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وزارة النقل والاتصالات وتقنية المعلومات
Sultanate of Oman
Ministry of Transport, Communications and Information Technology

Oman Transport Safety Bureau (OTSB)

Serious Incident

Final Report

OTSB Case File No: AIFN-002/09/2022

Air India Express Boeing 737-800 Engine Number 2 Fire

Operator: Air India Express Limited
Make and Model: Boeing B737-800NG.
Nationality and Registration Marks: India- VT-AXZ

Location of the Occurrence: Muscat International Airport, Oman
State of Occurrence: Sultanate of Oman
Date of Occurrence: 14th September 2022
Date of Publication: 02nd May 2024

Purpose of the Investigation

The investigation was conducted by Oman Transport Safety Bureau pursuant to Civil Aviation Law 76/2019 Chapter 10, and in compliance with the Civil Aviation Regulation CAR-13 - Aircraft Accident & Incident Investigation & Reporting Procedures. The investigation was in conformance with the standards and recommended practices in Annex 13 - Aircraft Accident and Incident Investigation to the Convention on International Civil Aviation Organization (ICAO).

The sole objective of the investigation of an accident and incident is to prevent future aircraft accidents and incidents and not to apportion blame or liability.

Oman Transport Safety Bureau issues this Final Report in accordance with the national and international standards, and industry best practice therefore concerned parties are invited to review this report and provide their significant and substantiated comments.

The Final Report will be publicly available at:

http://www.mtcit.gov.om

Oman Transport Safety Bureau

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The Sultanate of Oman

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Abbreviations

AAIB	Aircraft Accident Investigation Board
AGB	Accessory Gear Box
AGL	Above Ground Level
ALTN	Alternate
AMM	Aircraft Maintenance Manual
AMO	Aircraft Maintenance Organisation
AOCC	Airport Operation Coordination Centre
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ASST	Assistant
BA	Breathing Apparatus
BAC	Breathing Apparatus Committee
BEA	Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile
BRG	(French Safety Investigation Authority)
CAA	Civil Aviation Authority
CDU	Control Display Units
CFM	CFM International
CRM	Crew Resource Management
CRS	Cycles Since New
CSN	Cycles Since New
CVT	Center Vent Tube
CVR	Cockpit voice recorder
DFDR	Digital Flight Data Recorder
DGR	Dangerous Goods Regulations
DMS	Debris Monitoring System
EDS	Energy Dispersive Spectroscopy
EDI	Electronic Data Interchange
EDTO	Extended Range Operations
EEC	Electronic Engine Control
EFB	Electronic Flight Bag
EGT	Exhaust Gas Temperature
EOC	Emergency Operations Centre
FMC	Flight Management Computer
ETOPS	Extended Range Twin Operations Approval
FCV	Fire Command Vehicle
FFFP	Film Forming Flouroprotein
FO	First Officer
FOD	Foreign Object Debris
FTIR	Fourier Transform Infrared Spectroscopy
GMC	Ground Movement Control
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IDS	Instruction Detection System
IGV	Inlet Guide Vane
IIC	Investigator-In-Charge

Kts	Knot(s) (airspeed/wind speed unit)
LO	Low
MCD	Main Chip Detector
MCT	Muscat, Oman (OOMS)
NTSB	National Transportation Safety Board
NFF	No Fault Found
NNC	Non-Normal Checklist
OAP	Oman Air Ports
OEM	Original Equipment Manufacturer
OOMS	Muscat International Airport
OSC	On Scene Commander
OTSB	Oman Transport Safety Bureau
PA	Public Annunciation
PEMS	Passenger Evacuation Management Systems
PIC	Pilot In Command
POB	Person On Board
PRC	Passenger Reception Centre
PF	Pilot Flying
RFFS	Rescue Fire Fighting Services
ROP	Royal Oman Police
RTV	Roof Turbine Ventilator
RWY08L	Runway 08 Left
SAE	Safran Aircraft Engines
SB	Service Bulletin
SCCIC	Senior Cabin Crew In Charge
SOP	Standard Operating Procedures
TA/RA	Traffic Advisory/Resolution Advisories
TGB	Transfer Gear Box
TRF	Turbine Rear Frame
TSN	Time Since New
TWR	Tower
UTC	Universal Time Coordinated
VBV	Variable Bleed Valve
VDL	VHF Data Link
VOCI	Cochin
VR	Rotation Speed
VHF	Very High Frequency
VOR	VHF Omnidirectional Radio
VSV	Variable Stator Vane
QTY	Quantity
QRH	Quick Reference Handbook
QT	Quarter

Synopsis

On 14th September 2022, Oman Transport Safety Bureau (OTSB) was notified of a Serious Incident by Oman Airports through OTSB hotline.

The Serious Incident involves Air India Express aircraft, AXB442, where the crew reported to Tower technical issues with the aircraft and requested to vacate Runway (RWY) 08L. An aircraft on the apron reported observing fire from the right engine of Air India Express AXB442, Air Traffic Controller (ATC) confirmed the fire on aircraft AXB442 to the crew. received confirming the fire on the right-hand engine. The ATC further informed all the affected parties who responded to the scene of the incident. The crew followed the Quick Reference Handbook (QRH) procedures/drill followed by evacuation.

