AIRCRAFT ACCIDENT REPORT

DELTA/2018/02/13/F

Accident Investigation Bureau

Report on the Serious Incident involving an Airbus A330-223 aircraft operated by Delta Air Lines Inc. with nationality and registration marks N858NW which occurred after take-off from Runway 18R, Murtala Muhammed International Airport, Lagos on 13th February 2018

This report was produced by the Accident Investigation Bureau (AIB), Murtala Muhammed Airport, Ikeja, Lagos.

The report is based upon the investigation carried out by Accident Investigation Bureau, in accordance with Annex 13 to the Convention on International Civil Aviation, Nigerian Civil Aviation Act 2006, and Civil Aviation (Investigation of Air Accidents and Incidents) Regulations.

In accordance with Annex 13 to the Convention on International Civil Aviation, it is not the purpose of aircraft accident/serious incident investigations to apportion blame or liability.

Readers are advised that the Accident Investigation Bureau investigates for the sole purpose of enhancing aviation safety. Consequently, Accident Investigation Bureau reports are confined to matters of safety significance and should not be used for any other purpose.

As the Bureau believes that safety information is of great value if it is passed on for the use of others, readers are encouraged to copy or reprint for further distribution, acknowledging the Accident Investigation Bureau as the source.

Recommendations in this report are addressed to the Regulatory Authority of the State (NCAA). It is for this authority to ensure enforcement.

Printed in Nigeria for the Accident Investigation Bureau (AIB)

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GLOSSARY OF ABBREVIATIONS IN THIS REPORT

AD	Airworthiness Directives
AFM	Aircraft Flight Manual
AGL	Above Ground Level
AIB	Accident Investigation Bureau (The Bureau)
ARFFS	Airport Rescue and Fire Fighting Services
ATC	Air Traffic Controller
ATPL (A)	Air Transport Pilot Licence (Aeroplane)
C of A	Certificate of Airworthiness
CVR	Cockpit Voice Recorder
CSN	Cycles Since New
DME	Distance Measuring Equipment
ECAM	Electronic Centralised Aircraft Monitor
EEC	Electronic Engine Control
FAA	Federal Aviation Administration
FAAN	Federal Airport Authority of Nigeria
FDR	Flight Data Recorder
FMU	Fuel Metering Unit

h	Hour(s)
hPa	Hecto Pascal
IFR	Instrument Flight Rules
IFSD	In-Flight Shut Down
ILS	Instrument Landing System
lb	Pounds
LOS	Lagos
LPT	Low-Pressure Turbine
MCT	Maximum Continuous Thrust
MFP	Main Fuel Pump
MMIA	Murtala Muhammed International Airport
NCAA	Nigerian Civil Aviation Authority
PF	Pilot Flying
PM	Pilot Monitoring
P&W	Pratt & Whitney
QNH	Airfield Pressure corrected for mean sea level
RWY	Runway
SB	Service Bulletin

TEC	Turbine Exhaust Case
TSN	Time Since New
TWY	Taxiway
USA	United States of America
UTC	Universal Coordinated Time
VOR	Very High Frequency Omni-directional Radio Range

Aircraft Accident Report No.:	DELTA/2018/02/13/F
Registered Owner and Operator:	Delta Air Lines Inc.
Aircraft Type and Model:	Airbus A330-223
Manufacturer:	Airbus Industrie
Date of Manufacture:	2006
Nationality and Registration Marks:	N858NW
Serial Number:	0718
Location:	Take-off Flight Path, Runway 18R, Murtala Muhammed International Airport
Date and Time:	13th February, 2018 at about 22:51 h *(All times in this report are local time (UTC +1) unless otherwise stated)*

SYNOPSIS

On 13th February, 2018 at about 22:51 h, an Airbus A330-223 aircraft with nationality and registration marks N858NW owned and operated by Delta Air Lines Inc. departed Murtala Muhammed International Airport Lagos, Nigeria for Hartsfield-Jackson International Airport, Atlanta, Georgia, United States of

America, as a scheduled flight DAL55, operated on an Instrument Flight Rules (IFR) flight plan. The flight had 234 persons on board comprising two captains and two first officers; nine cabin crew members and 221 passengers including two infants.

During climb, at 22:52 h and at an altitude of about 1,700 ft, the fire warning on engine No. 1 activated (ON indication). At 22:52:25 h, the crew contacted ATC, declared an emergency, and requested a return to the airport and for the emergency services to be on stand-by. The aircraft turned back to the airfield.

At 22:53:50 h, DAL55 was cleared for landing on runway 18R. At about 22:59 h, the aircraft landed safely.

The Airport Rescue and Fire Fighting Services (ARFFS) reported observing a fire in engine No. 1 and attempted to extinguish it. ATC confirmed there was fire at the tail end of the engine No.1 exhaust pipe, the Captain then ordered an evacuation. The passengers were evacuated using the emergency slides on the Right-Hand side of the aircraft. One passenger was seriously injured, and 11 passengers sustained minor injuries during the evacuation.

The incident occurred at night.

The investigation identified the following Causal and Contributory factors:

Causal Factor

An overtemperature condition and localized fire within the No. 1 engine cowling triggered a fire warning. The overtemperature and fire were caused by the ignition of fuel from a hairline crack on the fuel manifold supplying fuel nozzle 1.

Contributory factor

The fuel manifold cracking can be attributed to high vibratory stresses due to coupling of an acoustic combustor mode and a fuel manifold structural mode.

One Safety Recommendation was made.

1.0 FACTUAL INFORMATION

1.1 History of the flight

On 13th February, 2018 at about 22:51 h, an Airbus A330-223 aircraft with nationality and registration marks N858NW owned and operated by Delta Air Lines Inc. departed Murtala Muhammed International Airport, Lagos, Nigeria for Hartsfield-Jackson International Airport, Atlanta, Georgia, United States of America, as a scheduled flight DAL55, operated on an Instrument Flight Rules (IFR) flight plan. The flight had 234 persons on board comprising two captains and two first officers, nine cabin crew members and 221 passengers, including two infants.

DAL55 was cleared for push back and taxi at 22:39 h with instruction to taxi to Holding Point Runway 18R via A1. The aircraft was cleared for take-off at 22:49 h and was airborne at 22:51 h.

At 22:52 h while passing 1,700 ft, the fire warning system on engine No. 1 activated. At 22:52:25 h, the crew contacted ATC, declared an emergency, and requested a return to the airport, and the emergency services to be on stand-by. The aircraft turned back to the airfield. Both fire bottles on engine No. 1 were discharged in sequence and the fire warning indications extinguished.

At 22:53:50 h, DAL55 was cleared for landing on runway 18R. At about 22:59 h, the aircraft made an overweight landing and was met by Airport Rescue and Fire Fighting Services (ARFFS) personnel on the runway.

The Airport Rescue and Fire Fighting services reported observing fire on engine No. 1 and attempted to extinguish it. It was also reported that the adjacent wheel

assembly was "red hot aglow." ATC advised the flight crew to evacuate passengers based on the observation of the ARFFS. At the Captain's command, the passengers were evacuated using the emergency slides on the right side of the aircraft. One passenger was seriously injured, and Eleven (11) passengers sustained minor injuries during the evacuation.

The incident occurred at night.

1.2 Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal	Nil	Nil	Nil	Not Applicable
Serious	Nil	1	1	Not Applicable
Minor	Nil	11	11	Not Applicable
None	13	209	222	Not Applicable
Total	13	221	234	

1.3 Damage to aircraft

The aircraft was not damaged.

Figure 1: The aircraft after the incident

1.4 Other damage

Nil.

1.5 Personnel information

1.5.1 Captain (Pilot Monitoring)

Nationality:	USA
Gender:	Male
Age:	60 years
Licence Type:	ATP (A)
Licence Validity:	30th November, 2019

Aircraft Ratings:	Airplane multiengine land: A330, B757, B767, DC-9, L-188 Commercial privileges: Airplane single engine land
Medical Certificate:	Issued 7th November, 2017
Simulator:	Issued 16th October, 2017
Proficiency Check:	6th February, 2018
Route/Line Check:	30th October, 2017
Total Flying Time:	19,279.28 h (with Delta Air Lines Inc.)
Total on Type:	266 h
Last 90 Days:	202.59 h
Last 7 Days:	10.5 h
Last 24 Hours:	0.00 h

1.5.2 First Officer (Pilot Flying)

Nationality:	USA
Gender:	Male
Age:	43 years
Licence Type:	ATP (A)
Licence Validity:	30th September, 2018
Aircraft Ratings:	Airplane multiengine land: BE1900, DC-9, Embraer 120, B757, B767, A320, A330 Commercial privileges: Airplane single engine land and sea
Medical Certificate:	Issued 22nd November, 2017

Simulator:	Issued 15th October, 2017
Proficiency Check:	16th October, 2017
Route/Line Check:	13th June, 2016
Total Flying Time:	5,869.38 h (with Delta Air Lines Inc.)
Total on Type:	997 h
Last 90 Days:	66 h
Last 7 Days:	10.5 h
Last 24 Hours:	0.00 h

1.6 Aircraft Information

1.6.1 General Information

Type:	A330-223
Manufacturer:	Airbus Industrie
Date of Manufacture:	2006
Serial No:	0718
Registered Owner/Operator:	Delta Air Lines Inc.
Registration Marks:	N858NW
Certificate of Airworthiness:	Issued 25th January, 2016
Certificate of Insurance:	21st December, 2018
Certificate of Registration:	Valid until 31st May, 2019
Noise Certificate:	Issued 7th March, 2016
Airframe Time:	51,532 h

The aircraft is not equipped with a fuel jettisoning system.

