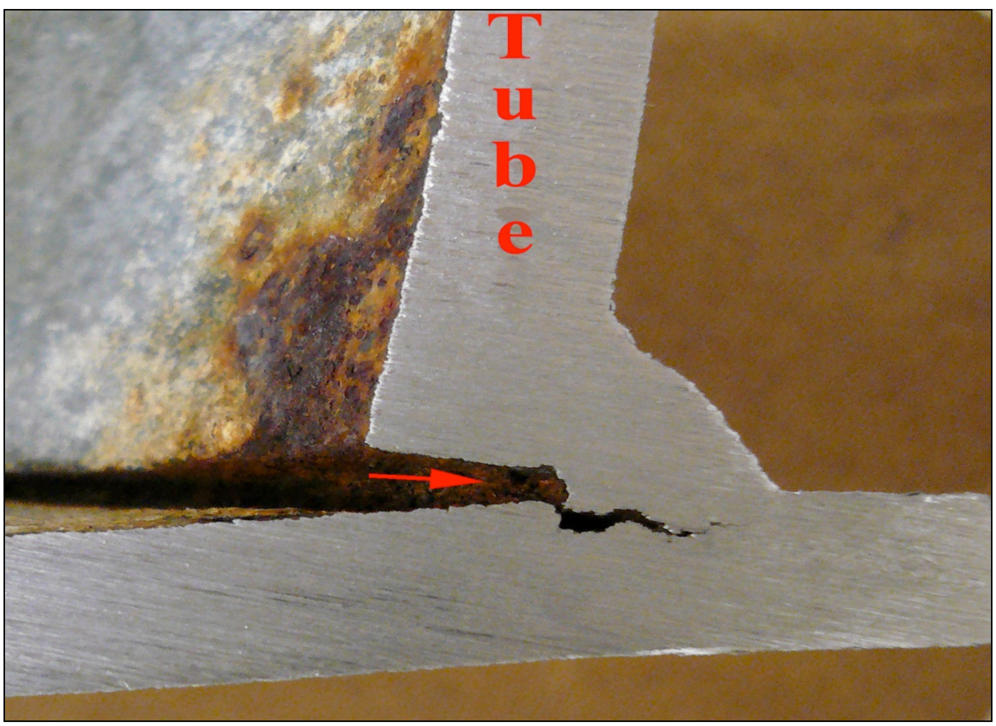


As-received for analysis. Figure 3. Reduced size.
Roof anchor #1. Red arrows point to the fractured region.



As-received for analysis. Figure 4. Reduced size.
Roof anchor #2. Red arrows point to the fractured region.

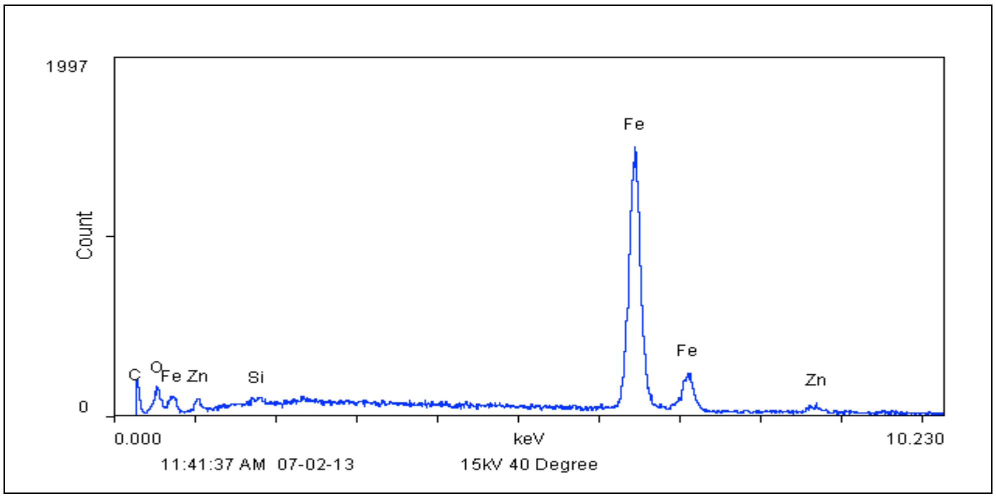
As-received for analysis. Figure 5. Reduced size.
Roof anchor #2. Micro-image illustrates inner condition of the roof anchor.