Following the review of the occurrence, the OTSB classified the occurrence as a Serious Incident and the Director of OTSB appointed investigator in charge (IIC) and investigation team to institute and conduct investigation. The following parties were notified:

- State of Operator, and Registry India (India-AAIB)
- State of Design and Manufacturer United States (NTSB)
- International Civil Aviation Organization (ICAO)

The OTSB led the investigation being the investigation authority, The Sultanate of Oman is the State of Occurrence. In conformance with the Air Accident and Incident Regulation CAR 13 and in line with the Annex 13 obligations, the OTSB appointed an investigator-in-charge (IIC), assigned Accident Investigation File Number AIFN/009/2022, and formed an investigation team.

The following parties were involved in the investigation through their appointed accredited representatives and advisers: -

- Aircraft Accident Investigation Bureau- United Kingdom (UK-AAIB)
- AI Engineering Services Limited- Mumbai
- Parker Airspace Group-USA
- CFM Engine manufacturer
- SAFRAN AIRCRAFT ENGINES-FRANCE
- Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile (French Safety Investigation Authority -BEA)-France

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Unless otherwise mentioned, all times in this report are UTC. Local Time in The Sultanate of Oman is UTC plus +4 hours. Photos and figures used in this report were obtained from ('source') and ('adjusted from the original for the sole purpose of improving the clarity of the report. Modifications to images used in this Report are limited to cropping, magnification, file compression, or enhancement of color, brightness, contrast or insertion of text boxes, arrows or lines.

1. Factual Information.

1.1 History of the Flight.

1.1.1 The Captain reported that he operated the aircraft with registration marks VT-AXZ flight AXB 443/442 COK-MCT-COK on 14thSeptember 2022 as a Pilot in Command (PIC) along with the First Officer (FO). The flight was scheduled first sector Cochin International Airport to Muscat International Airport (COK-MCT) departure Flight at 0230Z hours (UTC). The aircraft pushed back at 0254Z hours due to the delay caused by late arrival of incoming aircraft. The sector COK-MCT was uneventful as displayed by the Digital Flight Data Recorder (DFDR see figure 3) and the aircraft arrived at bay/stand 303 at Muscat International Airport (MCT) with total of 192 passengers. Chocks on time was at 0622Z hours and the scheduled time was 0605Z hours.

1.1.2 On 14th September 2022, the flight crew of India Express flight (AXB442) a Boeing 737-800, VT-AXZ) was scheduled for the second sector (MCT-COK) and was due at 0720 hours. Once fully ready, the aircraft commenced pushback with a total of 151 person on board at 0713Z hours. Push back was facing west and taxi clearance was via taxiway Tango (T), Victor (V) for Yankee (Y) 3 intersection departure for Runway 08L. After the arrival of one aircraft, they were given clearance to enter Runway 08L and cleared for take-off. As the aircraft was entering the runway, the crew alert box blinked followed by the right engine (#2 engine) low oil pressure. ATC was contacted and informed that they were unable to take off due to the technical problem. The flight crew was asked to vacate the runway via Yankee 5 and turn right on Whisky (W) taxiway without initiating take-off.

1.1.3 After stopping the aircraft at taxiway Whisky (W), the engine low oil pressure Non-Normal Checklist (NNC) was carried out. Oil pressure was observed to be dropping and also the oil quantity level indication, which eventually read zero. Then another aircraft reported smoke from the engine number #2. Smoke was also observed from the cockpit and fire was also reported. Engine fire or separation memory item was carried out as per the aircraft quick reference hand (QRH) book. Since fire was reported, fire extinguisher bottle was activated. Thereafter, NNC was carried out. Since fire was still reported, the second fire extinguisher bottle was also activated. The review of NNC directed the crew to go to evacuation checklist. The statement from the Captain collaborated the statement made by the Co-pilot hence only Captain statement was considered.

1.1.4 The ATC reported that RWY 08L was in use at the time and date of the occurrence: At 07:26:08Z, AXB442, B738, destination VOCI, with POB 151, was cleared for take-off from Yankee 3.

1.1.5 At 07:26:18Z, AXB442 during lining up reported unable to take off due to technical issue and he has to vacate the RWY. At AXB442 was instructed to vacate the RWY via Yankee 5 and to expedite to vacate.

1.1.6 At 07:26:59Z, TWR advised OMA818 (Which was at 4 miles descending through 1,300ft) to go around due to traffic on the RWY with a technical problem and to contact RDR 121.2.

1.1.7 At 07:27Z, TWR advised all concerned unit and CODE 7 was initiated. At 07:31:03Z, AXB442 was instructed to taxi on WHISKY to TANGO and to park on at apron stand 312R. The ATC officer further reported that, very high frequency (VHF) 3 frequency was changed to the ground Rescue Fire Fighting Service (RFFS) frequency to establish communication. As the fire tenders arrived, one of their team members was visually indicating to shutdown number 1 engine as well. Further, cabin crew were also reporting that lot of smoke was visible on the left side of the aircraft and inside the cabin area, the crew decided to shut-down, number 1 engine off. The cockpit crew vision was blocked due to the fire extinguisher foam which was spread on the aircraft including the cockpit windows. However, the cockpit crew noticed the smoke in the cockpit.

1.1.8 Based on information available to the crew at the time, that the fire was still continuing on the engine number: 2, the crew followed QRH procedures and took a decision to evacuate passengers and thereafter the PIC stepped out to supervise the evacuation. Later the PIC reported that he walked through the length of the aircraft to ensure that no one is left behind and then he exited from the aft slide.