1.6.2 Engine

Engine Model:	PW 4168A-1D
No. 1:	
Serial No.:	P733582
Time Since New (TSN):	53,396.9 h
Cycles Since New (CSN)	6,549 cycles
Time Since Overhaul (TSO):	20,484.5 h
Cycles Since Overhaul (CSO):	2,181
Year of Manufacture:	2005

The Pratt & Whitney PW4168A-1D is a model of the PW4000-100 Inch Fan engine and part of the PW4000 family of engines. The PW4168A-1D is a de-rated version of the PW4170 (Advantage70®) engine.

The PW4168A-1D specifically incorporates the TALON IIB combustor configuration. Aft of the Low-Pressure Turbine (LPT) is a Turbine Exhaust Case (TEC) that has provisions for the rear engine mount.

The engine is controlled by a Full Authority Digital Engine Control (FADEC) that includes an Electronic Engine Control (EEC). A Fuel Metering Unit (FMU), mounted to the main fuel pump (MFP), meters fuel to the Fuel Injectors (nozzles) based on inputs from the EEC.

Pressurized fuel supplied from the MFP is metered by the FMU and flows through a Fuel Flow Transmitter and then to a Flow Distribution Valve before supplying the engine Fuel Injectors. The fuel distribution valve supplies eight individual fuel supply tubes that each feed their own fuel manifold. The fuel manifolds, also known as triplets, each supply fuel to three fuel injectors. In total, there are 24

Fuel Injectors that are evenly spaced and mounted around the circumference of the Diffuser Case.

According to the type certificate data sheet No. E36NE Revision 7, the PW4168A-1D has a rated take-off thrust of 68,600 lb and a Maximum Continuous Thrust (MCT) of 59,357 lb. The PW4168A-1D was certified by the FAA on 25th November 2008.

The last engine overhaul/shop visit was in March 2013 at Eagle Services Asia where an Advantage70® conversion was completed in line with Pratt & Whitney (P&W) Service Bulletin (SB) (PW4G-100-72-220). This SB included the upgrade to the Talon IIB combustor configuration.

P&W released SB PW4G-100-A73-44 on 10th October 2014 to increase the fuel nozzle b-nut torque from the previous range of 180-200 in-lb to 250-270 in-lb. Delta Air Lines complied with this SB torque increase on 24th March 2015. There was an FAA Airworthiness Directive (AD) 2015-17-17, mandating the torque increase and was effective 2nd October 2015.

Pratt & Whitney released another SB PW4G-100-A73-45 on 16th February 2016 that recommended an 800-hour repetitive inspection of all 24-fuel nozzle braze joints to inspect for evidence of leakage, soot, or coke formation. The FAA mandated the inspection with an Airworthiness Directive (AD) 2016-22-05, effective 5th December 2016.

Delta Air Lines was in compliance with the aforementioned SBs/ADs.

1.6.3 Fuel Type Used

Jet A-1.

1.7 Meteorological Information

Time:	2200 UTC
Wind:	Variable/2 kt
Visibility:	7 km
Weather:	Nil
Cloud:	FEW at 1200 ft
Temperature:	28/25 ^{o}C
QNH:	1012 hPa

1.8 Aids to Navigation

The Instrument Landing System (ILS) was available and serviceable at the time of the incident.

1.9 Communications

There was effective communication between the flight crew and the Tower, also between the flight crew and the cabin crew.

Communication between the flight crew and the ARFFS personnel when the aircraft landed and stopped on the runway was relayed through the Air Traffic Controller in the Tower.

Following is an excerpt from the ATC transcript:[1]

22:00:12	DAL55	I'll like them to inspect the number one engine. It is shut down, inspect it for any signs of fire.
22:00:19	Tower	Copied. They will inspect number one engine for fire. Copied.
22:00:22	DAL55	Left side, left engine.
22:00:24	Tower	Copied.
22:04:14	Tower	DAL55, Lagos. Yes, the fire unit just confirmed smoke, smoke confirmed on engine one.
22:04:23	DAL55	Okay. Are you sure it's not the brakes that are smoking? It's probably the brakes.
22:04:30	Tower	Okay. Stand by shortly.
22:05:35	Tower	DAL55, Lagos.
22:05:37	DAL55	Go ahead.
22:05:38	Tower	Yeah, the fire unit just told us that they are battling the fire of engine one.
22:05:47	DAL55	Okay, …… (inaudible transmissions)

1.10 Aerodrome Information

Murtala Muhammed International Airport with location indicator DNMM has two runways with designations 18R/36L and 18L/36R.

Runway 18R/36L has a dimension of 3900 m by 60 m. Aerodrome Reference Point is 06°33'09N 003°18'48E. The elevation is 65 ft.

[1] All times in this transcript are UTC time

1.11 Flight Recorders

The aircraft was fitted with solid-state Flight Data and Cockpit Voice Recorders.

	Flight Data Recorder	**Cockpit Voice Recorder**
Manufacturer	Honeywell International Inc.	Honeywell International Inc.
Part Number	980-4700-042	980-6022-001
Serial Number	SSFDR-07672	CVR120-07848

The Flight Data Recorder was successfully downloaded and analysed at the Accident Investigation Bureau's Flight Safety Laboratory in Abuja, Nigeria.

The Cockpit Voice Recorder (CVR) was also successfully downloaded and transcribed at the Accident Investigation Bureau's Flight Safety Laboratory in Abuja, Nigeria.

1.12 Wreckage and Impact Information

Nil.

1.13 Medical and Pathological Information

No medical or pathological tests were done.

1.14 Fire

There were indications of fire and evidence of soot within the No. 1 engine cowling. In addition, during the examination of the engine No. 1 in-situ, there was evidence of an overtemperature condition within the engine cowling, consisting of melted plastic sheathing of the fire detector loop and wire harness.

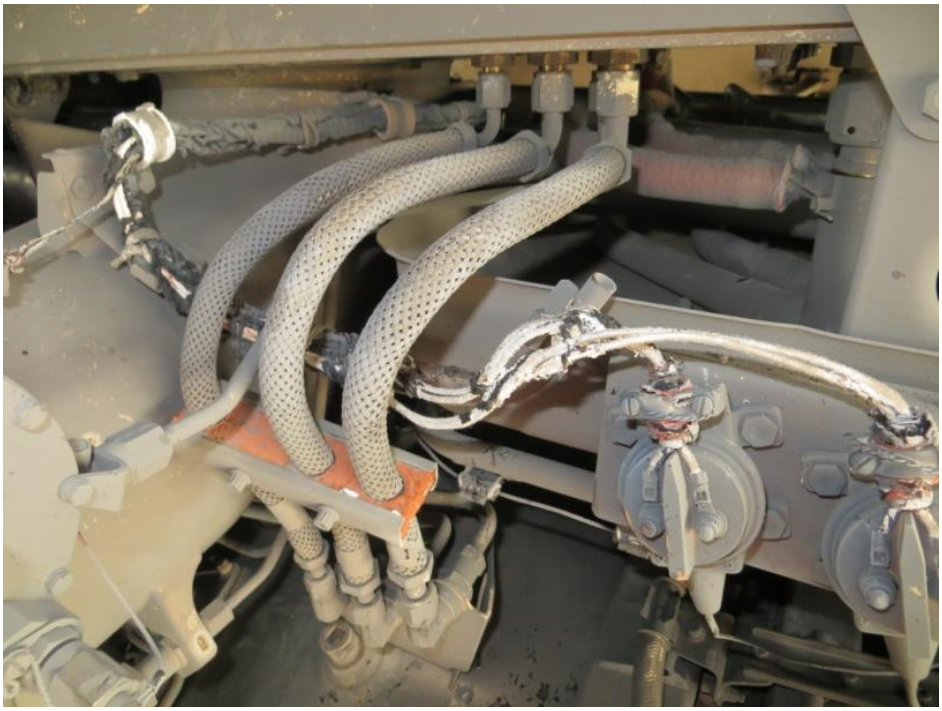


Figure 2: Photo showing melted plastic sheathing of the fire detector loop and wire harness within the engine cowling

