NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

May 16, 2019

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT
NTSB No: ENG17IA036

A. INCIDENT

Location: McCarran International Airport (LAS)- Las Vegas, Nevada

Date: September 6, 2017

Time: 0019 Pacific Daylight Time (PDT)

Aircraft: Boeing 757-232, N686DA, Delta Air Lines Flight 1057

B. POWERPLANTS GROUP

Group Chairman:	Robert Hunsberger National Transportation Safety Board Washington, DC
Member:	Kevin M. Clark Federal Aviation Administration Burlington, Massachusetts
Member:	John S. Koza Pratt & Whitney East Hartford, Connecticut
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Member:	Taylor Smith Delta Air Lines Atlanta, Georgia
Member:	Michael McDonald Delta Air Lines Atlanta, Georgia
Member:	Pat Paris Air Line Pilots Association International Atlanta, Georgia

C. SUMMARY

On September 6, 2017, at about 0019 PDT, a Delta Air Lines Boeing 757-232, registration N686DA, equipped with two Pratt & Whitney PW2037 turbofan engines, experienced a No. 1 (left) engine undercowl fire during takeoff from McCarran International Airport (LAS), Las Vegas, Nevada. The flight crew reported a left engine fire indication and associated aural fire alert at rotation/initial climb. The crew completed the quick reference handbook (QRH) procedures, declared an emergency, shut down the left engine and discharged one of the fire bottles. They then initiated LAS engine out procedures to return to airport. The fire warning indication initially cleared, but on the downwind leg of the pattern, the fire warning indication reappeared, and the second fire bottle was discharged, which cleared the fire warning again. The airplane made an uneventful overweight landing at LAS and were met by aircraft rescue and firefighting (ARFF) on the runway. ARFF sprayed fire retardant into the engine and confirmed the fire was extinguished. The airplane was cleared to taxi to the gate under its own power. There were no passengers or crew injuries reported. The flight was being operated in accordance with 14 *Code of Federal Regulations* Part 121 and was a regularly scheduled flight from LAS to John F. Kennedy International Airport (JFK), Queens, New York.

The No. 1 engine and nacelle was removed from the airplane by Delta Air Lines (DAL) maintenance personnel at LAS and shipped to Delta TechOps- Atlanta, Georgia for examination and disassembly. Party members from Delta Air Lines, Pratt & Whitney, Boeing, the Air Line Pilots Association (ALPA), the Federal Aviation Administration, and the National Transportation Safety Board met at Delta TechOps from September 26-28, 2017.

The thrust reverser exhibited thermal damage and discoloration on all interior surfaces except for a localized area between the 1 and 3 o'clock positions where the insulation appeared wet/shiny. The core cowls were thermally damaged, deformed and missing material. All exterior engine surfaces aft of the fan exit case were sooted. The engine had thermal damage and dark discoloration most concentrated over the high pressure compressor (HPC) and diffuser cases on the lower half of the engine (3 to 9 o'clock positions). Fuel components including the stator vane actuator and fuel flow transmitter were thermally damaged with melted and missing material. A leak check of the fuel manifold and fuel nozzle assemblies was performed by porting shop air into the fuel flow divider valve. A leak was identified at fuel nozzle #7, located at the 3 o'clock position. Fuel nozzle #7 was removed from the engine and x-rayed at Delta TechOps and then sent to the Pratt & Whitney Materials and Processes Engineering Lab in East Hartford, Connecticut for additional analysis. The fuel nozzle b-nut, which connects the fuel manifold supply line to the fuel nozzle was cross threaded and one or fewer threads were fully engaged. One of the two o-rings in the nozzle assembly was thermally damaged and broken into multiple pieces.

D. DETAILS OF THE INVESTIGATION

1.0 ENGINE AND NACELLE INFORMATION

1.1 Engine History/Maintenance

According to Delta maintenance records, engine serial number 716595 had accumulated 53.7 hours time since overhaul (TSO) and 18 cycles since overhaul (CSO). A heavy overhaul was completed on the engine at Delta TechOps prior to installation on August 31, 2017.

1.2 Engine Information

The PW2037 is a dual-spool, axial-flow, high bypass turbofan engine that features a 1-stage fan, a 4-stage low pressure compressor (LPC), a 12-stage high pressure compressor (HPC), an annular combustor, a 2-stage high pressure turbine (HPT), and a 5-stage low pressure turbine (LPT) (**Figure 1**). According to the Federal Aviation Administration (FAA) Type Certificate Data Sheet E17NE, Revision 15, dated October 23, 2014, the engine has a maximum takeoff thrust rating of 37,530 pounds, flat-rated[1] to 87°F (30°C) and a maximum continuous thrust rating of 34,640 pounds flat-rated to 77°F (25°C). All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF).

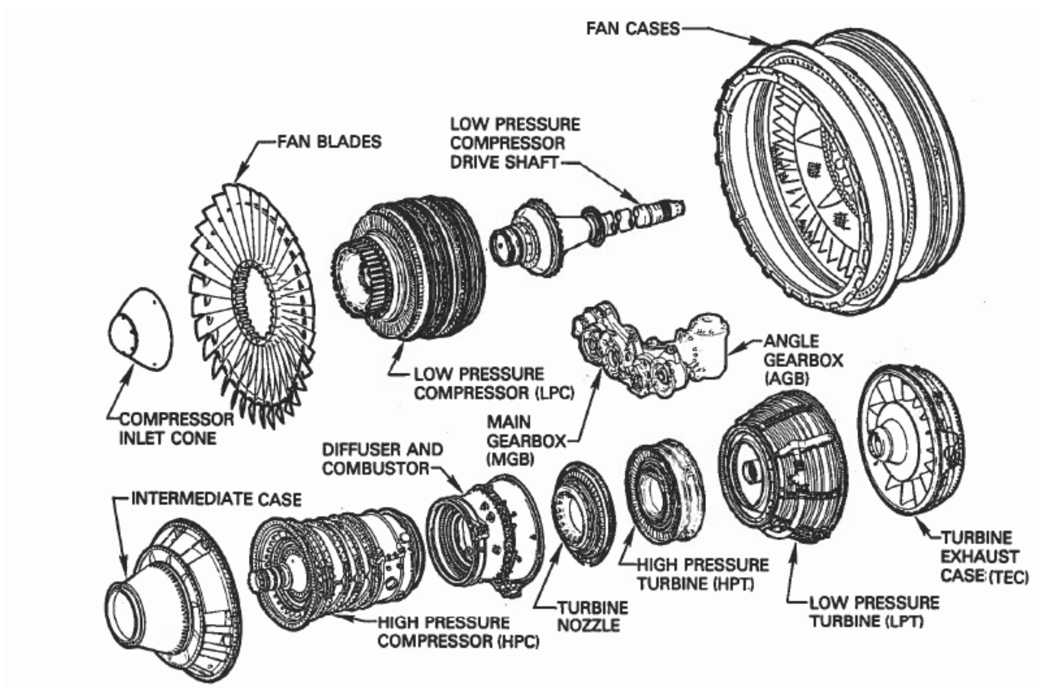

Figure 1- PW2037 Major Assemblies

[1] Thrust ratings are measured at static sea level conditions at ambient temperatures at and below the values listed.