1.1.9 After all passengers were evacuated to the terminal building, all six (6) crew members were also taken to the terminal building and refreshments were provided to all. Later both the PIC and FO returned to the aircraft to assist the investigating agencies with necessary documents (personal and aircraft related), once the aircraft obtained clearance was obtained to tow the aircraft, it was towed to one of the stands.

1.1.10 The Senior Cabin Crew in Charge (SCCIC), reported that during taxiing and after the aircraft had vacated from the runway, she approached the PIC and informed the PIC that there was fire on the right engine. The captain asked that the SCCIC inform the passengers not to worry or panic as they have shut down the affected engine and the situation was under control.

1.1.11 While inspecting the cabin, passengers were complaining that the smoke was coming from both left- and right-hand sides of the aircraft and also that the smoke and burning smell were present in the cabin. Aft crew were also present in the middle cabin as there were many crew call bells initiated during this period. The observation from the passengers were immediately conveyed to PIC in the cockpit. Strict instructions were communicated to passengers not to use emergency exit in case of evacuation if required.

1.1.12 After a while, the SCCIC reported that PIC informed of possible aircraft evacuation, the same was communicated to the aft cabin crew. After a minute the command for evacuation ("evacuate, evacuate evacuate") was given from the cockpit through Public Annunciation (PA). This was followed by emergency lights coming "ON" after the evacuation command. Furthermore, the cabin crew (L1 and R1) shouted emergency commands (emergency, emergency etc.) and they also checked the outside safety conditions properly, and the cabin crew removed the flags of the emergency doors. Afterwards through L1 and R1 doors slides were deployed and started evacuating passengers. There was no passenger standing at the bottom of the slide after giving instructions.

1.1.13 Despite instructions and shouting, the respective command repeatedly still few passengers were carrying bags with them during evacuation, which created an initial delay. In between FO also came out to help with the evacuation. After confirmation that all passengers have been evacuated from the cabin, FO and forward cabin crew evacuated through forward slide. As the crew moved away from the aircraft, one lady was seen in discomfort with a history of recent surgery and she received assistance. There was confirmation that all 145 passengers were safely evacuated, however there was 20 reported passengers who sustained minor injuries during the evacuation.

1.1.14 According to the DFDR and CVR recordings, the crew only followed the non-normal checklist procedure at 07:32:04Z, which was 6 minutes and 4 seconds after the occurrence was first identified or reported. According to the DFDR master caution light came on 07:19Z and the crew actioned the non-normal checklist after 07:26 which was 7 minutes after the first warning light.

1.1.15 The serious incident occurred during daylight at MCT at the Global Positioning System (GPS) co-ordinates: E023.6015386 degrees North 58.2899376 degrees east at an elevation of 8/15 feet (ft)/meters(m) Above Ground Level (AGL).

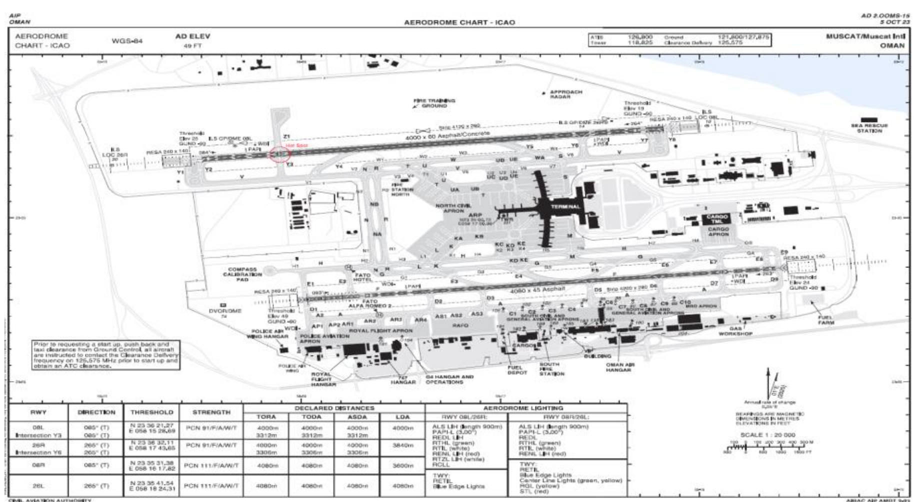


Figure 1 showing Airport layout and the position of the aircraft where the incident occurred before vacating the runway

1.2 Injuries to Persons:

Injuries	Pilot	Crew	Passenger	**Total on Board**	Other
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	20	**20**	-
None	2	4	125	**131**	-
Total	**2**	**4**	**145**	**151**	-

Note: Other means people on ground.

1.3 Damage to Aircraft.

1.3.1 The aircraft sustained substantial damages to the engine No: 2 exhaust cone heat damage, pylons areas heat damaged, flap fairing heat damaged and the bottom wing surfaces signs of after burns effects.

Figure 2 showing the aircraft after the fire fighters extinguished the fire on engine number: 2

1.4 Other Damage.

1.4.1 None.

1.5 Personnel Information:

Pilot-in-Command (PIC) – Captain

Nationality	Indian		
Licence Type	Airline Transport Pilot Licence		
Licence Valid	16th January 2027	Type Endorsed	Yes
Ratings	Multi-Engine, Night rating		
Medical Expiry Date	13th July 2023		
Restrictions	None		
Previous Accidents	None		

Note: Previous accidents refers to past accidents and or serious incidents the pilot was involved in, when relevant to this incident.