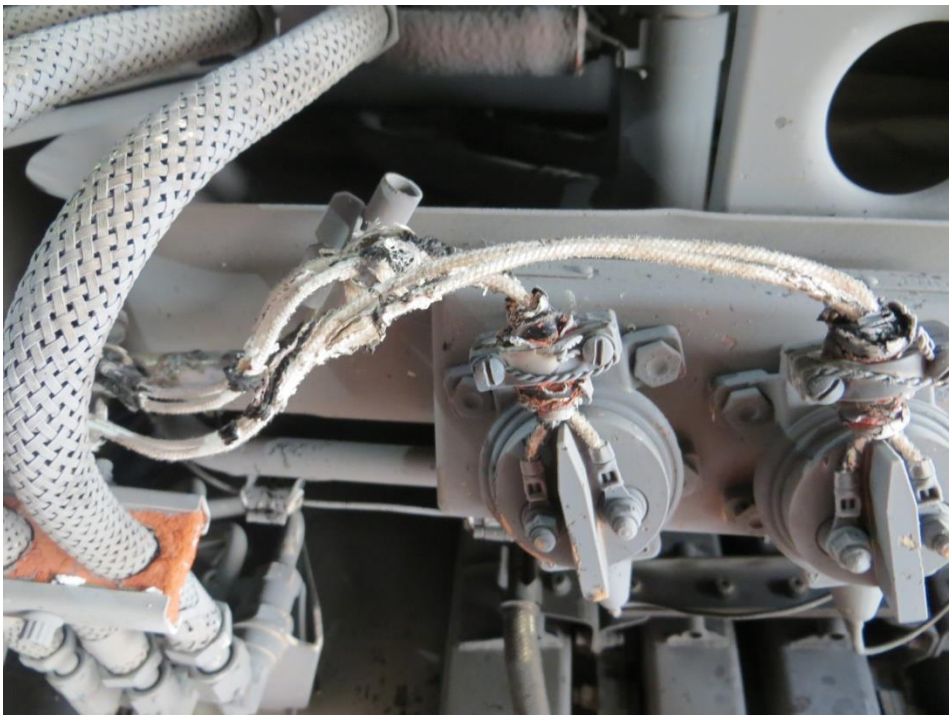


Figure 3: A close-up view of melted plastic sheathing of the wire harness

1.15 Survival Aspect

The aircraft was intact; hence, survival was not an issue. In the evacuation, the emergency slides were deployed on the right side of the aircraft and the passengers were evacuated. During the evacuation, one passenger was seriously injured, and 11 (Eleven) passengers sustained minor injuries.

1.16 Test and Research

1.16.1 Fuel

Fuel samples were obtained from the No. 1 engine and sent for testing and analysis. The results indicated that the fuel was free of contaminants and within recommended quality standards.

1.16.2 Borescope Inspection

A borescope inspection was carried out on the No. 1 engine. It showed some discoloration/foreign deposits in the turbine section and combustion chambers. These deposits were attributed to the fire extinguishing agents deployed by the ARFFS.

Figure 4: A view of the interior of the combustion chamber of No. 1 engine

Figure 5: Photo showing discoloration/foreign deposits in the turbine section

1.16.3 Engine Teardown

The No. 1 engine was removed from the aircraft in Lagos and shipped to Delta TechOps in Atlanta, Georgia, USA for a detailed examination. Oversight of the engine examination was delegated to the National Transportation Safety Board (NTSB), USA in its capacity as State of Registry and State of Manufacture. Representatives from Pratt & Whitney, Delta Air Lines and the Federal Aviation Administration (FAA), USA were present at the examination in their capacity as Technical Advisers to the accredited representative of NTSB.

1.16.4 Metallurgical Investigation of Fuel Manifold and Bracket from PW4168A-1D Engine P733582

Following the investigative teardown of the subject PW4168A-1D engine at Delta TechOps, Atlanta, Georgia, one fuel manifold, one fuel nozzle, and one bracket were returned to Pratt and Whitney for metallurgical investigation. Cracking was identified in the fuel manifold at the runout of the braze joint near the #1 fuel nozzle attachment. The bracket from that location was also found to be fractured.

Cracking in the fuel manifold progressed in high cycle fatigue from an origin at the toe of a tack weld. No defects or anomalies were found to be associated with the crack. X-ray examination as well as an examination of a metallographic cross-section through the fatigue origin found full braze coverage with very little porosity. The tube, braze, and elbow were confirmed to be similar in composition to the applicable material specifications. The tube thickness near the crack surface was 0.028", which conformed to drawing requirements.

Examination of the fractured bracket found that the fracture progressed in high cycle fatigue from an origin area at the toe of the weld. No defects or anomalies were found to be associated with the cracking.

The full text of the examination is attached in **Appendix A**.

1.17 Organizational and Management Information

Delta A330/340 Flight Crew Operating Manual Procedures – Abnormal and Emergency Procedures

DELTA

A330/A340
FLIGHT CREW OPERATING MANUAL

PROCEDURES
ABNORMAL AND EMERGENCY PROCEDURES
ENG

ENG 1(2) FIRE
(IN FLIGHT)

Applicable to: MSN 0524-0865

Ident.: PRO-ABN-ENG-EA-00017466.0001001 / 21 MAR 16

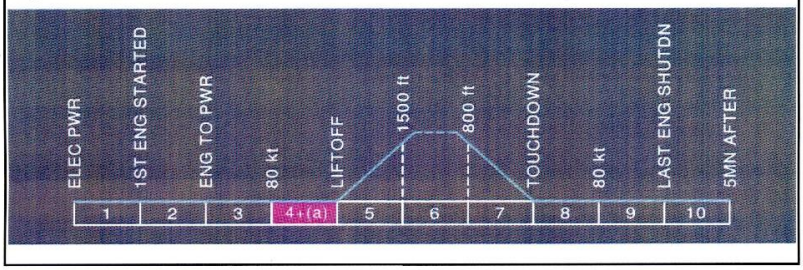
ANNUNCIATIONS

Triggering Conditions:

L2 This alert triggers when:

- Fire is detected by both loops, or
- Fire is detected by one loop when the other loop is failed, or
- A rupture occurs in both loops within 5 s.

Flight Phase Inhibition:



Note: *(a) Alert inhibited between V1 and lift off +15 s.*

Continued on the following page

DELTA

A330/A340
FLIGHT CREW OPERATING MANUAL

PROCEDURES

ABNORMAL AND EMERGENCY PROCEDURES

ENG

ENG 1(2) FIRE (Cont'd)
(IN FLIGHT)

Ident.: PRO-ABN-ENG-EA-00011607.0002001 / 14 FEB 17

LAND ASAP

THR LEVER (AFFECTED)..... IDLE
ENG MASTER (AFFECTED)..... OFF

L2 *Associated LP and HP valves close.*

L1 ENG FIRE P/B (AFFECTED)..... PUSH

L2 *When pushed:*
- *Aural warning stops*
- *The light remains on, until the fire is extinguished, regardless of the position of the ENG FIRE pb-sw*
- *FADEC is no longer supplied.*

L1 ENG BLEED (AFFECTED ENG IF NOT AUTOMATICALLY CLOSED)..... OFF
APU BLEED (ONLY FOR ENG 1)..... OFF
X BLEED (IF NOT AUTOMATICALLY CLOSED)..... CLOSE

L2 *The affected side is isolated from any source of air.*

L1 AGENT 1 AFT 10 S..... DISCH

L2 *The 10 s delay allows N1 to decrease, reducing nacelle ventilation, and thereby increasing the effect of the agent. Automatic countdown on the ECAM.*

L1 ATC..... NOTIFY

L2 *Notify ATC of the nature of the emergency, and state intentions.*

L1 ● **IF FIRE AFTER 30 S:**
AGENT 2..... DISCH

L2 *Discharge the second agent, if the fire warning remains 30 s after the discharge of the first agent.*

L12

ASSOCIATED PROCEDURES

ENG 1(2) SHUT DOWN

Do not attempt to restart the engine.
For the ENG SHUT DOWN procedure, see the ENG section (Refer to PRO-ABN-ENG ENG 1(2) SHUT DOWN).