As cross-section condition. Figure 6. Reduced size.
Roof anchor #2. Macro-image illustrates origin of the fracture (red arrow).

EDS Analysis:

The target of the analysis was to elementally characterize the corrosion deposit at the weld-fractured surface using the technique of EDS (Energy Dispersive X-ray Spectroscopy) for qualitative identification of elements with atomic number greater than-ten. The resulting EDS spectra are attached hereto and are described on the following pages.



Elemental Content

Major (>10%)	Moderate (2-10%)	Minor (<2%)
Oxygen	Carbon	Silicon
Iron	Zinc	

Note: EDS spectrum obtained on the top surface of the part using 15kV beam voltage.

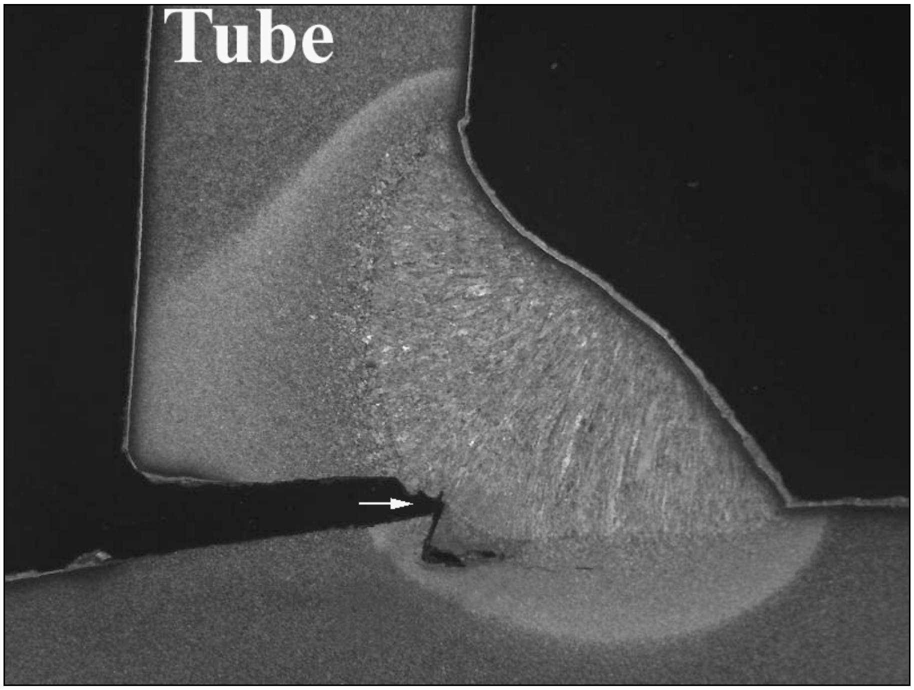
Note: Based on the elemental analysis of the corrosion product it can be concluded that the fractured surface has no evidence of specific ions or substances that have been known to cause and/or accelerated corrosion.

Metallographic observations:

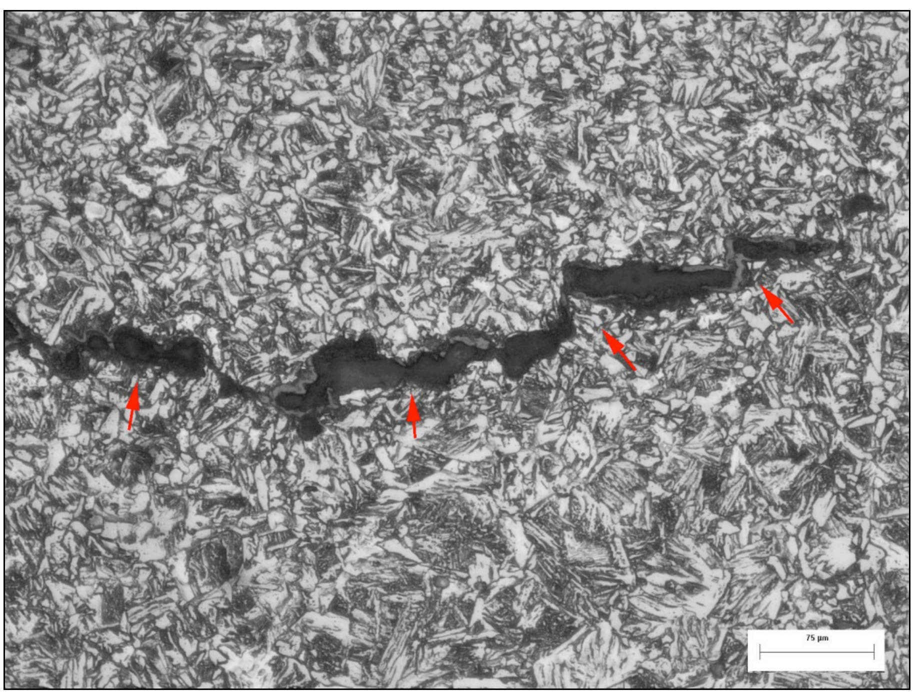
To further the investigation Roof anchor #2 was sectioned transversally throughout fractured region (see fig. 6), metallographically prepared in accordance with ASTM E3-11, and microscopically examined in the as-polished and etched conditions.