1.3 Boeing 757 Nacelle Information

The Boeing 757 nacelle system is comprised of an engine inlet cowl, fan cowl, and thrust reverser (TR) (**Photo 1**). The inlet cowl and exhaust nozzle are fixed components and the fan cowl, TR, and core cowl are split halves that are hinged at the top of the engine and secured with latches at the bottom of the engine.

The TR halves each feature a sliding (translating) sleeve, cascades, blocker doors, drag lines, actuators, locks, position sensors, outer torque box structure, and an inner fan duct cowl. The inner wall of the TR forms the engine fire wall and is coated with fire rated MA-25S®[2] insulation.

All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF).

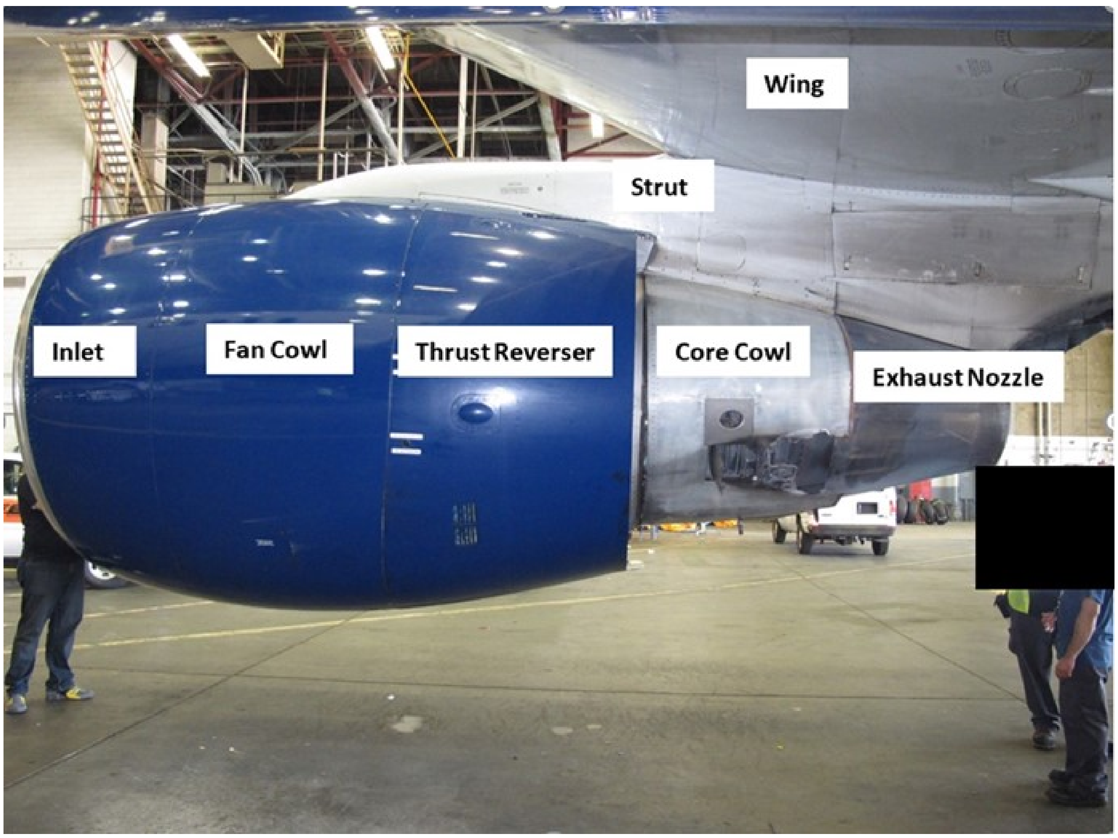

Photo 1- Boeing 757 Nacelle Components, Exemplar Engine

[2] MA-25S is a medium density filled elastomeric silicone insulator that is used for thermal protection/fire proofing. The Lockheed Martin Corporation holds the patent.

2.0 NACELLE EXAMINATION

The No. 1 engine fan cowl, TR, and core cowl halves were removed from the airplane and shipped to Delta TechOps in Atlanta, Georgia where they were quarantined in the TR shop until the investigative team arrived.

2.1 Fan Cowl

Both halves of the fan cowl were complete, and the three latch and hinge assemblies were intact and functional. According to the DAL maintenance crews, the fan cowl latches were secured when the airplane landed at LAS. Both fan cowl halves had discoloration, sooting, and thermal damage at the 6 o'clock position most concentrated near the aft edge (**Photo 2**).