DELTA

A330/A340
FLIGHT CREW OPERATING MANUAL

AIRCRAFT SYSTEMS
FIRE PROTECTION
ENGINE AND APU - SYSTEM DESCRIPTION

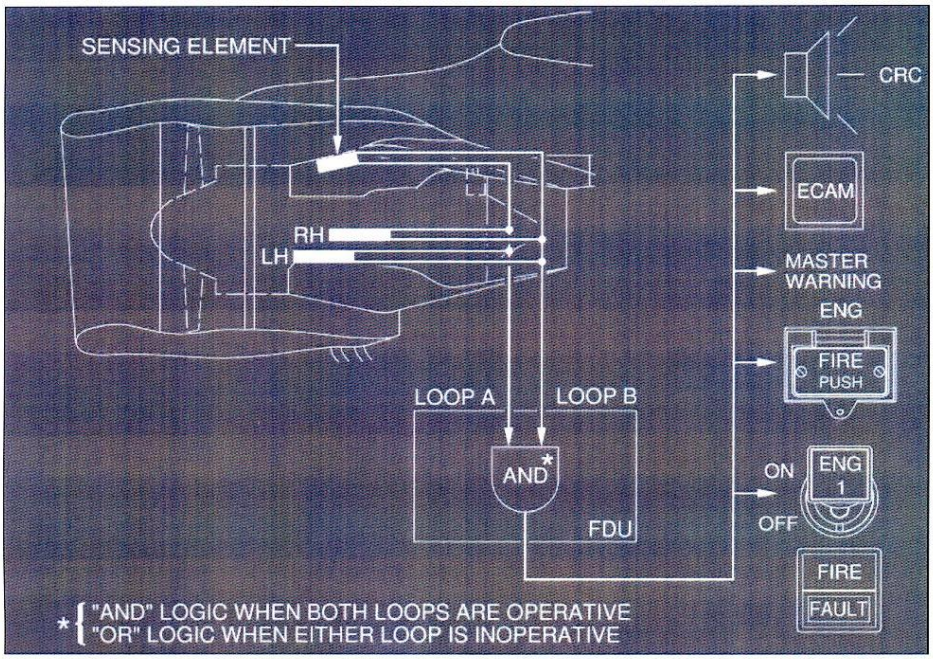
FIRE DETECTION

Ident.: DSC-26-20-10-00000381.0003001 / 17 MAR 17
Applicable to: MSN 0524-0865

The engines and the APU each have a fire and overheat detection system consisting of :
- Two identical gas detection loops (A and B) mounted in parallel.
- A Fire Detection Unit (FDU).

The gas detection loops consist of :
- Three sensing elements for each engine, located in the pylon nacelle, in the engine core sections.
- One sensing element in the APU compartment.

When a sensing element is subjected to heat, it sends a signal to the fire detection unit.
As soon as loops A and B detect temperature at a preset level, it triggers the fire warning system.
A fault in one loop (break or loss of electrical supply) does not affect the warning system. The unaffected loop still protects the aircraft.
If the system detects an APU fire while the aircraft is on the ground, it shuts down the APU automatically and discharges extinguishing agent.



FIRE EXTINGUISHING

Ident.: DSC-26-20-10-00021202.0001001 / 17 MAR 17
Applicable to: ALL

ENGINES

Each engine has two extinguisher bottles equipped with electrically-operated squibs to discharge their agents. Each squib has a dual electric supply. The flight crew controls the discharge of the extinguisher bottles from the ENG FIRE panel in the cockpit.

APU

The APU has one fire extinguisher bottle that has two electrically-operated squibs to discharge its agent.
The flight crew controls the discharge from the APU FIRE panel in the cockpit.
When an APU fire is detected on the ground, the APU automatically shuts down, and the extinguisher bottle discharges automatically.

FIRE DETECTION AND DETECTION FAULT LOGIC

Ident.: DSC-26-20-10-00021201.0001001 / 17 MAR 17
Applicable to: ALL

Fire detection units process all the warnings and cautions originating in the sensing elements:

- A fire warning appears if:
  - Both loop A and B send a fire signal, or
  - One loop sends a fire signal and the other one is failed, or
  - Breaks occur in both loops within 5 s of each other (flame effect), or
  - A test is performed on the associated FIRE panel
- A loop-fault caution appears if:
  - One loop is failed, or
  - Both loops are failed, or
  - The FDU fails.

DELTA

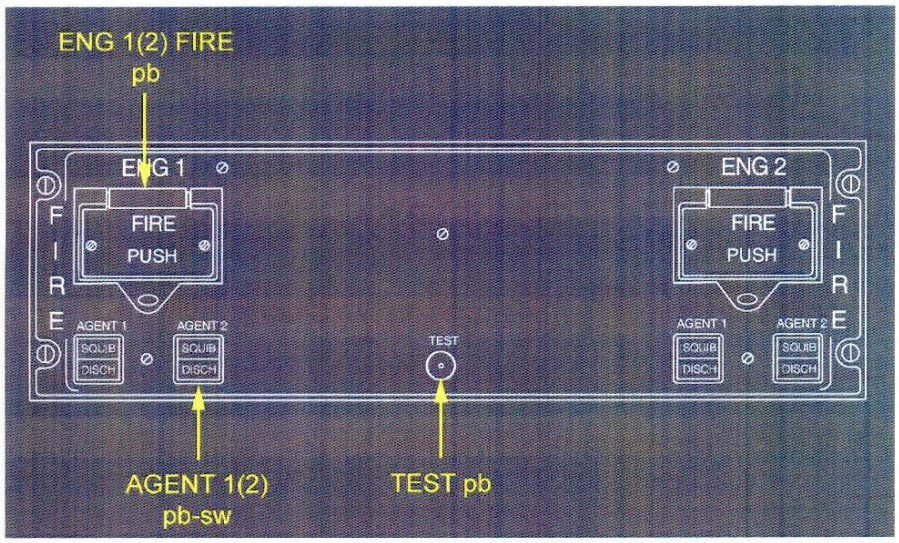
A330/A340
FLIGHT CREW OPERATING MANUAL

AIRCRAFT SYSTEMS
FIRE PROTECTION
ENGINE AND APU - CONTROLS AND INDICATORS

ENG FIRE PANEL

Applicable to: ALL

Ident.: DSC-26-20-20-10-00021185.0001001 / 17 MAR 17



Ident.: DSC-26-20-20-10-00021186.0001001 / 17 MAR 17

ENG FIRE PB

The pushbutton normal position is in, and guarded. When the flight crew pushes it, the pushbutton is released and sends an electrical signal that performs the following for the corresponding engine:

- Silences the aural fire warning
- Arms the fire extinguisher squibs
- Closes the low-pressure fuel valve
- Closes the hydraulic fire shut off valve
- Closes the engine bleed valve
- Closes the pack flow control valve
- Cuts off the FADEC power supply
- Deactivates the IDG.

The red lights come on, regardless of the pushbutton position, whenever the fire warning of the corresponding engine is activated.

Ident.: DSC-26-20-20-10-00021187.0001001 / 17 MAR 17

AGENT 1(2) PB-SW

Both AGENT pushbutton-switches of an affected engine become active when the flight crew releases the ENG FIRE pb.
A brief push on the pushbutton-switch discharges the corresponding fire agent.

- "SQUIB" comes on white when the flight crew releases the associated ENG FIRE pb to help the flight crew identify the AGENT pb-sw to be activated
- "DISCH" comes on amber when the corresponding fire extinguisher bottle has lost pressure.

Ident.: DSC-26-20-20-10-00021188.0001001 / 17 MAR 17

TEST PB

This pushbutton tests the operation of the fire detection and extinguishing system for the engines.

When pressed:
- A continuous repetitive chime sounds
- The MASTER WARNING lights flash
- The ENG FIRE warning appears on ECAM
- On the ENG FIRE panel:
  - The ENG FIRE pushbuttons light up red
  - The SQUIB lights come on white if discharge supplies are available
  - The DISCH lights come on amber
- On the ENG MASTER panel (pedestal):
  - The FIRE lights come on red.

DELTA

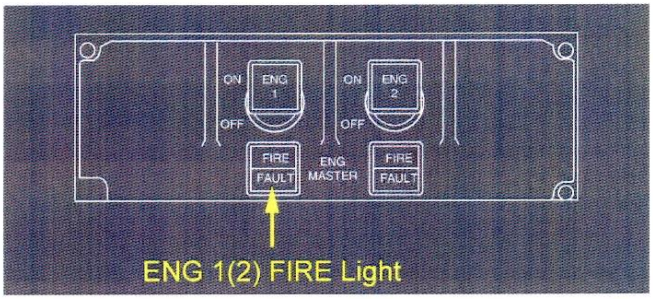
A330/A340
FLIGHT CREW OPERATING MANUAL

AIRCRAFT SYSTEMS
FIRE PROTECTION
ENGINE AND APU - CONTROLS AND INDICATORS

ENG MASTER PANEL

Applicable to: ALL

Ident.: DSC-26-20-20-30-00021193.0001001 / 17 MAR 17



Ident.: DSC-26-20-20-30-00021194.0001001 / 17 MAR 17

ENG FIRE LIGHT

This light identifies the engine to be shutdown in the case of fire.
The light comes on red when an engine fire warning is triggered.

