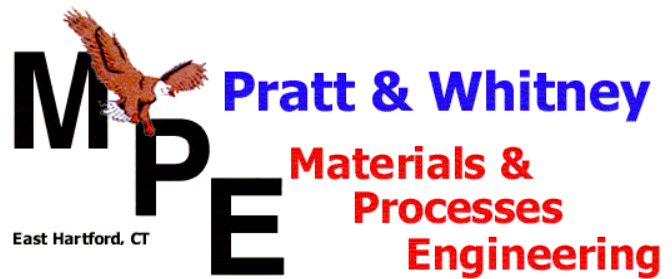


Metallurgical Investigation Final Report



Subject: Metallurgical Investigation of Delta Air Lines PW2037 Engine No. 716595

Date: January 2nd, 2018

Summary and Conclusions:

Following the investigative teardown of the subject PW2037 engine at Delta TechOps, Atlanta, Georgia, one fuel nozzle and the SVA hose and tube assembly were returned to Pratt and Whitney for metallurgical investigation.

Visual and X-ray examination of the fuel nozzle and B-nut assembly found that the B-nut appeared cross threaded on the nozzle. Examination of a section prepared through the center of the joint found that at most one thread was engaged. The tube was not fully seated on the nozzle. The nozzle side O-ring appeared intact; however, the tube side O-ring was only partially intact. Fragments of the tube side O-ring were noted in the area of the Voi-Shan seal.

The lack of the tube side O-ring and lack of engagement by the B-nut cone seat likely allowed fuel leakage that led to the observed fire.

1.0 Background

PW2037 engine serial number 716595 was installed in the number 1 (left) position of a Delta Air Lines Boeing 757-232, aircraft registration N686DA. On September 6, 2017, the engine experienced an undercowl fire at rotation during takeoff from McCarran International Airport (LAS) in Las Vegas, Nevada. The aircraft completed an uneventful overweight landing at LAS.

The engine was shipped to Delta TechOps in Atlanta, Georgia for NTSB-led teardown. Teardown and a leak check per the engine manual of the fuel manifold identified a leak at the B-nut and nozzle interface at the 3 o'clock position (labeled #7). The fuel supply line was cut and the nozzle and B-nut assembly were returned to Pratt & Whitney East Hartford for investigation. Additionally, the stator vane actuator (SVA) hose and tube assembly was returned for examination.

2.0 Details of Examination

One fuel nozzle and the SVA hose and tube assembly were submitted for review. Detailed examination of each component was as follows.

2.1 Fuel Nozzle

Visual examination of the fuel nozzle found that no significant distress was observed. The nozzle heat shield was intact and was dark brown in color. The B-nut was still in place; the attached tube had been sectioned in order to facilitate removal from the engine without moving the B-nut. The fuel nozzle was identified as being from position 7 (Figure 1).

Prior to any further analysis, the fuel nozzle was submitted to the Pratt & Whitney Quality & Standards Laboratory for X-ray examination. X-ray found that the B-nut appeared cross threaded on the fuel nozzle with at most one thread engaged (Figure 2). The B-nut contains approximately 9-10 threads and the mating thread on the fuel nozzle has approximately 13 threads.

Continued visual examination of the fuel nozzle confirmed that the B-nut appeared to be tilted relative to the nozzle platform and threads. Review of the end of the B-nut found that the tube was not centered in the nut (Figures 3-4).

A metallographic section (section a-a) was prepared through the nozzle and tube assembly, as shown in Figure 4. Examination of the section confirmed that at most one thread was engaged. The tube and B-nut were not fully seated. The nozzle was tilted relative to the B-nut, indicating that it was cross threaded. The nozzle side O-ring appeared in place and intact in the groove. The tube side O-ring was only partially intact; some pieces of O-ring were noted in the area of the Voi-Shan (conical sheet metal) seal (Figure 5). The distressed/torn O-ring and angled/not fully engaged B-nut cone seat appeared to have provided a leakage path for fuel.