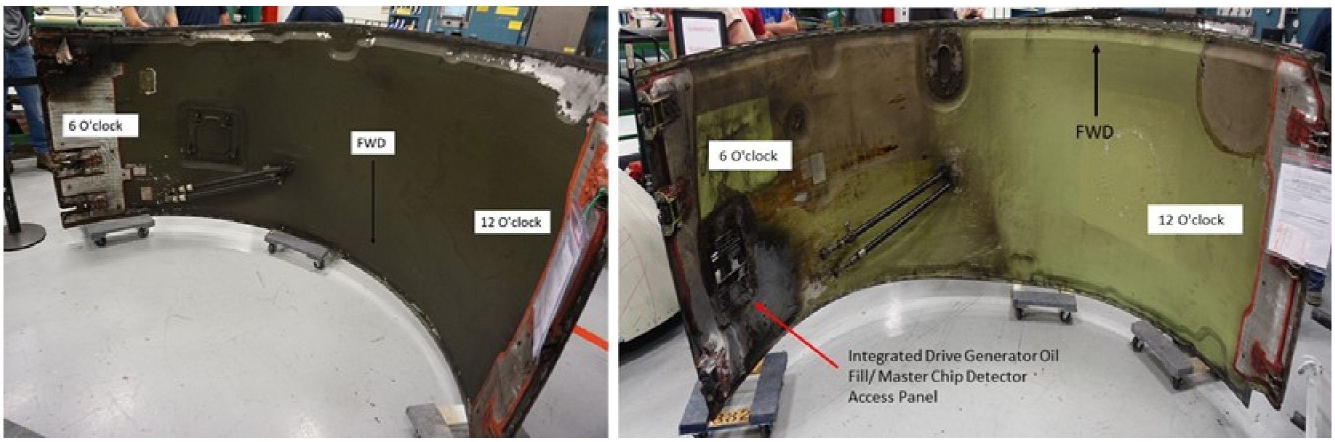

Photo 2- (L) Left (Outboard) Fan Cowl, (R) Right (Inboard) Fan Cowl

2.2 Thrust Reverser

The TR translating sleeves were both in the stowed position. All hinges and latches were intact and there was no visible damage to thrust reverse actuation controls. The MA-25S insulation on the interior surface of the TR halves exhibited thermal distress, sooting and discoloration, except for a localized area on the right half from the 1 to 3 o'clock positions (**Photos 3 and 4**). The insulation in this area retained its reddish orange color and appeared wet/slick. The lower bifurcation wall located at the 6 o'clock position of each thrust reverser half showed evidence of dark discoloration and thermal distress.

Photo 3- Left (Outboard) Thrust Reverser

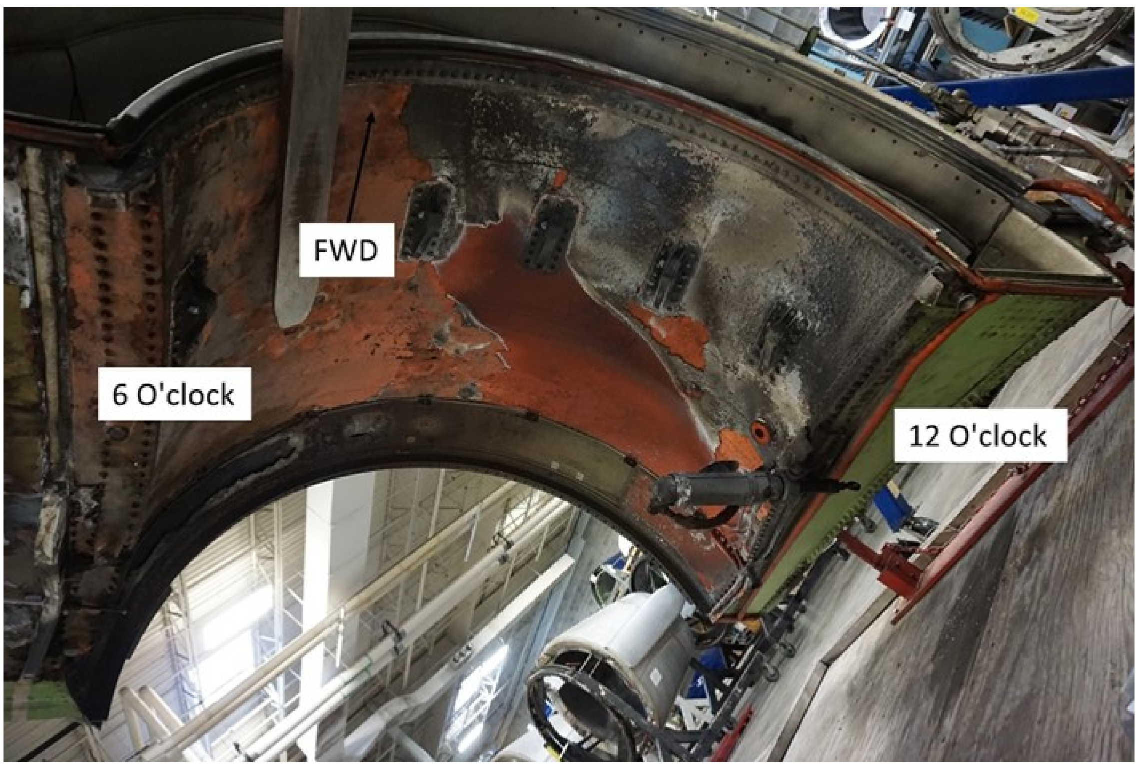

Photo 4- Right (Inboard) Thrust Reverser

2.3 Core Cowl

The left core cowl half exhibited thermal damage and deformation. A large section measuring about 48 inches circumferentially by 37 inches axially was separated and missing, and the remaining metal was deformed in the aft direction. The aft most of the three latches located at the bottom of the engine was separated and missing. The three hinges located at the top of the engine were intact (**Photos 5 and 6**).

The right core cowl also had thermal damage, deformation, and missing material. A section measuring about 22 inches circumferentially by 17.25 inches axially was separated and missing. The aft most of the three latches the secure the core cowl was separated and missing. The three hinges located at the top of the engine were intact (**Photo 6**).