Metallographic examination of the etched cross-section revealed that the fracture originated at the root portion of the weld and propagated throughout heat-affected re-crystallized region at the round plate side (see.fig.7). It should be noted that the weld also has very shallow fusion at the failed region. Undercut is also present. The microscopic examination of the fracture revealed tearing (tensile overload) morphologies (see fig. 8).

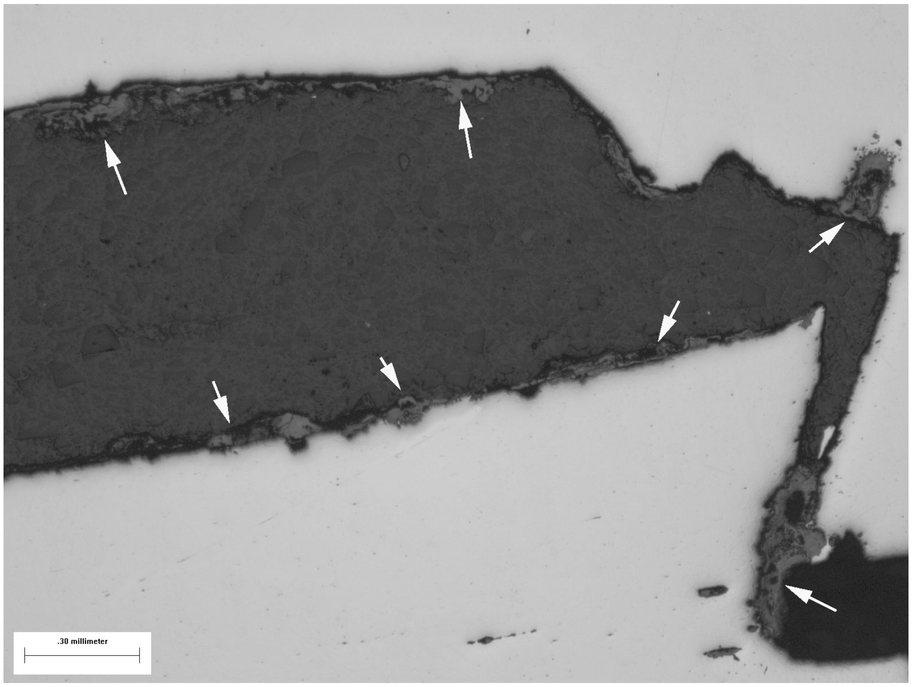
Metallographic examination of the as-polished cross-section revealed some corrosion product at the fracture surfaces (see fig. 9 & fig. 10). However, there was no evidence of severe corrosion attack, which can promote catastrophic failure. In addition, the fracture associated with heavy series if alumina type non-metallic inclusions (see fig. 10 & fig.11). It should be pointed out that the residual stress at the welded region and numerous case non-metallic inclusions will decreases strength of the welded joint to any tensile loading.