Flying Experience:

Total Hours	7333.40
Total Past 24 Hours	03.28
Total Past 7 Days	20.36
Total Past 90 Days	227.28
Total on Type Past 90 Days	227.28
Total on Type	2202.34

1.5.1 The PIC was initially issued an Airline Transport Pilot license (ATPL) on 17thJanuary 2017 in accordance with the India Civil Aviation Law, Civil Aviation Regulations and with Annex 1 to the Chicago Convention, as amended. The license was valid with an expiry date of 16th January 2027.

1.5.2 The PIC was issued a Class 1 medical certificate on 12th July 2022 with an expiry date of 13th July 2023.

First Officer (F/O)

Nationality	Indian		
Licence Type	Commercial Pilot Licence		
Licence Valid	7th August 2024	Type Endorsed	Yes
Ratings	Instrument rating, Night rating		
Medical Expiry Date	9th March 2023		
Restrictions	None		
Previous Incidents	None		

Note: Previous accidents refers to past accidents and or serious incidents the pilot was involved in, when relevant to this incident.

Flying Experience:

Total Hours	998.53
Total Past 24 Hours	03.28
Total Past 7 Days	27.29
Total Past 90 Days	207.16
Total on Type Past 90 Days	207.16
Total on Type	698.26

1.5.3 The First Officer was initially issued a commercial pilot license on 9th March 2009 in accordance with the Indian Civil Aviation Law, Civil Aviation Regulations and with Annex 1 to the Chicago Convention, as amended. The license currency was on 24th May 2022 with an expiry date of 7th August 2024.

1.5.4 The First Officer was issued a Class 1 medical certificate on 31st August 2022 with an expiry date of 3rd September 2023.

Senior Cabin Crew in Charge (SCCIC)

Nationality	Indian		
Licence Type	Senior Cabin Crew Competency Card		
Licence Valid	31st October 2022	Type Endorsed	Yes
Ratings	DGR, AVSEC TRG, DITCHING DRILL, FIRE DRILL, EMERGENCY EXIT TRAINER, ESCAPE SLIDE DRILL, CRM/JTCRM and MEDICAL CHECK		
Medical Expiry Date	13th July 2023		
Restrictions	None		
Previous Incidents	None		

Note: Previous accidents refers to past accidents and or serious incidents the SCCIC was involved in, when relevant to this incident.

1.5.5 The SCCIC was initially issued with a cabin crew competency card on 29th September 2008 in accordance with the Indian Civil Aviation Law, Civil Aviation Regulations and with Annex 1 to the Chicago Convention, as amended. His last license validation was on 1st November 2021with an expiry date of 31st October 2022.

1.5.6 The SCCIC was issued and rated on Boeing B737 competency card.

1.5.7 There were 3 cabin crew working under and or with the senior cabin crew. All were rated on Boeing B737, issued with competency card and received the following trainings: DGR, AVSEC TRG, DITCHING DRILL, FIRE DRILL, EMERGENCY EXIT TRAINER, ESCAPE SLIDE DRILL, CRM/JTCRM and MEDICAL CHECK

- The first cabin crew was initially issued with a cabin crew competency card on 19th February 2019 in accordance with the India Civil Aviation Law, Civil Aviation Regulations and with Annex 1 to the Chicago Convention, as amended. His last license validation was on 10th January 2022.with an expiry date of 9th January 2023.

- The second cabin crew was initially issued with a cabin crew competency card on 12th February 2018 in accordance with India Civil Aviation Regulation Part 61. His last license validation was on 6th December 2021 with an expiry date of 5th December 2022.

- The third cabin crew was initially issued with a cabin crew competency card on 11th September 2015 in accordance with India Civil Aviation Regulations Part 61. His last license validation was on 3rd December 2021.with an expiry date of 2nd December 2022.

Air Traffic Controller (ATC)

Nationality	Omani		
Licence Type	Air Traffic Controller Licence		
Licence Valid	6th April 2024	Type Endorsed	Yes
Ratings	ADC, tower, ground and GMC		
Medical Expiry Date	06 April 2024		
Restrictions	VDL, VNL		
Previous Incidents	None		

Note: Previous incidents refers to past accidents and or serious incidents the ATC was involved in, when relevant to this incident.

1.5.8 The ATC was initially issued in accordance with the Oman Civil Aviation Law, Civil Aviation Regulations and with Annex 1 to the Chicago Convention, as amended. The license validation was on 31st March 2022 with an expiry date of 06th April 2024.

1.5.9 ATC was also issued with English language proficiency on 21st October 2003, renewed on 1st January 2019 with an expiry date of 31st December 2023.

1.5.10 The ATC was issued a Class 3 medical certificate on 31st March 2022 with an expiry date of 06th April 2023

NOTE: The licence is not valid unless accompanied by valid medical certificate and current record of aerodrome or places at which ratings are valid, and of the types of radar equipment for which radar ratings are valid.

1.5.11 The ATC was issued with ratings to allow operating as the controller.

Aircraft Maintenance Engineer (LAME)

Nationality	Indian		
License Type	Boeing 737-700/800/900(CFM 56)		
License Valid	26/08/203	Type Endorsed	Boeing737-700/800/900 (CFM 56)
Ratings	B1.1 (Aeroplanes Turbine)		
Medical Expiry Date	Nov 2024		
Restrictions	3,7		
Previous Incidents	NIL		

1.5.12 According to the licensed aircraft maintenance engineer (LAME), there was no defect reported or observed during their pre-flight inspections both from India and in Muscat International Airport.