Photo 5- Left (Outboard) Core Cowl Prior to Engine Removal

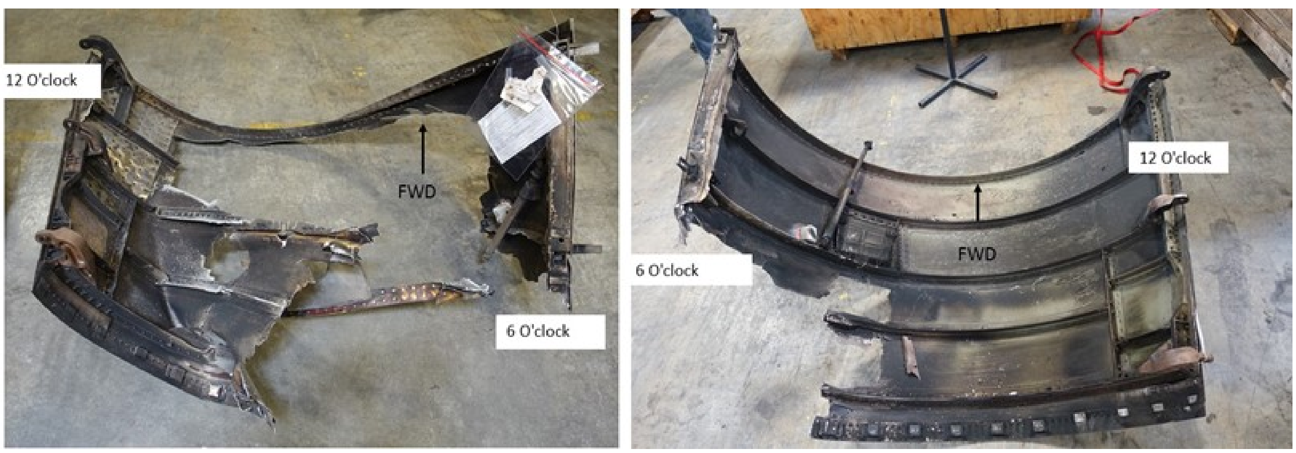

Photo 6- (L) Left (Outboard) Core Cowl, (R) Right (Inboard) Core Cowl

2.0 NO. 1 (LEFT) ENGINE, SERIAL NUMBER 716595 EXAMINATION

The engine was placed on work pedestals prior to the investigative team’s arrival (**Photos 7, 8, and 9**). The engine fan blades were all intact and in good condition. Three consecutive blades (labeled 4, 5, and 6) at the 6 o’clock position were displaced about 1 inch in the aft direction but did not exhibit any impact damage on the blade surfaces. The midspan shrouds of the three consecutive blades at the 6 o’clock position were shingled, and the blade tips were dug into the fan case rub strip (**Photo 10**). The three blades had rub strip material accumulation on the blade tip convex side, consistent with counter clockwise rotation. The fan case rub strip was rubbed/gouged between the 4 and 8 o’clock positions in line with the fan blade trailing edge plane of rotation. The three displaced blades were forcefully released from the rub strip and following release they returned to their normal orientation and the fan/N1 spool could be spun freely by hand.

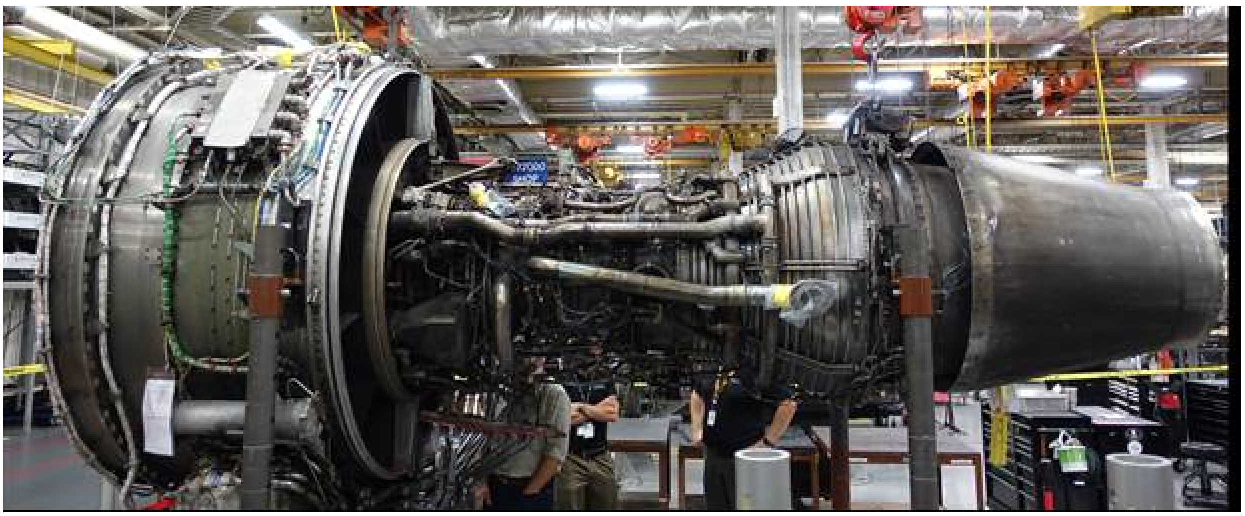

Photo 7- Left Side of Engine, As Received

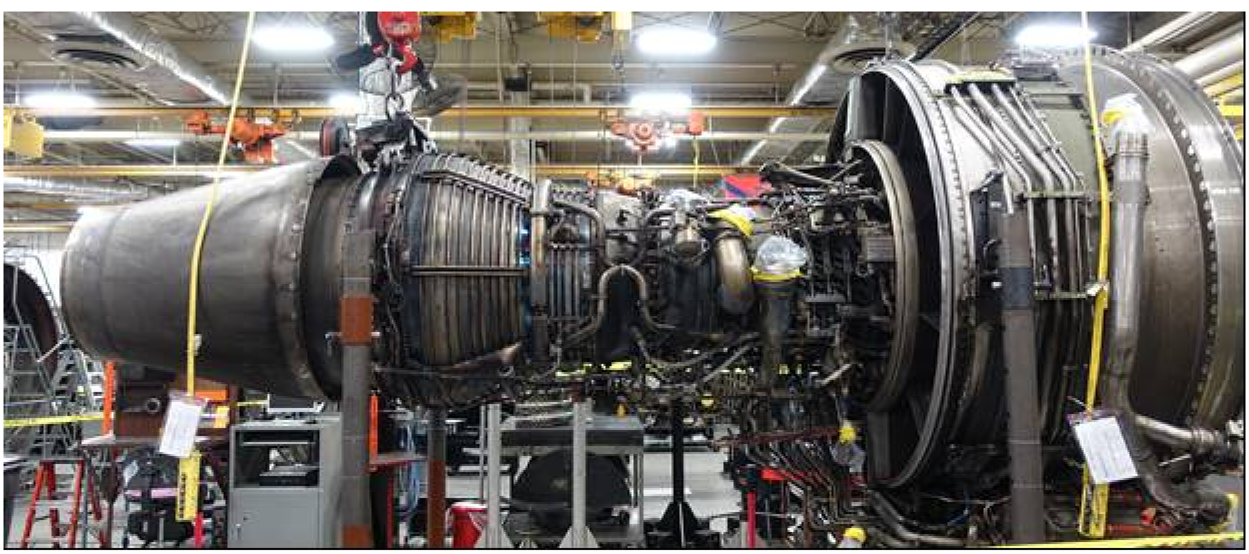

Photo 8- Right Side of Engine, As Received

Photo 9- Engine Data Plate

Photo 10- Fan Blade Displacement

The fan case and fan exit case exterior surfaces had sooting accumulation mostly concentrated between the 3 o'clock and 9 o'clock positions. The gearbox, fuel control, and accessories located at the 6 o'clock position had dark discoloration and multiple components appeared to be wet (**Photo 11**). All wiring and flexible lines located between the 5 and 7 o'clock positions on the fan exit case were thermally damaged and the protective sleeves were charred.