1.18 Additional Information

TALON IIB combustor configuration is an element of the conversion of a PW4000-100 engine to a PW4168A-1D engine made available by the P&W Service Bulletin (SB) (PW4G-100-72-220) as part of an Advantage70® conversion.

The B-Nut is the common description of the nut that is used to connect fluid lines and hoses. It is used in aircraft tubing to connect a piece of flared tubing to a threaded fitting. B-nuts are used with a sleeve that is slipped over the flared tubing. It requires a specific torque in order to maintain system integrity.

1.19 Useful and Effective Investigation Techniques

Nil.

2.0 ANALYSIS

2.1 Conduct of the flight

According to the FDR, during climb out at an altitude of 1,739 ft, and less than a minute after take-off, the fire warning system activated.

The procedure in the event of a fire warning activation in the A330/A340 Flight Crew Operating Manual stipulated that the flight crew land as soon as possible. The flight crew completed the Electronic Centralized Aircraft Monitor (ECAM) procedures, shut down the No. 1 engine and discharged one of the engine No. 1 fire bottles. The flight crew declared an emergency to the ATC and obtained clearance to return to the airfield for an immediate landing. The crew also requested the emergency services to be on stand-by.

Following the discharge of the fire bottle, the No. 1 engine fire warning indication remained illuminated. Hence, the flight crew also discharged the second fire bottle. After the second fire bottle was discharged, the fire warning continued briefly, but cleared during the approach for landing. It can be deduced that the overtemperature condition which likely had caused the activation of the fire warning had been contained or cooled, possibly by the fire extinguishing agent.

At take-off, the aircraft take-off weight was above the maximum landing weight, due to the fuel quantity uplifted, in order to be sufficient for the long-haul flight. The requirement in the Flight Crew Operating Manual to land as soon as possible implied that there would not be an opportunity to jettison fuel before such a landing. Nevertheless, in this occurrence, the aircraft was not equipped with a fuel jettisoning system. Hence, the landing would be conducted at a weight slightly

below the take-off weight, and in excess of the maximum landing weight. Based on the CVR transcript, the flight crew acknowledged that the landing would be conducted at a landing weight in excess of the maximum landing weight. The aircraft was, however, certified for overweight landing. Subsequently, the flight crew made the appropriate preparations for an overweight landing.

The aircraft landed safely on the runway and was met by Airport Rescue and Fire Fighting Services (ARFFS). The ARFFS personnel communicated via the ATC the information to the flight crew that there was an active fire in the No. 1 engine, and advised the flight crew that the passengers be evacuated.

ATC confirmed there was fire at the tail end of the engine No.1 exhaust pipe, the Captain then ordered evacuation. The passengers were evacuated from the right side of the aircraft.

2.2 Maintenance

The aircraft was maintained in accordance with the relevant FAA regulations. Records made available showed that applicable Service Bulletins and Airworthiness Directives up to the date of the occurrence had been complied with.

Nevertheless, a Service Bulletin, PW4G-100-73-48 released on 14th March 2018, after the occurrence, recommended the installation of triplet clamps to reduce vibration stress. Although an Airworthiness Directive had not been issued by the FAA to that effect.

According to Delta Air Lines maintenance records made available, the No. 1 engine had accumulated a total of 53,396.9 h and 6,549 cycles since new and 20,484.5 h

and 2,181 cycles since last major overhaul. The No. 1 engine was last inspected in accordance with the relevant SBs and ADs on 31st December, 2017. The engine had accumulated a total of 474 h since the last inspection and this fire warning occurrence. Delta Air Lines' maintenance records showed that the No.1 engine had suffered two previous fuel supply manifold fracture findings. The first fracture finding occurred on 19th January, 2016 on fuel triplet 8/fuel nozzle 22, after maintenance personnel reported a fuel leak on the airport ramp. The Delta maintenance replaced the triplet 8 with the engine on the wing, and the aircraft was returned to service. The second fracture finding occurred on 15th April, 2016 on fuel triplet 2/fuel nozzle 4 during a line maintenance engine idle power test. The triplet 2 was replaced with the engine on wing, and the aircraft was returned to service. Neither of these two fracture findings involving the fuel leak occurred in flight or resulted in an engine fire.

2.3 The Fuel Manifold Leak

The fire warning came ON during climb out, about a minute after take-off. The engine teardown report showed that there was a leak from a hairline crack on the fuel manifold tube that supplied fuel nozzle 1, when a testing pressure of approximately 65 psi was applied.

According to the type certificate data sheet No. E36NE Revision 7, the PW4168A-1D engine rated take-off thrust was 68,600 lb and Maximum Continuous Thrust (MCT) was 59,357 lb. At take-off, the aircraft was at full thrust and the engines required increased fuel supply. The fuel pressure would logically be high. Hence, a fuel leak would result in a high-velocity fuel spray.

There have been reported cases of fuel manifold fractures on some Pratt & Whitney engines with TALON IIB burner configuration, which resulted in either fire or in-flight shutdown (IFSD) of the engine. The fractures were examined and found to be due to high cycle fatigue caused by over-torque of the B-nut or high vibratory stress. Examinations have shown that high stress locations usually occur if the B-nut is over-torqued without using a back-up wrench, resulting in fracture at those locations.

In this occurrence, evidence showed that Delta Air Lines had complied with SB PW4G-100-A73-44 of 10th October 2014 to increase the fuel nozzle B-nut torque from the previous range of 180-200 in-lb to 250-270 in-lb.

Thus, the torque of the B-Nut appeared not to be a factor in this occurrence.

The metallurgical examination of the fuel manifold and the bracket showed that the fracture in the fuel manifold progressed in high cycle fatigue from an origin at the toe of a tack weld.

The engine teardown report showed that during removal of fuel nozzle 1, the intermediate cooling duct support bracket bolted to the fuel nozzle 1 pad was found fractured on the left side (See Figure 6 below). The fuel manifold cracking is due to a structural mode of the fuel manifold being excited by a combustor acoustic tone.

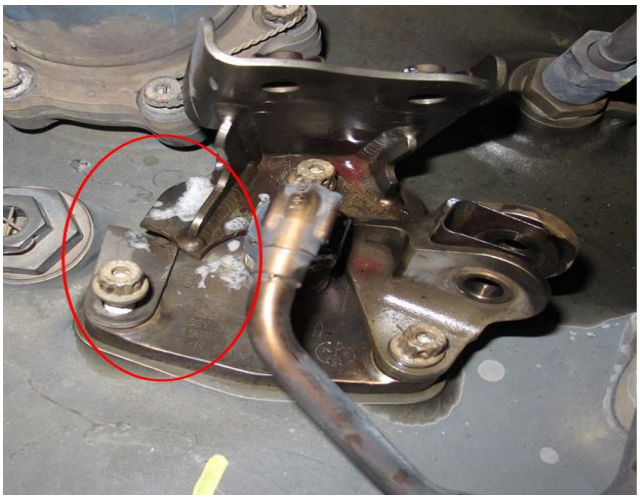


Figure 6: Photo showing the fractured support bracket (circled in red) adjacent to fuel nozzle 1.

The engine teardown report showed an area of localized discoloration and sooting between the 11:30 to 1 o'clock positions, axially from the diffuser case forward flange (K-flange) to the aft end of the fuel manifold triplets (about 15 in). The discoloration and soot were concentrated around the fuel nozzles/manifold lines (nozzles 1, 2, 3, 4, and 24). The intermediate cooling duct (piccolo tube) and starter air duct were discoloured and contained soot immediately above and aft of fuel nozzle 1 located at the 12 o'clock position. Within the area of soot on the intermediate cooling duct was a localized clean area consistent with a fluid spray pattern, see Figure 7. The spray pattern corroborated the extent and effect of the leak found during the engine teardown. The discoloration, soot and localized area clean of soot was consistent with where the fuel was propagated from the fracture during the occurrence.

Figure 7: The pattern of soot on the intermediate cooling duct

It was evident from the melted plastic sheathing of the fire detector loop/wire harness and the scorch marks on various surfaces and components, that the fire warning had been triggered by fire within the engine nacelle and not just an overtemperature condition.