2.2 SVA Hose and Tube Assembly

Visual review of the SVA hose and tube assembly as received found that the tube exhibited signs of thermal damage, including melted and re-solidified material on one B-nut and discoloration of the tube and wire braid. Additionally, the wire braid had separated from one end of the joint and there was no remaining evidence of the hose liner or fire sleeve present. Examination of the tube

and wire braid at the separation found no evidence of fracture; the wire braid appeared to have pulled out from the joint (Figures 6-7).

Metallographic sections were prepared through the approximate center of both the intact and separated joints. Review of the sections confirmed that the wire braid appeared to have pulled out on the separated side. No significant differences were observed between the two joints (Figure 8).



Figure 1: Overall appearance of the fuel nozzle in the as-received condition.

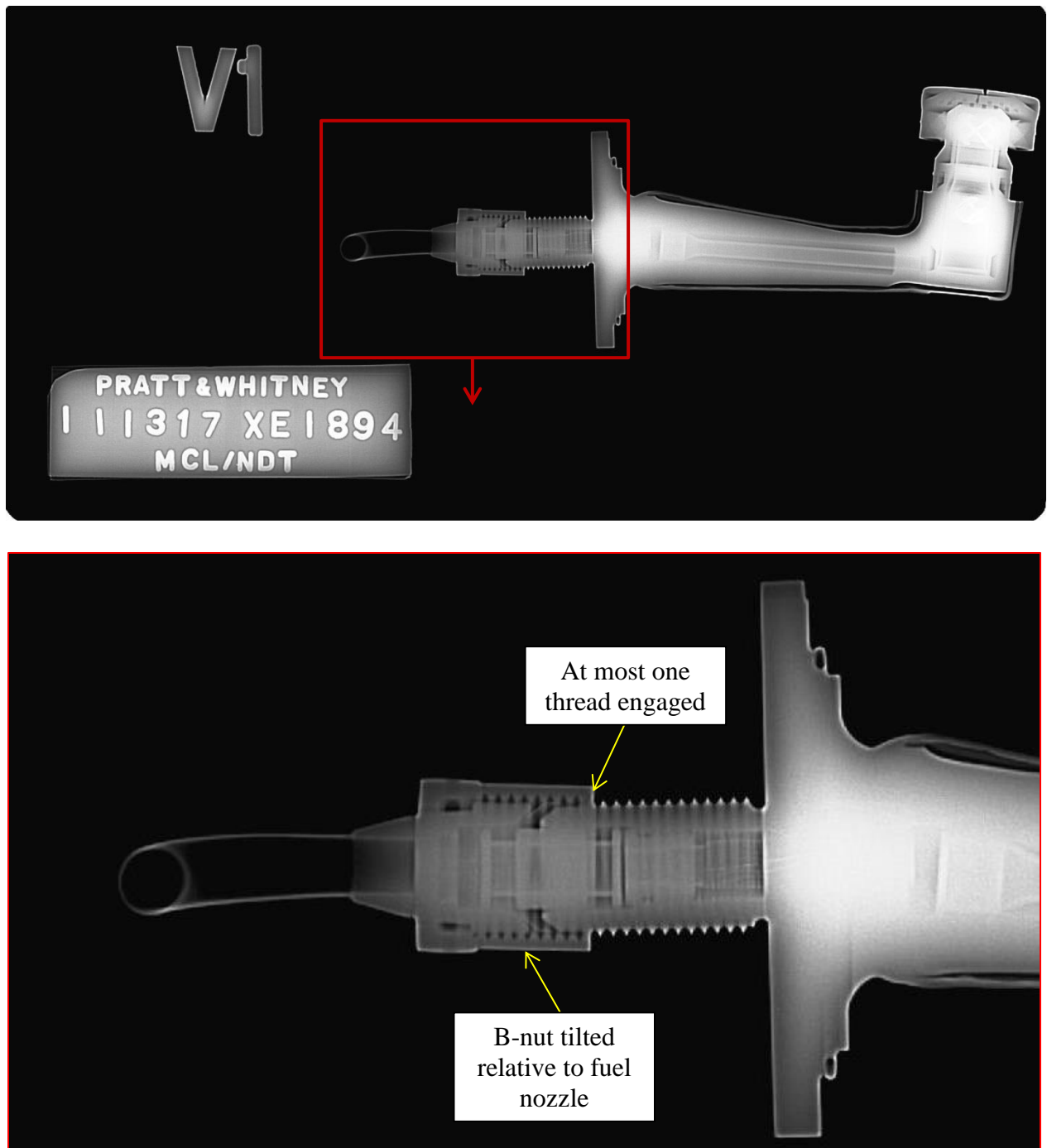


Figure 2: X-ray images showing apparent cross threading of the B-nut on the fuel nozzle and lack of full engagement.



Figure 3: Views of the B-nut showing apparent cross threading observed.

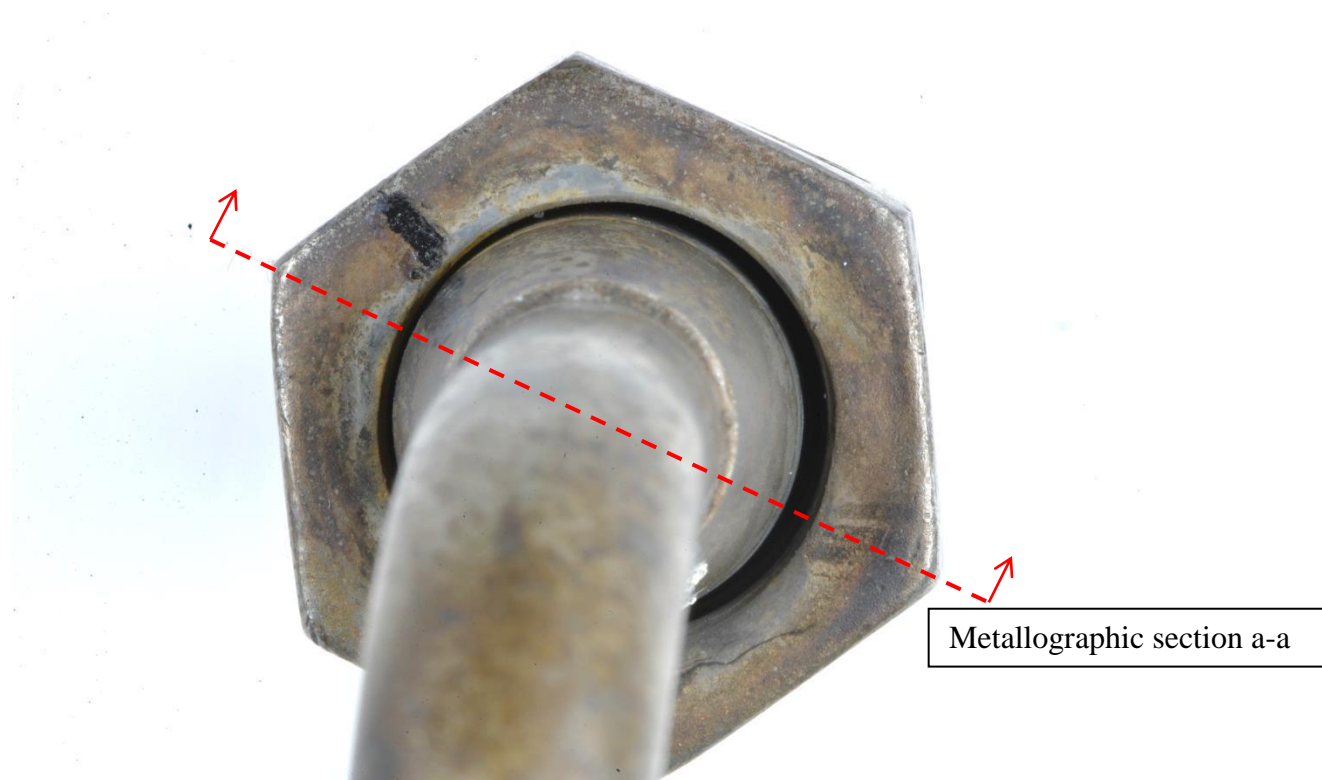


Figure 4: Image showing the off-center location of the tube in the B-nut. Dashed lines indicate the approximate location of metallographic section a-a.