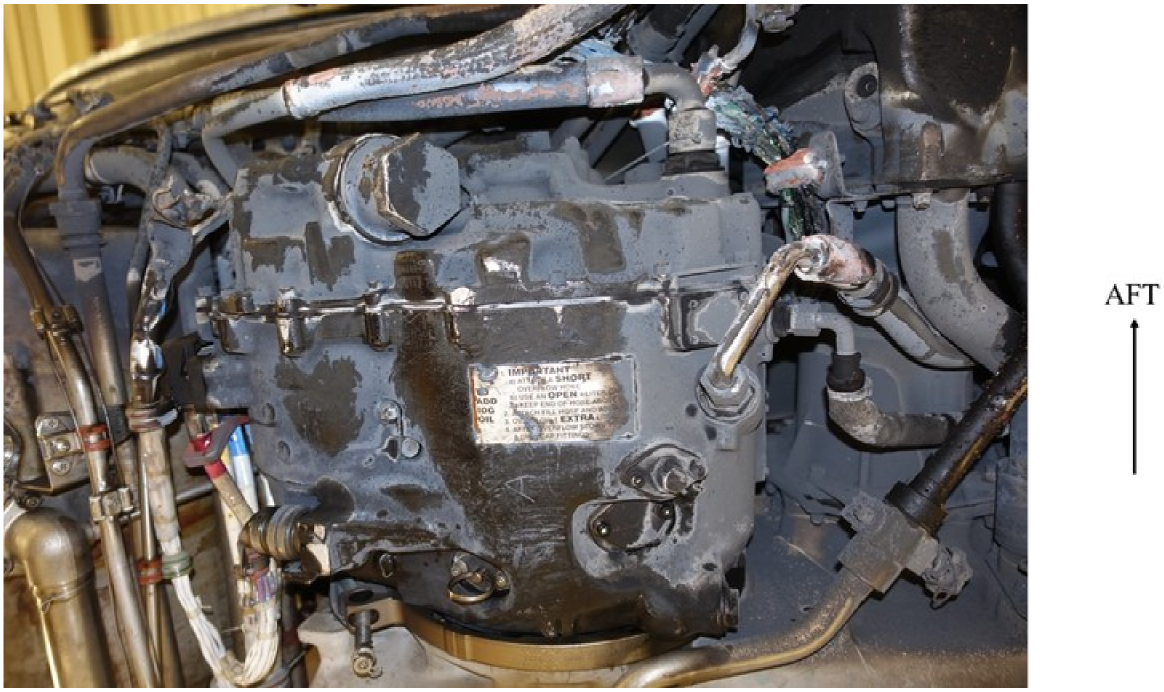

Photo 11- Gearbox and Accessory Sooting and Discoloration, 6 o'clock

The wiring and flexible hoses on the top and bottom HPC split front cases also exhibited thermal damage including charring of the protective sleeves and discoloration (**Photo 12**). Multiple lines were partially consumed. Melted metal slag was adhered to several lines at the 6 o'clock position. The HPC 7th stage variable stator vane inner unison ring was partially consumed at the 6 o'clock position. The bifurcation panel had puddled metal slag on the top surface and the rigid lines running through the panel were thermally damaged and discolored. The bulb seal around the bifurcation panel was complete but was deformed and the seal material had reduced elasticity (**Photo 13**). The discoloration and sooting of the lines running through the bifurcation panel continued below the panel to the gearbox/accessories. The turbine cooling air duct located at the 10 o'clock position had a breach about 21 inches aft of intermediate case v-groove that measured about 2 inches by 2 inches. The edges of the duct breach were rough and discolored consistent with thermal damage. The stator vane actuator (SVA) exhibited melting on the bottom forward side, as viewed in-situ. The two canon plug connector ports on the bottom of the SVA were melted and the wires were no longer secured. The SVA fuel open line was separated on both sides and was hanging from the SVA by lock wire (**Photos 14 and 15**).