1.6 Aircraft Information:

1.6.1 The Boeing 737-800 was a stretched version of the 737-700 launched on September 5th, 1994. The Boeing 737-800 seats162 passengers in a two-class or 189 passengers in a high-density, one-class layout.

Manufacturer/Model	Boeing B737-800NG	
Serial Number	36336	
Year of Manufacture	2009	
Total Airframe Hours (At Time of Accident)	46368	
Last Inspection (Date & Hours (TSN))	46334 (weekly Check)	11 September 2022
Last Inspection Airframe Cycles (CSN)	15194	
Hours Since Last Inspection	34 hours	
Type of inspection preformed	Phase -22	
CRS Issue Date	25 August 2022	

C of A (First/initial Issue Date)	02 February 2009
C of A (Expiry Date)	11 February 2023
C of R (Issue Date) (Present Owner)	13 December 2021
Type of Fuel Used	Jet A1
Operating Category	Passenger and Cargo
Previous Accidents	Nil

Engine 1:

Manufacturer/Model	CFM56-7B
Serial Number	894-401
Part Number	CFM56-7B
Hours Since New	44316
Hours Since Overhaul	5713
Hours since last shop visit	5713
Cycles Available Before Next Shop Visit	4660
Oil type	Mobil Jet 2

Engine 2:

Manufacturer/Model	CFM56-7B
Serial Number	894-850
Part Number	CFM56-7B
Hours Since New	44099.00
Hours Since Overhaul	Nil
Hours since last shop visit	17148
Cycles Available Before Next Shop Visit	5201
Oil type	Mobil Jet 2

1.6.2 The aircraft was issued with Certificate of Airworthiness issued by the India Regulator on 02nd February 2009 with an expiry date 11th February 2023. The operator was issued with Certificate of Registration on13th December 2021.

1.6.3 Engine shop visit: According to work order no: EWO-000545-17, the engine #2 was sent for overhaul to the engine overhaul facility, OAP, MUMBAI in 2017. This was following the repeated Exhaust Gas Temperature (EGT) exceedance on the engine. The following was observed:

1.6.3.1 The engine was received without the hydraulic pump,

1.6.3.2 Inspection on the filters and magnetic chip detectors:

- No contamination on the forward and rear sump,
- No contamination on Accessory Gear Box (AGB) and Transfer Gear Box (TGB) sump,
- No contamination observed on starter magnetic plug,
- No contamination observed on main oil scavenge fuel filter,
- No contamination on the hydraulic filter
- No contamination observed in the fuel filter

1.6.3.3 No discrepancy observed for N1 and N2 for spool free rotation

1.6.3.4 No discrepancy observed on Variable Stator Vane (VSV) system Inlet Guide Vane (IGV) to stage 3 actuation rings, connecting links, lever arms and bushings inspected for wear, cracks, distortions, loose and proper engagement,

1.6.3.5 Variable Bleed Valve (VBV) door seal/linkage inspected for looseness/damage, no looseness/damage observed

NB: All affected areas/components and parts during borescope inspection and engine teardown were replaced.

- The affected components were as follows:
- Stage 3 and 4 Vanes corrosion and pitting observed but permitted as per AMM
- HPC ROTOR-Stage 1 to 9 blades not complied as Core Module removed for Performance
- Combustion Chamber Inner Liner and Outer Liner -Removed for overhaul
- Fuel nozzles removed for inspection
- NVG HPT and HPT blades- modules removed for Performance.

Engine was repaired, reassembled and tested for performance and was found satisfactory. Post test borescope inspection was carried out and found satisfactory.

Below are the figures showing oil scavenge tube and oil supply tube:

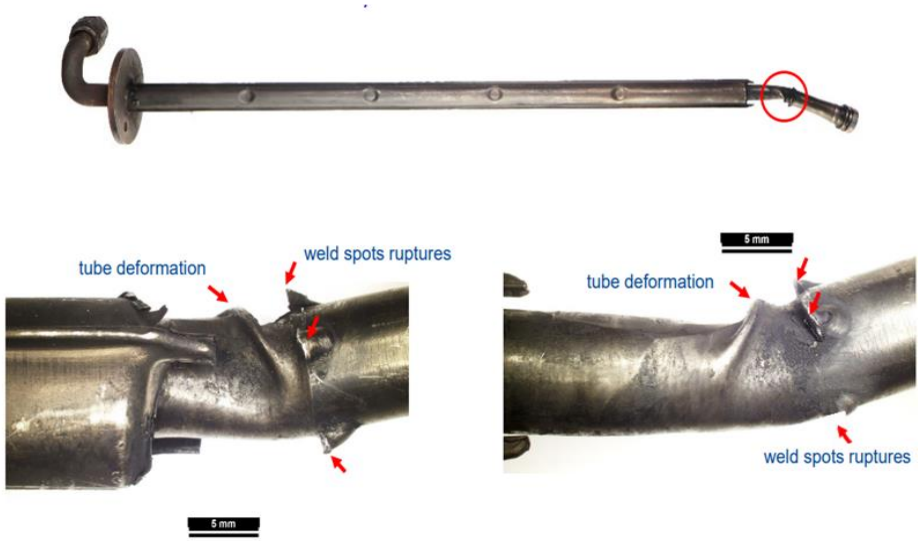


Figure 3 showing damaged/ welded oil supply tube.