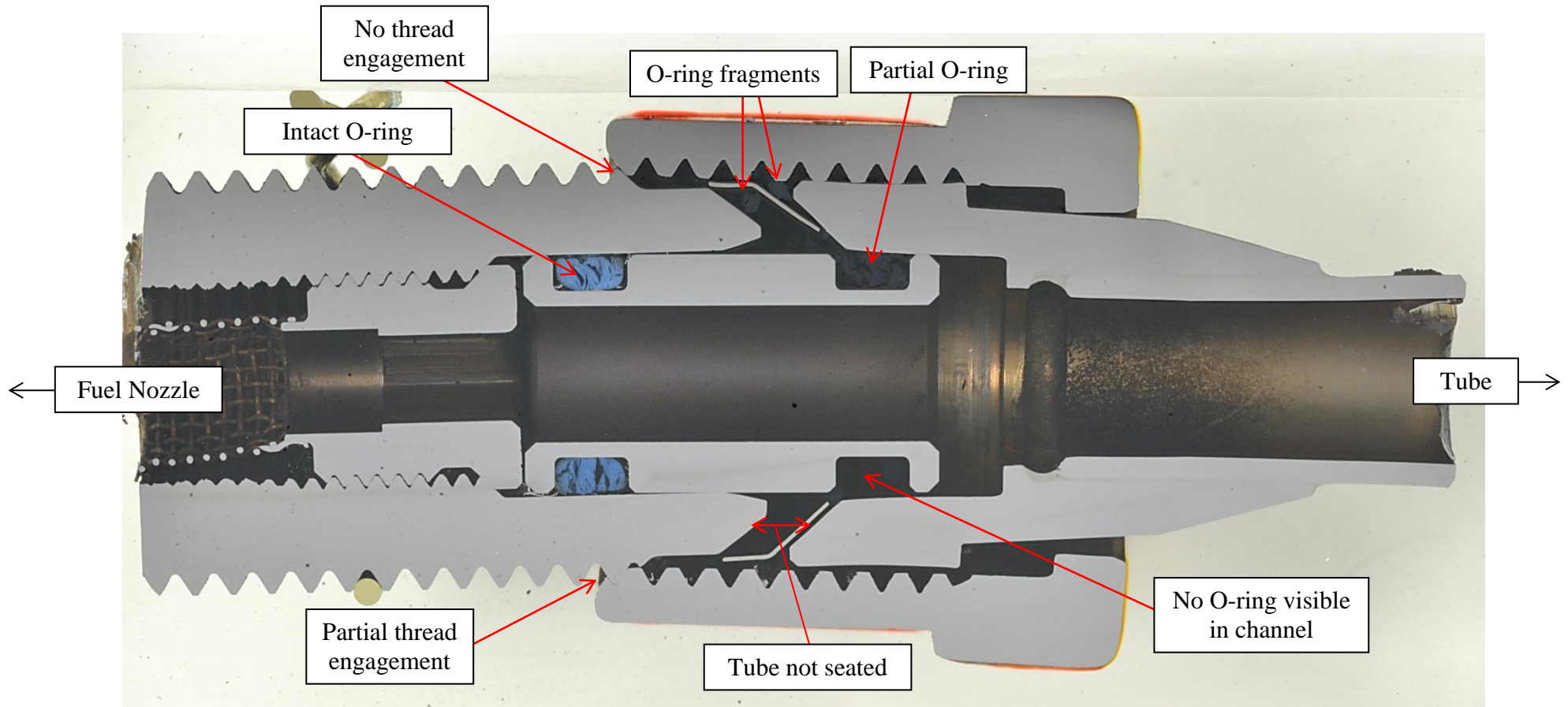


Figure 5: Image of metallographic section a-a showing internal condition of fuel nozzle.