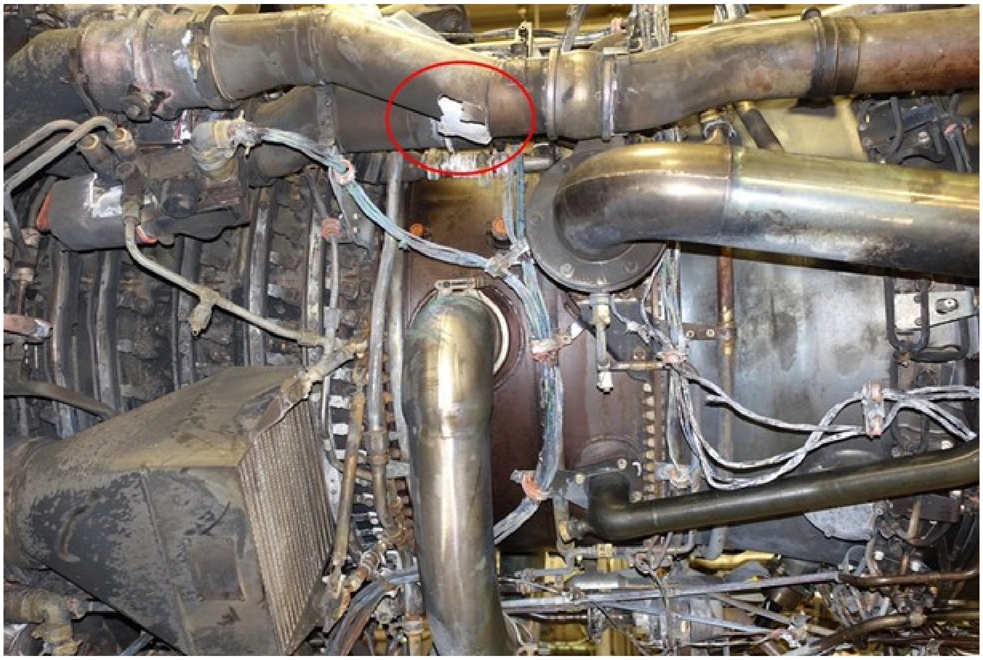

Photo 12- HPC Front and Rear Case Thermal Damage, Left Side

Photo 13- Bifurcation Panel Thermal Damage, 6 o’clock

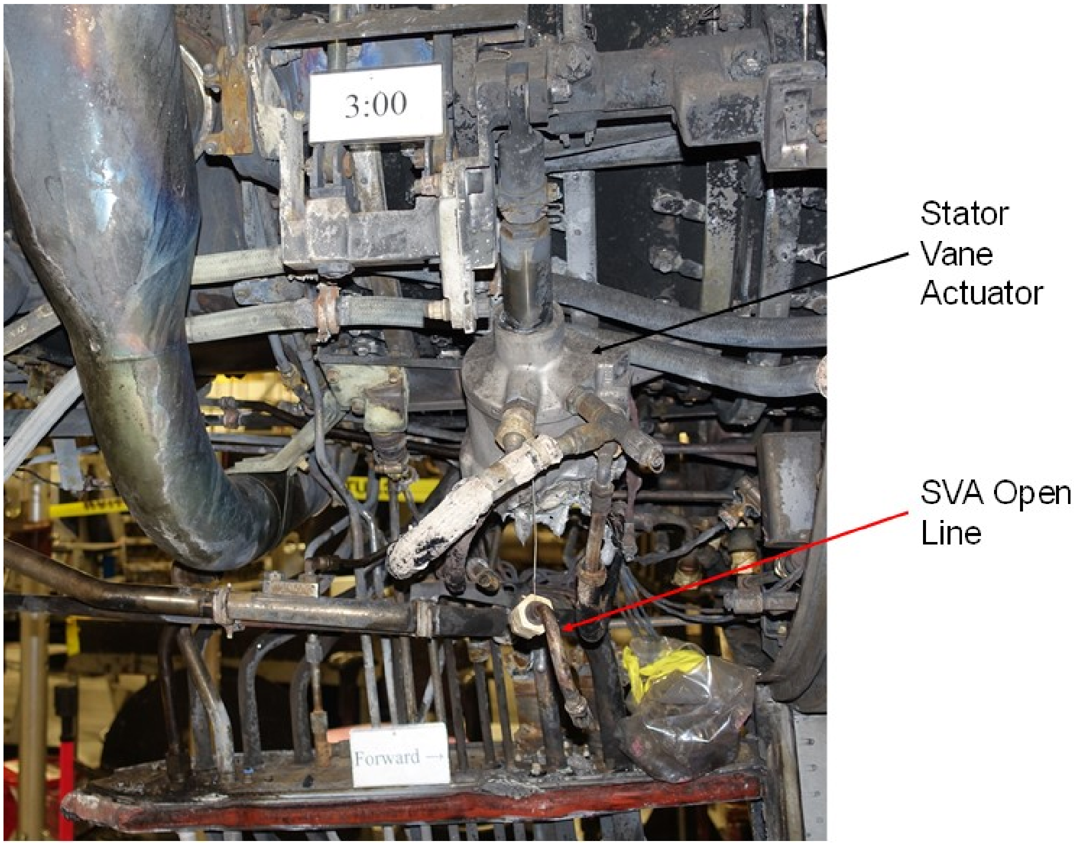

Photo 14- Stator Vane Actuator Thermal Damage

Photo 15- Stator Vane Actuator with Exemplar

The fuel flow transmitter (FFT) located at the 6 o’clock position on the diffuser case exhibited severe thermal damage. A majority of the FFT housing was consumed leaving only the aft flange connection intact (**Photo 16**). Both the top and bottom fire loops wiring remained intact but all the silicone isolator grommets were thermally damaged or consumed (**Photo 17**). The ignition exciter leads at the 4 and 5 o’clock positions had thermal damage and discoloration on the flexible wiring braid sheathing and the silicone in the cushion clamp supports was charred/consumed. The igniter lead at the 5 o’clock position was separated at the transition from the flexible braid to the igniter housing on the diffuser case and was hanging free from the engine.

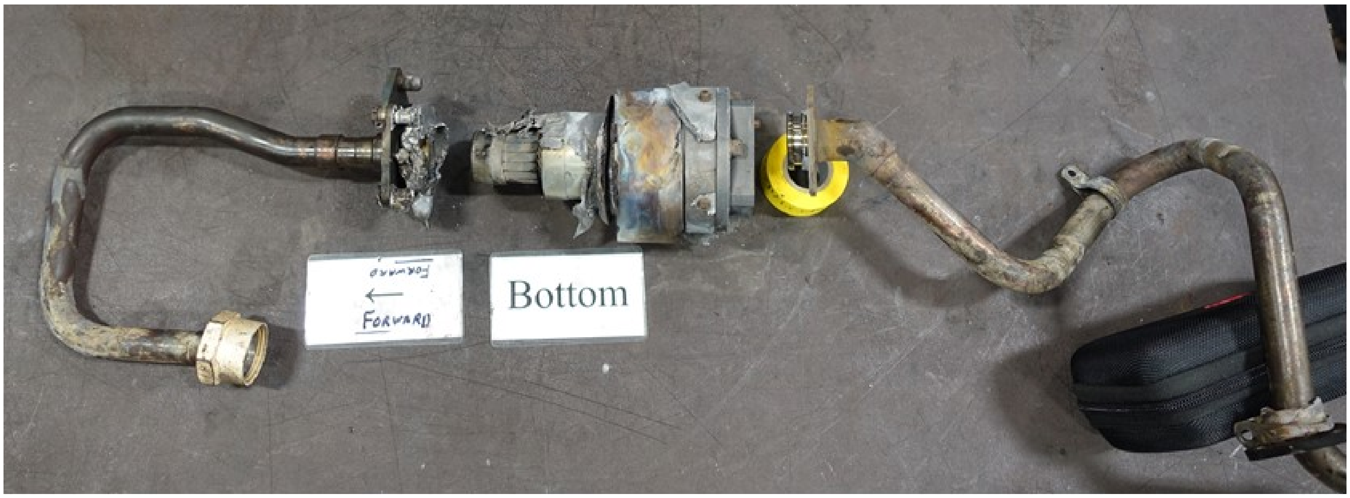

Photo 16- Fuel Flow Transmitter

Photo 17- Fire Loop Thermal Damage

The HPT and LPT cases had light sooting around the engine and metal spray was observed from the 8 to 12 o'clock positions coincident with the core cowls (**Photo 18**).