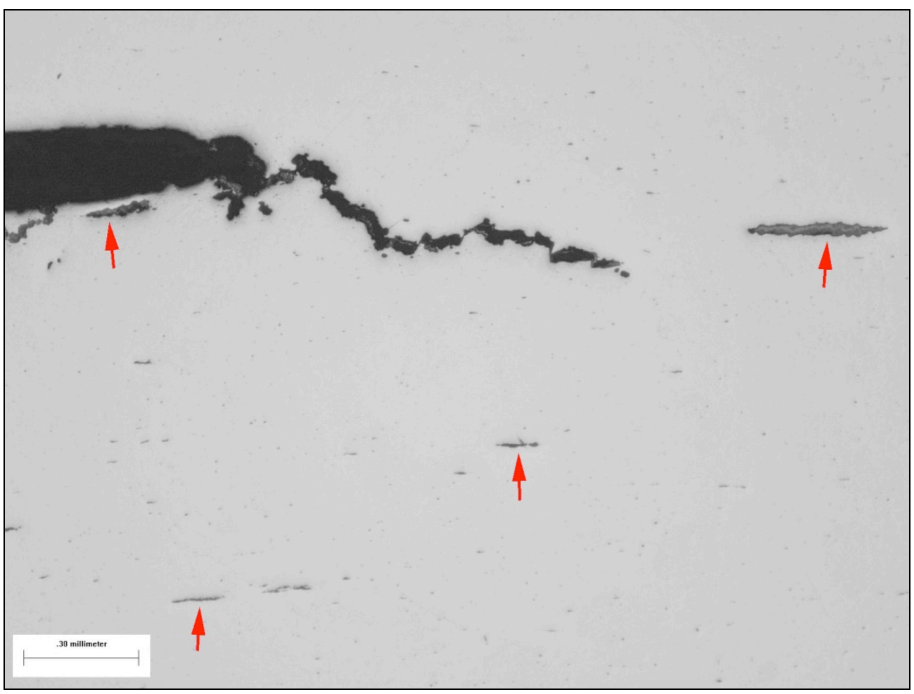
Etched condition. Figure 7 7x
Micro-image illustrates transverse cross-section fractured region.



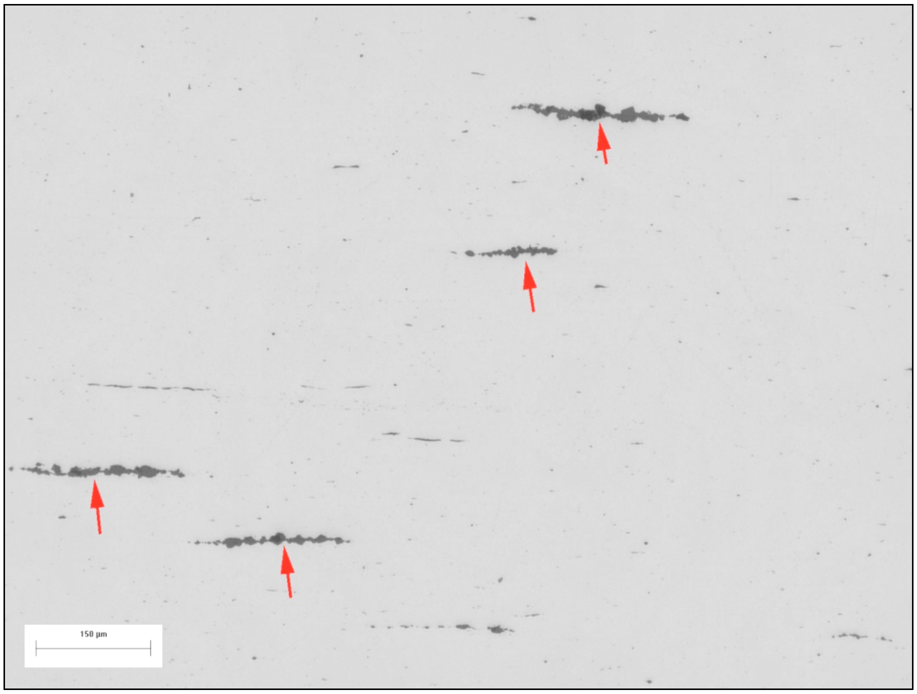
Etched condition. Figure 8 200x
Micro-image illustrates tearing morphologies.



As polished condition Figure 9. 50x
Micro-image illustrates corrosion product at the origin of the fracture.



As polished condition Figure 10. 50x
Micro-image illustrates corrosion product at the end portion of the fracture.



As polished condition Figure 11. 100x
Micro-image illustrates numerous heavy series if alumina type non-metallic inclusions in the round plate matrix.

Conclusion:

It is our considered opinion in view of the conditions observed in the samples submitted that the roof anchors failed due to tensile overload, which exuded strength of the part. The weld interface between tube and top round pate was most vulnerable to the failure. The corrosion process caused only secondary damage.