It could be deduced that the presence of leaked fuel from the fuel manifold, combustible oxygen from the intake air and a heat source, such as the hot surfaces of the Diffuser case provided possible conditions for ignition to occur, and therefore, for the production and propagation of the fire.

2.4 The Firefighting Actions

Personnel of the Airport Rescue and Fire Fighting Services reported observing a fire in the left engine when the aircraft landed. The crew, however, reported that the fire warning indication was extinguished on approach for landing. The FDR flight data corroborated the report of the crew and showed that the overtemperature condition that had annunciated the warning had been resolved prior to landing. The ARFFS personnel attempted to extinguish the fire by directing the fire extinguisher into the aircraft exhaust pipe, as was obvious on visual inspection of the engine when the investigators arrived at the scene. Although the ARFFS personnel reported seeing flames in the left engine, the fire damage to the No. 1 engine was localized within the engine cowling. It was therefore difficult to corroborate the observations of the ARFFS personnel.

Since the incident occurred at night and the aircraft stopped on the runway, it is possible that the exhaust glow of the engine No. 1 could have been taken for a fire.

In addition, since the aircraft landed in excess of its maximum landing weight, the braking force required to stop the aircraft would be sufficient to cause overheating of the wheels resulting in the red-hot glow reported by the ARFFS.

3.0 CONCLUSIONS

3.1 Findings

1. The flight crew were certified and qualified to conduct the flight in accordance with applicable FAA regulations.
2. The First Officer was the Pilot Flying while the Captain was the Pilot Monitoring.
3. The left engine fire warning came ON less than one minute after take-off.
4. At 22:52.25 h, the flight crew contacted ATC and declared an emergency.
5. At about 22:59 h, the aircraft landed safely on runway 18R.
6. At about 23:04 h, the Airport Rescue and Fire Fighting Services reported smoke, and later fire on the left engine.
7. There was evidence of overtemperature condition within the engine cowling, as well as a small area of fire with soot to some extent.
8. The two fire extinguishing bottles on the left engine were discharged.
9. Delta Air Lines was in compliance with the applicable Service Bulletins (SBs)/ Airworthiness Directives (ADs) at the time of the occurrence.
10. The aircraft is not equipped with a fuel-jettisoning system, and the successful landing was conducted at a weight in excess of the maximum landing weight, although the aircraft is certified for overweight landing.

3.2 Causal Factor

An overtemperature condition and localized fire within the No. 1 engine cowling triggered a fire warning. The overtemperature and fire were caused by the ignition of fuel from a hairline crack on the fuel manifold supplying fuel nozzle 1.

3.3 Contributory factor

The fuel manifold cracking can be attributed to high vibratory stresses due to coupling of an acoustic combustor mode and a fuel manifold structural mode.

4.0 SAFETY RECOMMENDATIONS

4.1 Safety Recommendation 2019-024

The NTSB may consider recommending to the FAA to issue an Airworthiness Directive with respect to Pratt & Whitney Service Bulletin PW4G-100-A73-47 and PW4G-100-73-48 to address the fuel nozzle and fuel manifold failure modes.

APPENDIX

Appendix A: Metallurgical Report

Metallurgical Investigation
Final Report

Pratt & Whitney
Materials & Processes Engineering
East Hartford, CT

Subject: **Metallurgical Investigation of Fuel Manifold and Bracket from PW4168A-1D Engine P733582 (Public Release Version)**

Date: **February 21, 2019**

Summary and Conclusions:

Following the investigative teardown of the subject PW4168A-1D engine at Delta TechOps, Atlanta, Georgia, one fuel manifold, one fuel nozzle, and one bracket were returned to Pratt and Whitney for metallurgical investigation. Cracking was identified in the fuel manifold at the runout of the braze joint near the #1 fuel nozzle attachment. The bracket from that location was also found to be fractured.

Cracking in the fuel manifold progressed in high cycle fatigue from an origin at the toe of a tack weld. No defects or anomalies were found to be associated with the crack. X-ray examination as well as an examination of a metallographic cross-section through the fatigue origin found full braze coverage with very little porosity. The tube, braze, and elbow were confirmed to be similar in composition to the applicable material specifications. The tube thickness conformed to drawing requirements.

Examination of the fractured bracket found that the fracture progressed in high cycle fatigue from an origin area at the toe of the weld. No defects or anomalies were found to be associated with the cracking.

1.0 Background

PW4168A-1D engine serial number 733582 was installed in the number 1 (left) position of a Delta Air Lines Airbus A330-200, aircraft registration N858NW. On February 13, 2018, the engine experienced an undercowl engine fire during initial climb from Murtala Muhammed International Airport, Lagos, Nigeria (LOS). The aircraft completed an uneventful overweight landing at LOS.

The engine was shipped to Delta TechOps in Atlanta, Georgia for NTSB-led teardown. The subsequent investigative teardown identified a leak in the fuel manifold at the fuel nozzle #1 position. A crack was visible on the manifold at that location. To remove the part from the engine, the fuel manifold line was cut at a location away from the crack in order to keep the joint intact. During teardown, it was additionally noted that the intermediate cooling duct support bracket bolted to the fuel nozzle 1 pad was fractured. Both the cracked manifold and the fractured bracket were returned to Pratt & Whitney East Hartford for investigation.

2.0 Details of Examination

The cracked manifold, fractured bracket, and one fuel nozzle were submitted for review. Detailed examination of each component was as follows.

2.1 Fuel Manifolds & Nozzle

Visual examination of the fuel manifold and nozzle found that the parts were dark in color. The joint between the nozzle and the manifold was intact; the manifold had been sectioned in order to facilitate removal from the engine without disassembling the joint. The fuel nozzle was identified as being from position 1 (Figures 1-5).

Prior to any further analysis, the fuel manifold and nozzle were submitted to the Pratt & Whitney Quality & Standards Laboratory for X-ray examination. X-ray found that the manifold braze joints appeared to have nearly 100% braze coverage. The only crack identified was the one observed during teardown (Figure 6).

Continued visual examination of the fuel manifold confirmed the crack located at the braze near the fuel nozzle attachment. The crack extended for approximately half of the circumference of the tube. The crack was approximately aligned with a tack weld, but was not through the tack weld (Figure 7).

The crack was fractured open and examined using a binocular microscope. Binocular examination identified fatigue progressing through wall from an origin on the outer diameter of the tube. The origin was located in line with the toe of a ball tack weld. The total crack length was approximately 0.4" along the outer diameter (OD) surface of the tube.

Scanning electron microscope (SEM) evaluation of the crack surface identified cleavage features consistent with high cycle fatigue (HCF) progressing through wall from an origin area on the outer diameter of the tube. No anomalies or defects were observed at the origin.

A metallographic section was prepared through the origin area on the braze side of the crack. Review of the section found that the braze appeared to be in good condition with limited porosity observed. Bulk microstructure of the tube material appeared typical of properly processed 321 stainless steel. At the crack location, the tube wall thickness conformed to the drawing requirement. It was noted that a portion of remnant tube material was observed in the joint away from the crack location, likely due to a prior repair (Figure 8).

Energy dispersive spectrometry (EDS) analysis of the section found that the tube, elbow, and tack weld compositions were similar to 321 stainless steel, 347 stainless steel, and Inconel 625, respectively. The braze was confirmed to be a gold-nickel braze.

2.2 Bracket

Visual review of the bracket as received found that the fracture was located at the edge of a weld in one of two legs (Figures 9-10). Binocular review of the fracture surface found that it progressed in fatigue from an origin area at the toe of the weld. SEM examination identified crystallographic features typical of HCF progression extending from the edge of the weld. No evidence of any material/weld defects was observed.