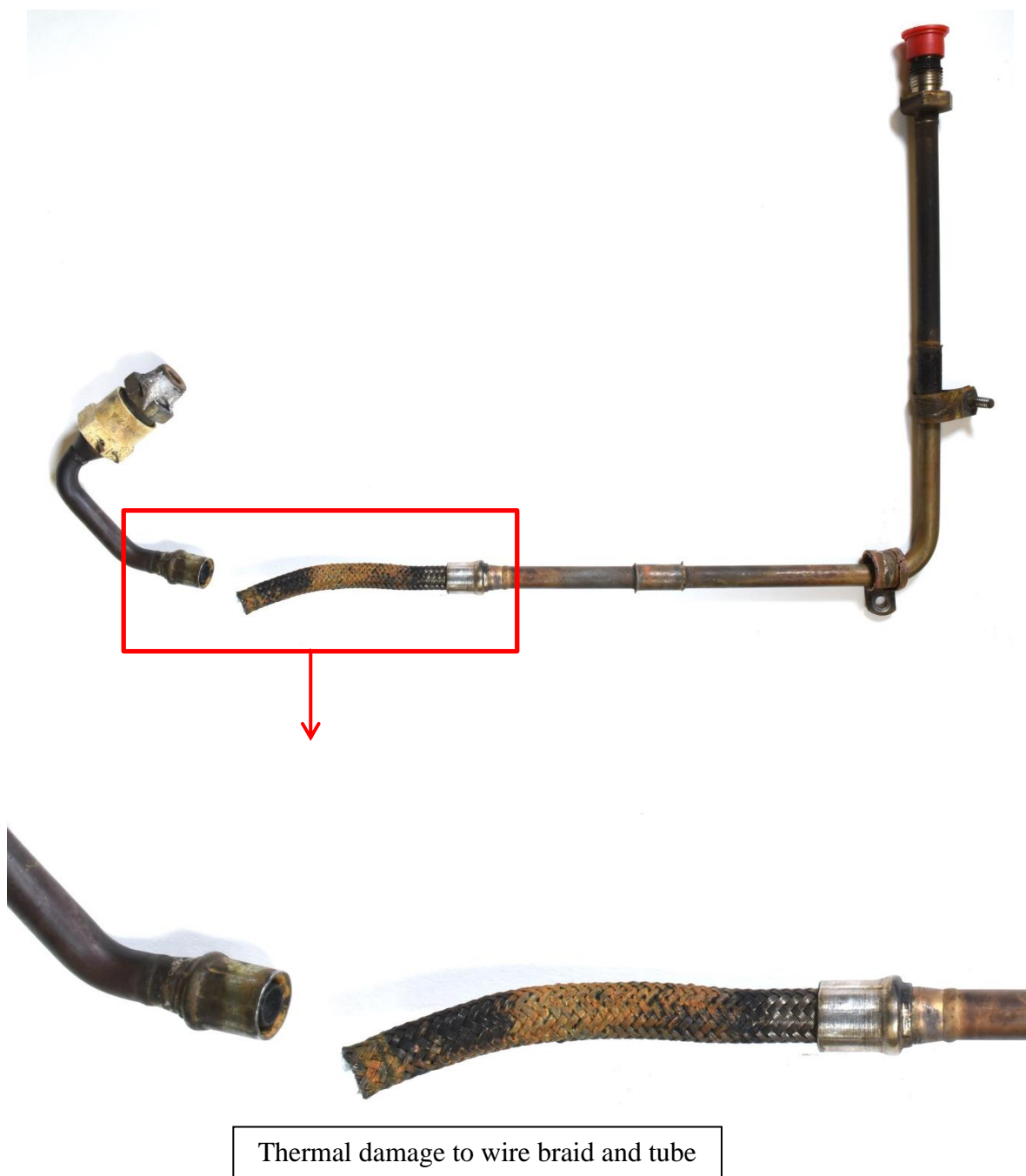


Figure 6: Images of the SVA hose and tube assembly in the as-received condition.



Figure 7: Views of the end of the wire braid and the swage joint. The wire braid appeared to have pulled out from the joint and the inner liner was gone.