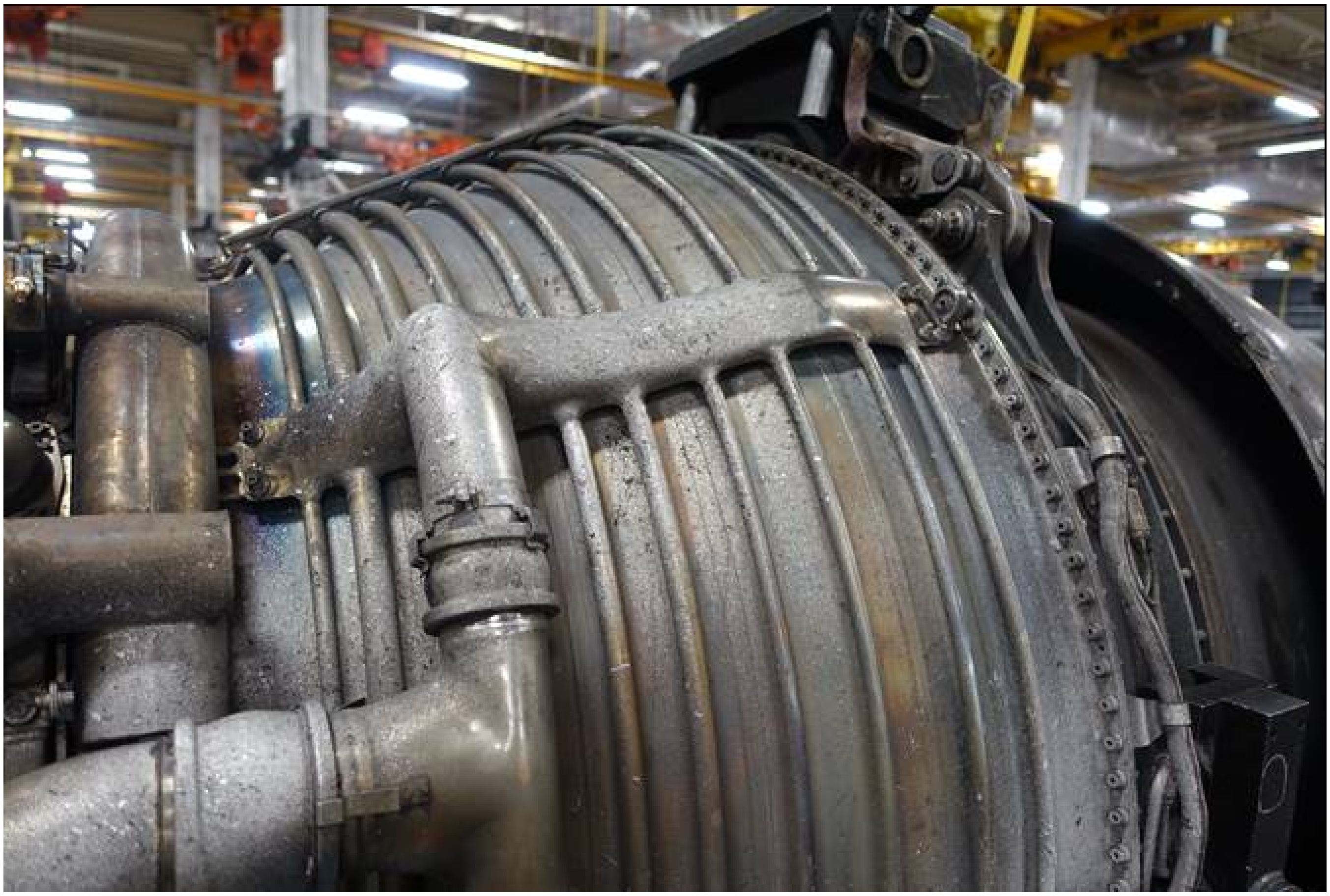

Photo 18- LPT Case Metal Spray, 8 to 12 o'clock

4.0 FUEL MANIFOLD TESTING

An adapter fitting was attached upstream of the fuel distribution valve and shop air (90 psi) was ported through the valve to check for leak. When the pressurized air was applied, an air leak could be heard and felt from the fuel manifold assembly at the b-nut nozzle interface located at the 3 o'clock position (labeled #7). The #7 fuel nozzle and adjacent nozzles, #6 and #8 were removed from the engine. A cutting wheel was used to cut the fuel supply lines so the fuel nozzle assembly could be removed without breaking torque on the fuel nozzle b-nuts (**Photo 19**). Fuel nozzles #6 and #8 had about 0.50 inch of thread visible between the nozzle platform and the bottom of the b-nut. The leaking nozzle had about 0.764 inch of threads visible, and the b-nut appeared to be cross threaded.

Photo 19- Nozzle #7 and Nozzle #8

5.0 NOZZLE X-RAY IMAGING

The #7 fuel nozzle assembly was x-rayed at Delta TechOps (**Photo 20**). The assembly features two o-rings and a conical washer seal (Voi-Shan[3]). The x-ray images confirmed the b nut was cross threaded and not properly torqued. The o-ring on the fuel nozzle side of the nozzle and the Voi-Shan seal were visible in the x-ray but it could not be confirmed if the second o-ring located on the fuel manifold supply line side of the nozzle was present.

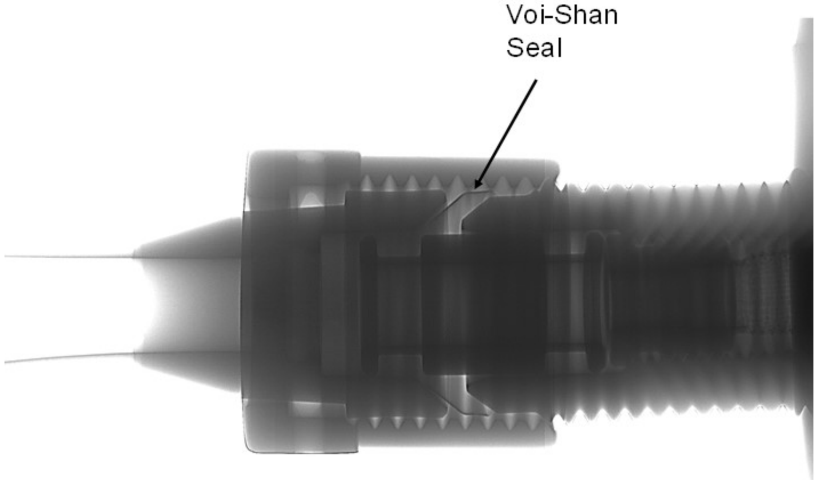

Photo 20- Nozzle #7 X-Ray

[3] The conical washer is commonly referred to by the manufacturer, Voi-Shan. Voi-Shan metallic seals are malleable crush washers designed to yield and "flow" into imperfections of the mating surfaces.