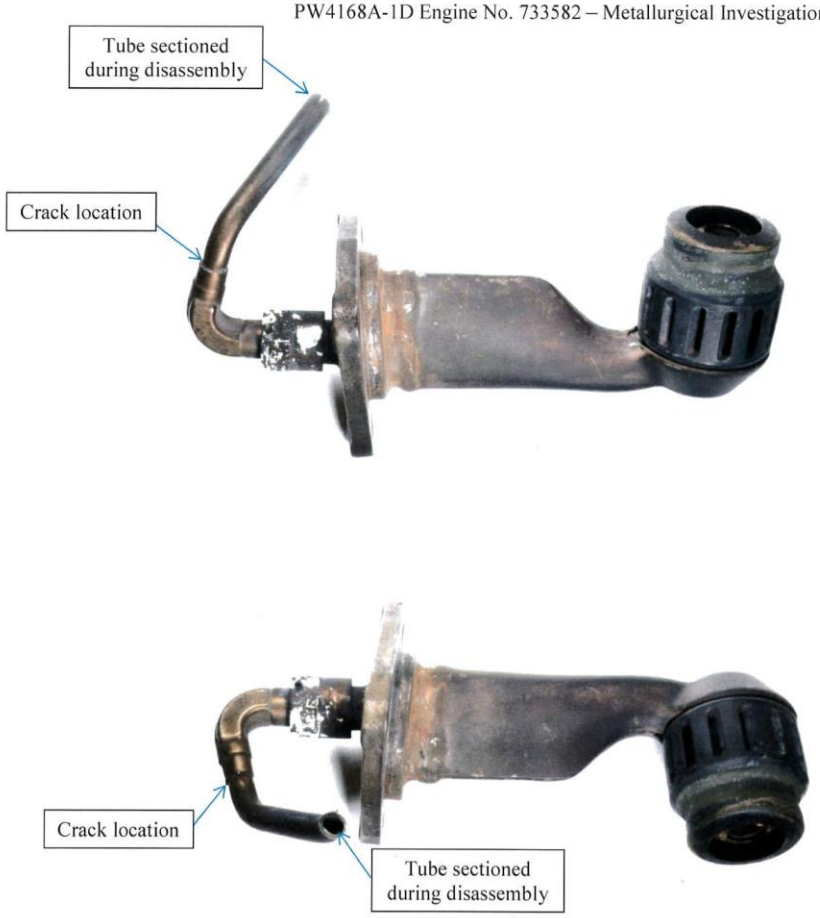


Figure 1: Overall appearance of the fuel nozzle and partial fuel manifold in the as-received condition.

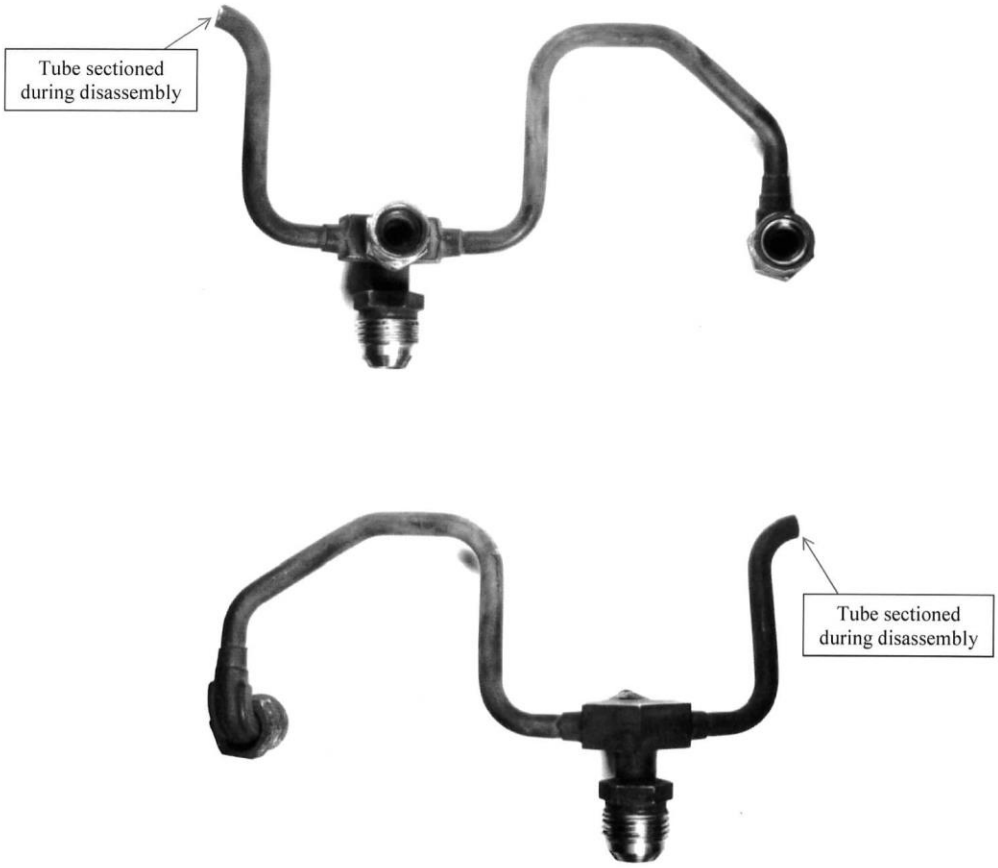


Figure 2: Overall appearance of the fuel manifold in the as-received condition

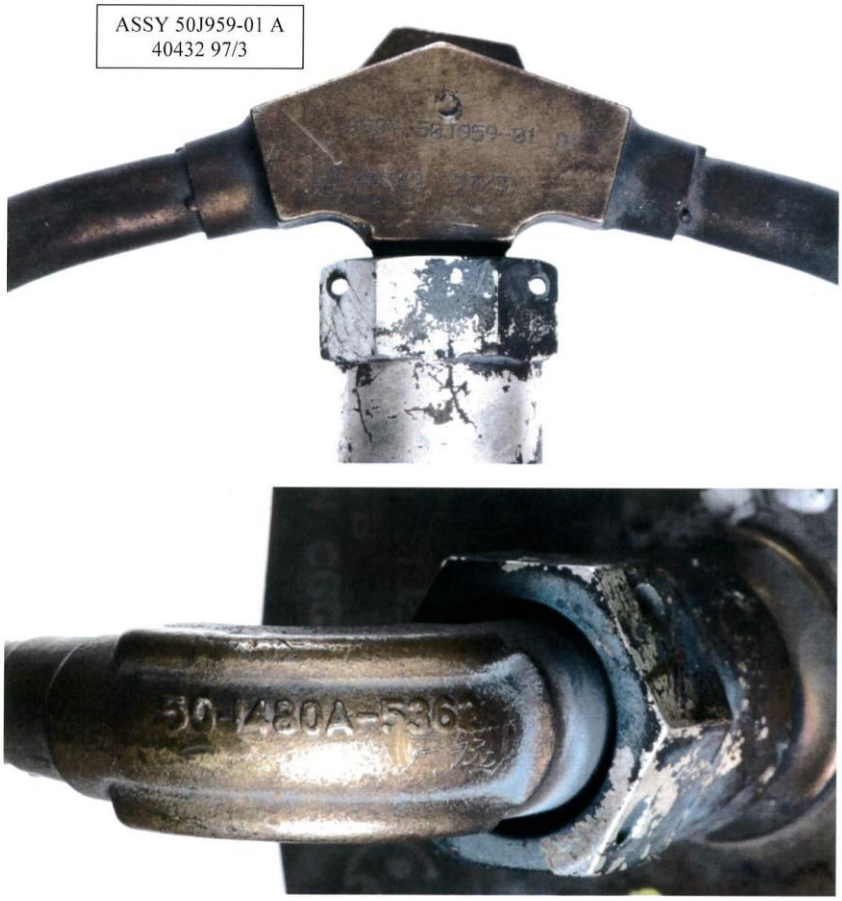


Figure 3: Part markings noted on the manifold.

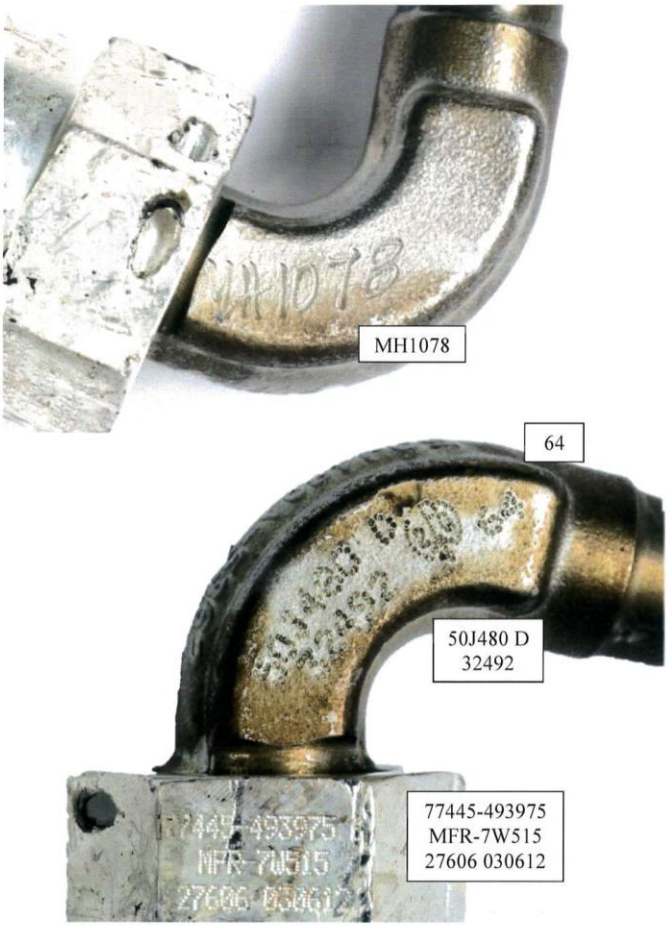


Figure 4: Part markings noted on the manifold.