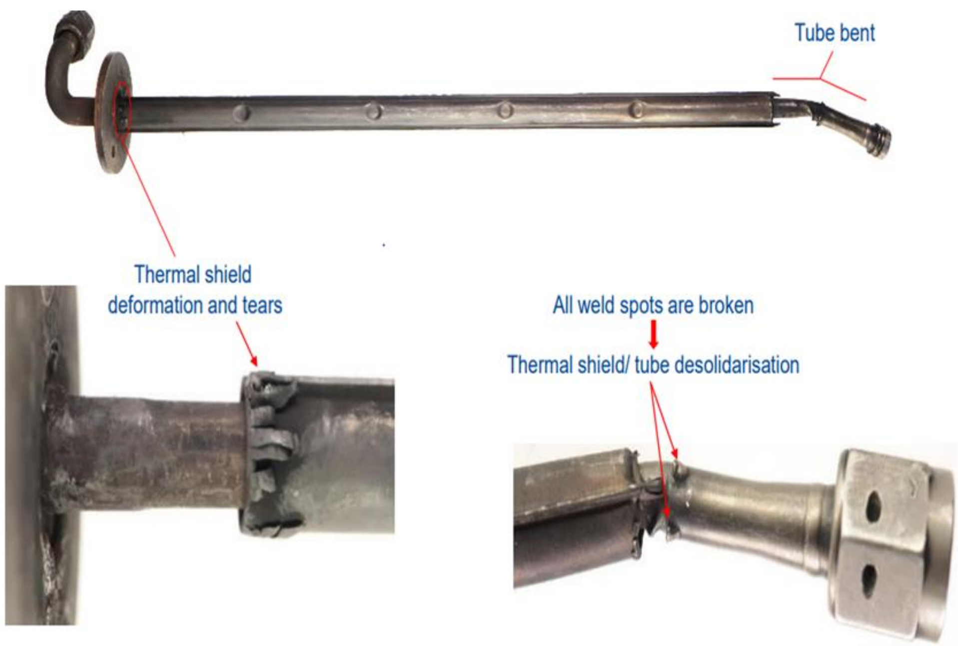


Figure 4 showing thermal shield deformation and tears of the oil supply tube

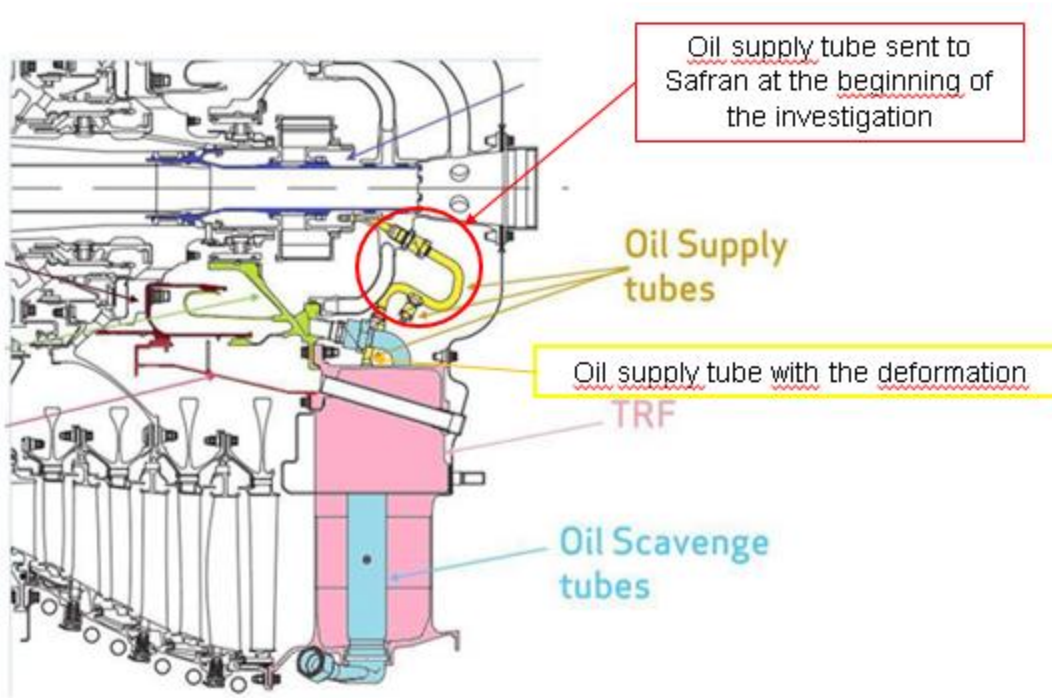


Figure 5 showing the position of the deformed oil supply tube and oil scavenge tube

1.6.4 Following the follow up with the manufacturer on the oil supply tube the following were established (see figure 3 and 4):

(1) Kindly confirm by the OEM CFM/SAFRAN if the welding of the oil supply tube is allowed or not.
Manufacturer confirmed that the welding of the oil supply tube is design intent ("4 welding spots").

(2) The Thermal shield deformation and tears are related to the heat/ fire or not.
Based on the manufacturer experience in service, this finding is unusual but more in relation with a mechanical damage (not a consequence of heat/fire) and could be linked to the axial movement of the thermal shield after breakage of the welding points.

(3) All weld spots are broken, thermal shield/ tube de solidarization related to the heat/fire or not.
Tubes with broken welding spots are seen in service. Not in relation with heat or fire event but more in relation with vibration.

(4) Tube deformation related to the heat/fire.
A repair exists in the Engine Shop Manual to repair welding spots (REP036) but seems to have very low application rate.