6.0 METALLURGY

Fuel nozzle #7 and the SVA hose and tube assembly were submitted to the P&W Materials and Processes Engineering Laboratory in East Hartford, Connecticut for additional examination. The complete materials lab report in available in the docket, titled Pratt & Whitney Metallurgical Investigation of Delta Air Lines PW2037 Engine No. 716595.

6.1 Fuel Nozzle #7

Prior to destructive examination, fuel nozzle #7 was x-rayed a second time at the P&W Quality and Standard Laboratory in East Hartford, Connecticut. The x-ray images showed that one or fewer threads were engaged between the fuel nozzle and the b-nut. The b-nut contains approximately 9-10 threads and the mating thread on the fuel nozzle has 13 threads. The x-ray images and visual examination also identified that the b-nut was tilted relative to the nozzle platform and the end of the b-nut was not centered with the nozzle fuel supply tube.

The fuel nozzle was sectioned (**Photo 21**). The sectioned assembly confirmed that the b nut was cross threaded. The o-ring on the fuel nozzle side was present and intact. The second o ring located on the fuel manifold supply line side was damaged and o-ring fragments were recovered outside of the o-ring gland, near the Voi-Shan seal.

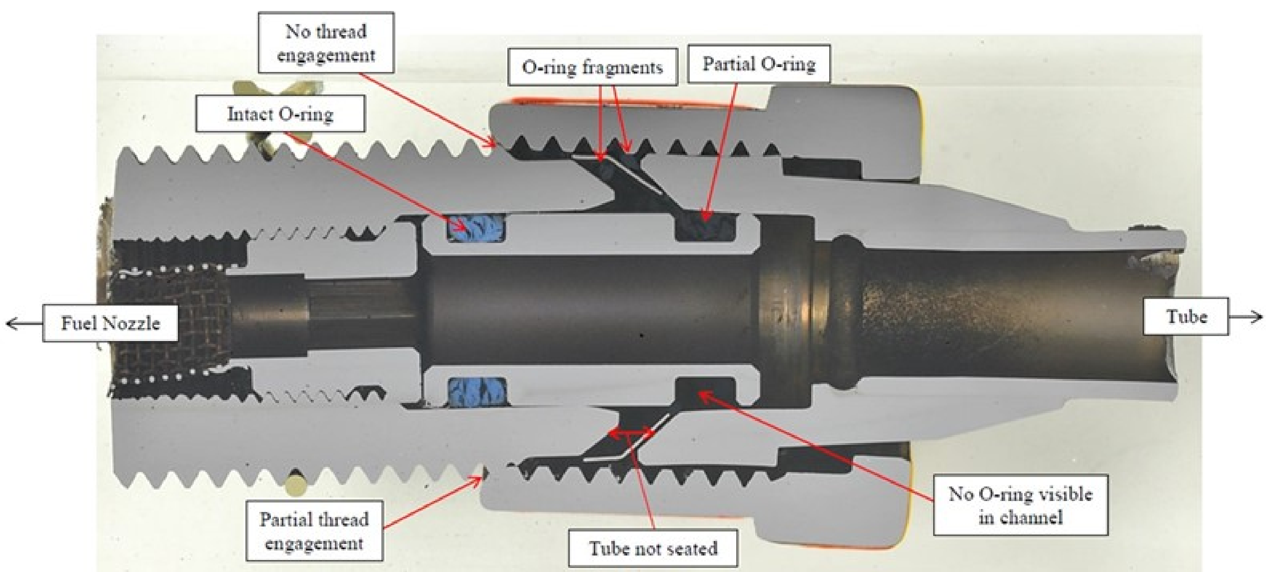

Photo 21- Fuel Nozzle #7, Sectioned

6.2 SVA Hose and Tube Assembly

The SVA hose and tube assembly were submitted to the P&W Materials and Processes Engineering Laboratory to verify there were no anomalies in the SVA flexible hose to rigid tube connection joint (**Photo 22**). The SVA flexible hose section exhibited thermal damage including a missing fire sleeve and hose liner. The hose liner was separated at one end of the connection to the rigid tube, but other joint connection remained intact. Metallographic sections were taken of both the intact joint and the separated joint and there were no significant differences observed (**Photo 23**).

Photo 22-SVA Hose and Tube Assembly

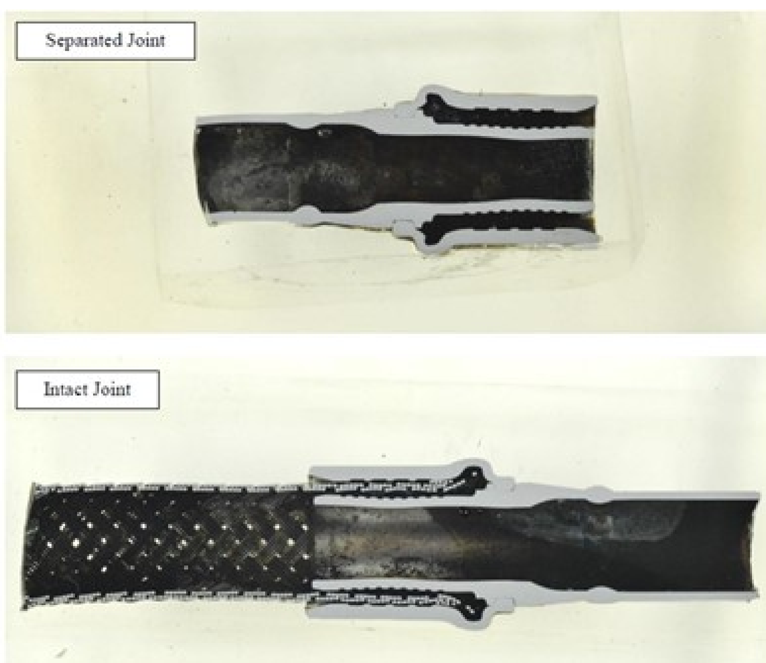

Photo 23- SVA Hose and Tube Assembly Cross Section

7.0 CORRECTIVE ACTIONS

Following the event, DAL voluntarily inspected all PW2000 engines in the TechOps engine shop, test cell and spares supply (17 total engines) for proper fuel nozzle installation with no findings. DAL also reviewed their records and identified two in service engines that were in the shop at approximately the same time as ESN 716595. The fuel nozzle installation on those two engines were inspected with no findings. Lastly, DAL amended the PW2000 diffuser and combustor assembly job instruction card to require inspector sign off of the pneumatic leak check step during fuel system assembly.

Robert Hunsberger
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