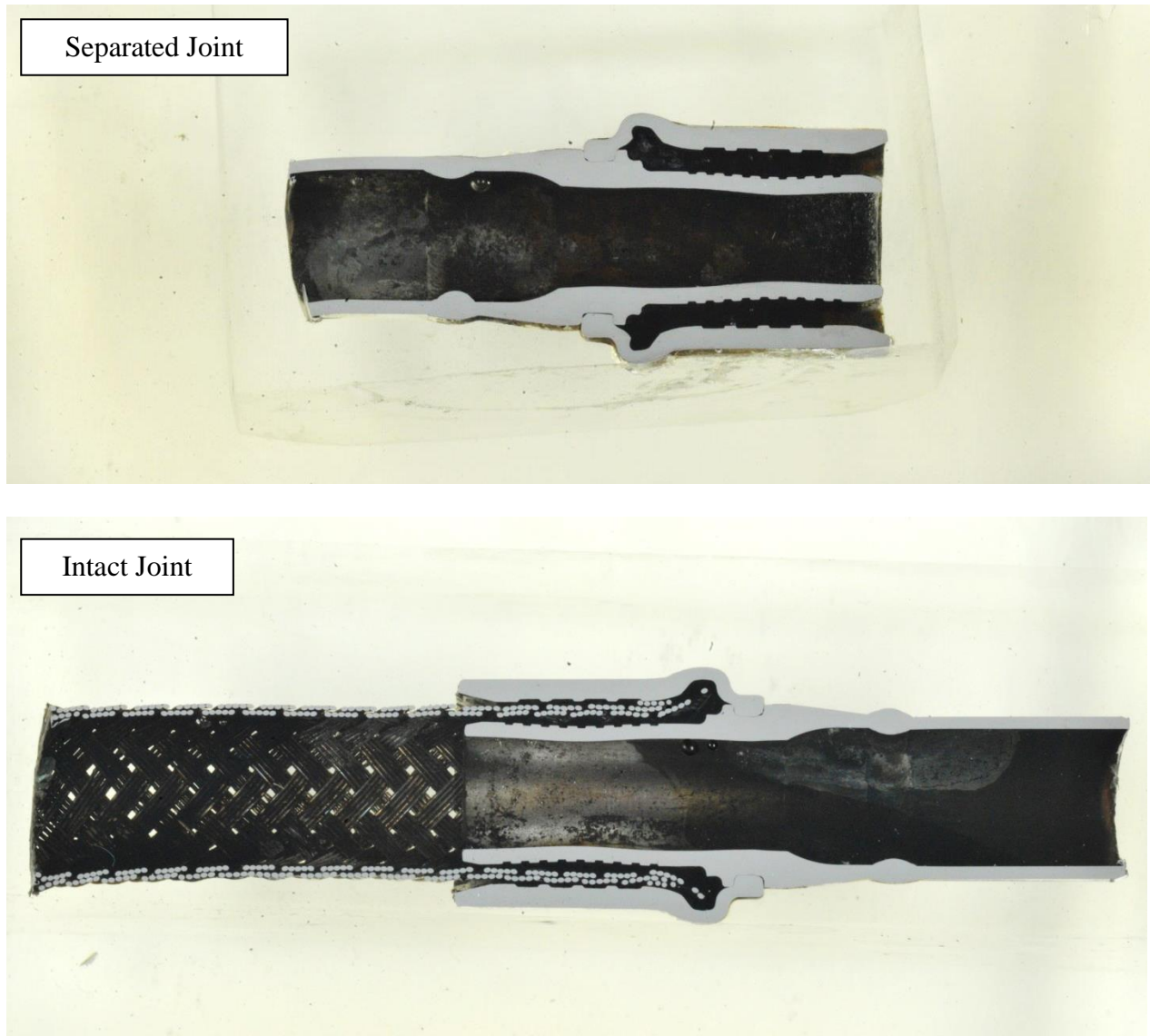


Figure 8: Views of metallographic sections through the approximate center of the intact and separated joints. No significant differences were observed. The entire inner liner was no longer present.