(5) The manufacturer reported that the hypothesis on the oil supply tube was as a result of the below:

Damage to the tube could be linked to the vibration in service and breakage of the 4 welding spots of the thermal shield that could create a movement of the thermal shield and wear of the tube (some oil leakage encountered in service due to the tube wear in this zone). If the thickness of the tube is less than nominal design, or/and if the operator didn't take precaution when he disassembled the other oil supply tube, he could make a torsion of the tube (mechanical effort greater than recommended).

(6) Manufacturer reported that, the customer uses the repair REP017 to replace the oil supply tube which is approved by manufacturer.

(7) Tube deformation related to the heat/fire, manufacturer reported that the deformation is not the hypothesis suspected, more a mechanical deformation during disassembly. This deformation existed on the tube when the manufacturer received the TRF with the tube inside (see figures 3 and 4 above).

1.6.5 According to available and reviewed records three borescope inspections on engine serial number 894850 prior to the incident was conducted the first was on 18th April 2022 at 42572 hours' time since new (TSN) and 14317 cycles since new (CSN). Second borescope inspection on same engine was conducted on 22nd June 2022 at 43402 hours' time since new (TSN) and 14568 cycles since new (CSN). Third borescope inspection on same engine was conducted on 28th July 2022 at 43817 hours' time since new (TSN) and 14685 cycles since new (CSN). All three borescope inspections were as the result of SBs requirements and they were not related to the incidents.

1.6.6 According to available and reviewed maintenance records provided by the operator the aircraft oil consumption for the period 16th to 31st August 2022 on both engines was normal and recorded as follows 48 and 47.5 respectively with consumption of 0.244 and 0.242 respectively. The second oil consumption for the period 1st to 14th September 2022 on both engines was also found to be normal and recorded as follows 48.5 and 45.5 respectively with consumption of .263 and .247 respectively.

1.6.7 According to Air India Pre-Departure Check Standard Operating Procedure (SOP) Issue Number 2, Revision number 2 dated October 2020 (Form number: AIXL/AMP/SCH/59), S/N 21 EDTO/ ETOPS Significant item says: Verify the #1 and #2 engine oil level and service as necessary. Record details in signature sheet form in accordance with AMM: 12-13-11-610-026.The operator recommended this should be carried out preferably two hours prior to the departure.

1.6.8 Performance Log for Engine Parameters for the period 12th to 14th September 2022, there were no defects except the reported captain Electronic Flight Bag (EFB) surveillance video which was reported unserviceable on 13th September 2022.

1.6.9 Engine EGT Operating Condition Temperature Limits Time Limit Takeoff 950°C 5 Minutes** Maximum Continuous 950°C No Limit Starting 725° C No Limit ** 10 minutes allowed in the event of loss of thrust on one engine during takeoff for airplanes authorized to use Ten Minute Takeoff Thrust performance data under Authorized Alternate Performance in AFM-DPI Section of this AFM.

1.6.10 Electronic Engine Control (EEC) Takeoff with the EECs in Alternate (ALTN) Mode is prohibited for the 737-800 when using CFM56-7B26/B2 Takeoff Thrust.

For other thrust levels, prior to incorporation of the wire bundle installation in accordance with the following table of Boeing Service Bulletins, or the production equivalent, takeoff with the EECs in Alternate (ALTN) Mode is prohibited:

Boeing Service Bulletin Aircraft Model 737-73-1013 737-600 737-73-1012 737-700 737-73-1015 737-800 Not Applicable 737-900/900ER 737-73-1014 737-700 with 7B26/B1 or 7B27/B3 engines.

Engine Oil System Minimum oil pressure is 13 psi.

If engine oil pressure is in the yellow band with takeoff thrust set, do not takeoff.

Maximum oil temperature limit for continuous operation is 140°C.

Maximum oil temperature is 155°C.

Operation between 140°C and 155°C is limited to 45 minutes.

1.6.11 According to available records the last oil maintenance upliftment was done during the last oil servicing (~1l) occurred the night before flight AXB443 in COK, which makes the distress flight the 2nd flight AXB442 of the day.

1.6.12 According to available information, the aircraft was first registered with the present owner/operator on 13th December 2021 and the aircraft was re-issued a Certificate of Release to Service (CRS) on 25th August 2022.

1.6.13 Based on aircraft maintenance records, the last inspection was carried out on 25thAugust 2022 at 46099.58 airframe hours. The aircraft had a total of 46363 airframe hours at the time of the incident. The aircraft had accumulated an additional 263.22 airframe hours in operation since the last inspection and no defects were recorded or reported on the aircraft maintenance tech-log.

1.6.14 According to the CRS dated 25th August 2022 from the operator, there was no work done on both engines except for normal engine operational checks and the engines oil consumptions was recorded as 0.23 on both engines.

1.6.15 The operator has provided a batch number / data sheet certificate supplied with the engine oil used prior to the incident flight, oil upliftment was done on the flight to Muscat, and according to the records provided by the operator, normal Mobil jet oil was used to replenish oil on both engines. The operator further submitted the batch number: 70390539, Certificate of conformance and the store inspection checklist.

1.6.16 The Oil supply tube is an on-condition item with no specific limit of time or hrs. for discard from service. The review of the maintenance data of the Engine 894950 reveals that no maintenance was carried out on the oil supply tube of the mentioned engine which could have lead to oil leakage. This was also followed up with the operator who confirmed that no work was conducted on the oil supply tube prior to the incident.

1.6.17 Review of documentation provided by the operator of two shop visits of the Engine serial 894850 did not reveal any repair that could be linked to the incident or oil supply system. Both engines were the original engine installed on the aircraft and had not been subjected to any major repairs or overhaul. On 13th September 2022, an oil upliftment was done on the left engine.