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Figure 5: Part markings noted on the manifold.

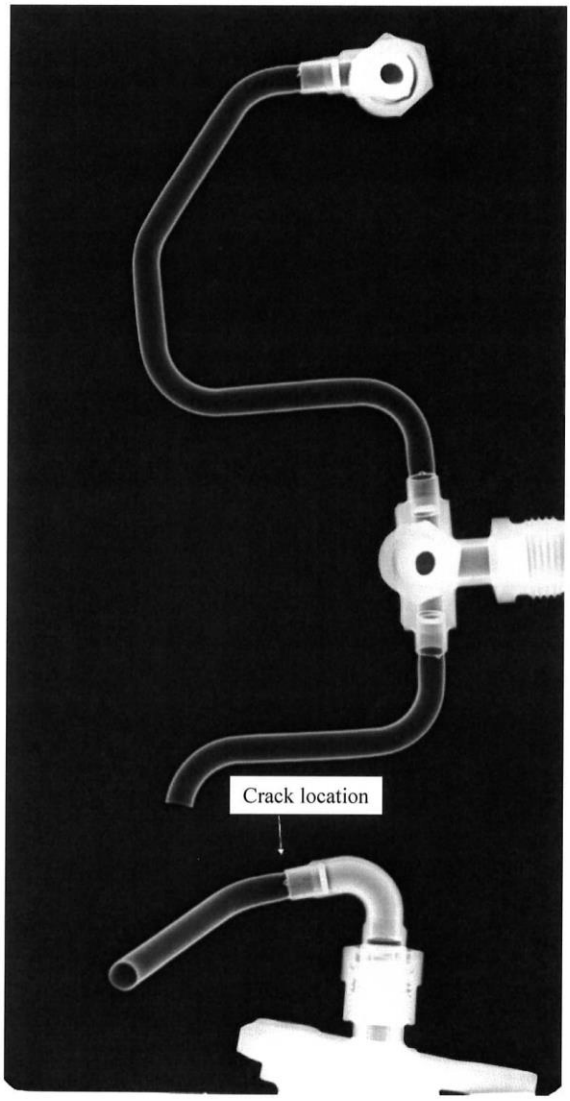

Figure 6: X-ray image of manifold showing location of crack and appearance of braze joints.

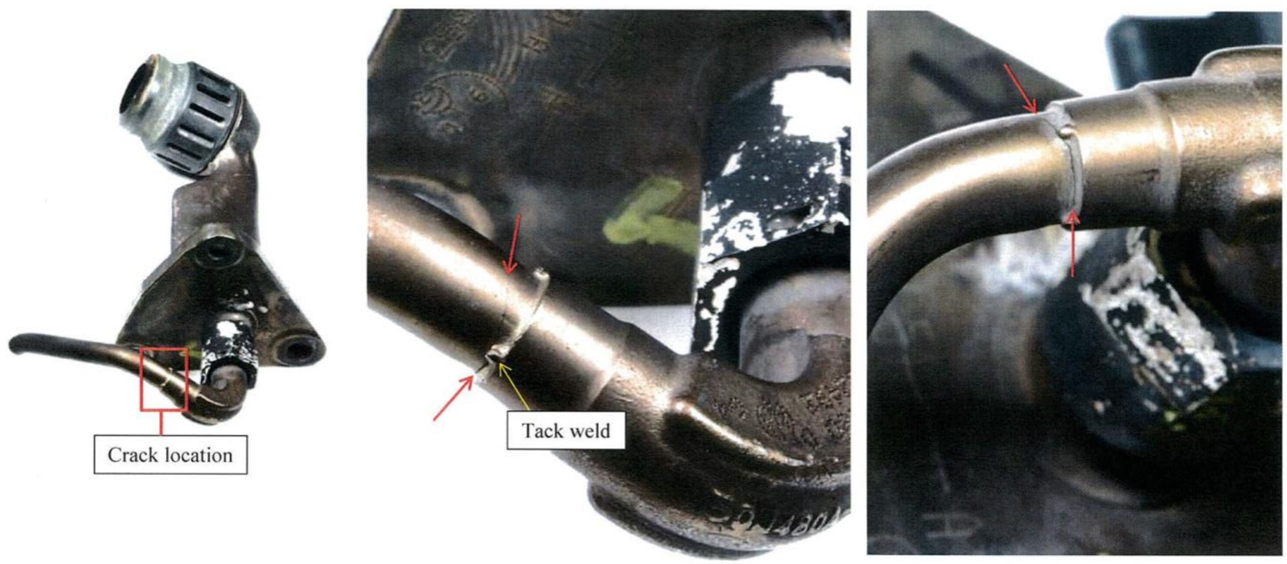

Figure 7: Images of the crack (red arrows) at the fuel manifold braze joint near the fuel nozzle.

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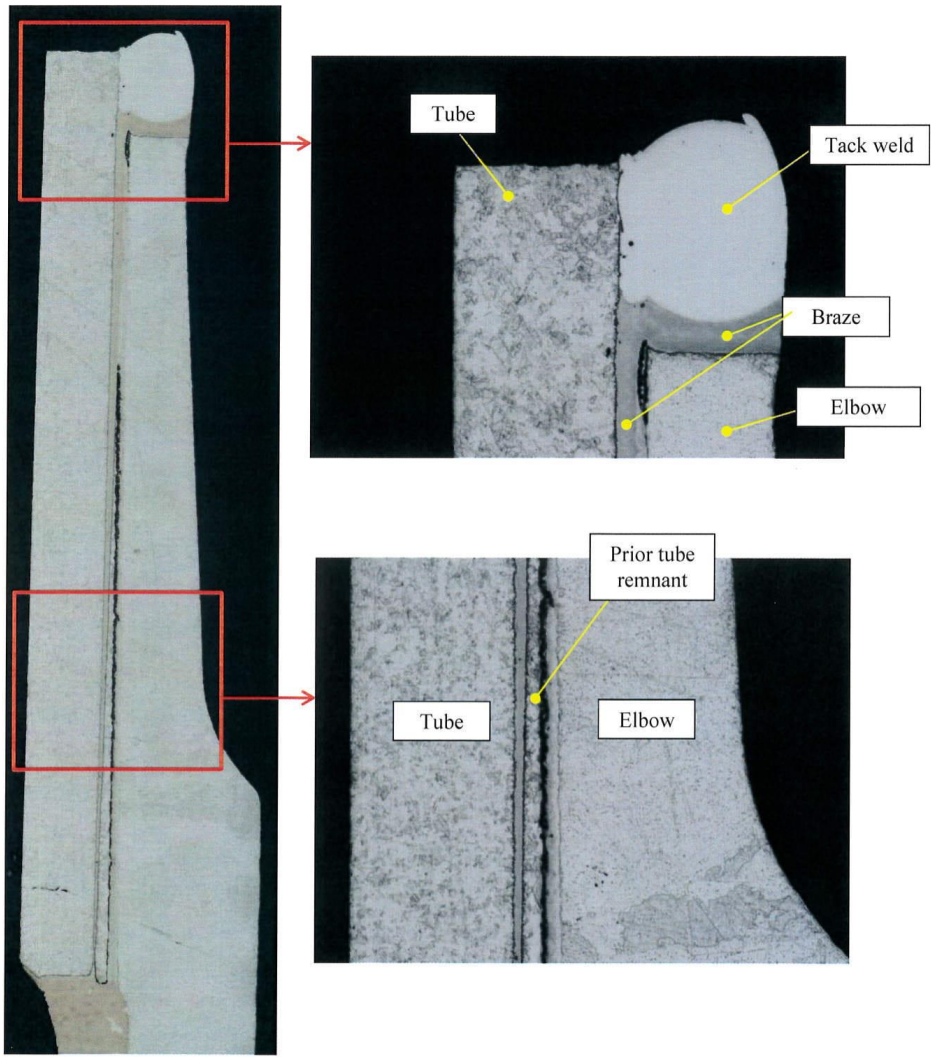

Figure 8: Photomicrographs showing appearance of the braze joint at the crack location.

Figure 9: Images of the bracket showing location of fracture at the edge of a weld.

Figure 10: Location of fracture and part markings observed on bracket.