1.6.18 The aircraft was grounded in Muscat following the incident, and once it was cleared by OTSB and released for service, the operator performed engine change to the affected engine number 2 and ferried back the aircraft to India.

1.6.19 **ENGINE OIL – INTRODUCTION (ENGINE OIL - GENERAL DESCRIPTION *CFM56 ENGINES (CFM56-7)* 737-600/700/800/900 AIRCRAFT MAINTENANCE MANUAL 79-00-00)**

Purpose

The engine oil system supplies oil to lubricate, cool, and clean the engine bearings and gears. The engine oil system has the following subsystems:

- Storage
- Distribution
- Indicating.

Storage

The oil storage system keeps sufficient oil for a continuous supply to the oil distribution circuit. The oil storage system lets you do an oil level check and to fill the oil system. The oil storage system holds oil in the oil tank.

Distribution

The oil distribution system has these circuits:

- Supply
- Scavenge
- Vent.

The supply circuit sends oil to lubricate the engine bearings and gears. Oil from the tank goes to the lubrication unit through an anti-leakage valve. The lubrication unit pressurizes and filters the oil. The oil then goes to the engine. The scavenge circuit takes the oil from the engine.

Oil first flows through the lubrication unit. The lubrication unit also scavenges the oil. The oil goes to the scavenge oil filter and then to the servo fuel heater. The oil goes from the servo fuel heater to the main oil/fuel heat exchanger and then back to the servo fuel heater. Then the oil flows back to the oil tank. The vent circuit balances the internal air pressures in the oil system. Externally, a vent line connects the engine to the oil tank. Unwanted air pressure goes out of the oil tank through the vent line.

Indication

The oil quantity indicating system sends this data to the display electronic units (DEUs):

- Scavenge oil filter bypass indication
- Low oil pressure indication
- Oil pressure
- Oil temperature
- Oil quantity.

ENGINE OIL - DISTRIBUTION - GENERAL DESCRIPTION General

The engine oil distribution system supplies oil to cool and lubricate the engine bearings and gears. The engine oil distribution system also removes oil from sumps and gearboxes and sends it to the storage system. The engine oil distribution system has these systems:

- Supply system
- Scavenge system
- Vent system.

Supply System

Oil comes from the supply system to lubricate and cool internal components in the engine. From the oil tank, the oil flows to the lubrication unit through the anti-leakage valve. In the lubrication unit, the supply pump pressurizes the oil. The oil goes from the supply pump to the supply oil filter. The supply oil filter is part of the lubrication unit. The oil flows out of the lubrication unit in three lines to lubricate these areas:

- Forward sump and transfer gearbox (TGB)
- Rear sump
- Accessory gearbox (AGB).

Scavenge System

The scavenge system takes the oil that collects at the lowest point of these three areas:

- Forward sump
- Rear sump
- AGB and TGB.

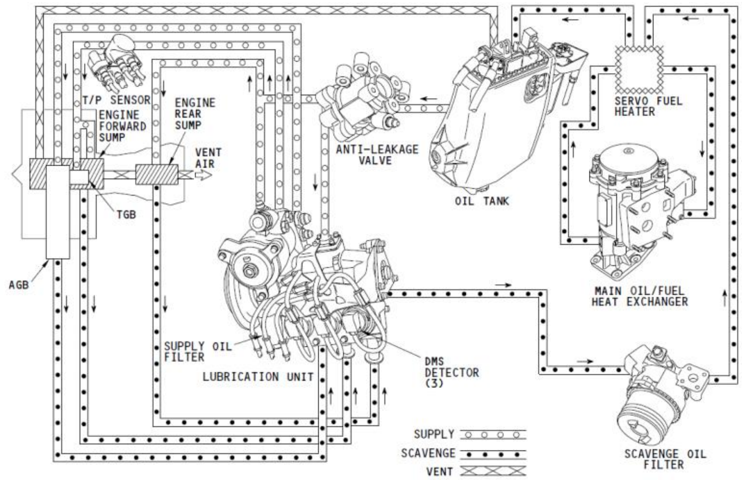


Figure 6: Engine Oil - Distribution - General Description (Source: ***CFM56 ENGINES (CFM56-7)-*** 737-600/700/800/900 Aircraft Maintenance Manual)

From these areas, the oil flows through three lines to three debris monitoring system (DMS) detectors. Three scavenge pumps move the oil in the three scavenge lines. The oil from each scavenge line goes to the scavenge oil filter and then to the servo fuel heater. The oil goes from the servo fuel heater to the main oil/fuel heat exchanger. In the exchanger, the oil cools as it heats the fuel. The oil flows back through the servo fuel heater and then to the oil tank. The scavenge system also supplies hot oil to heat the hydromechanical unit (HMU) servo fuel supply through the servo fuel heater. See the engine fuel distribution system for more information on the servo fuel heater.

Vent System

The vent system connects the oil tank with the forward sump. There are also internal connections between the engine sumps and gearboxes. The vent circuit bleeds out of the exhaust plug at the rear of the engine.
Component Locations

These components of the engine oil distribution system are on the left side, and at the bottom of the fan case:
• Lubrication unit (6:00 position)
• Main oil/fuel heat exchanger (9:00 position)
• Oil scavenge filter assembly (7:00 position; not shown)
• Anti-leakage valve (6:00 position).
The oil supply filter and the three debris monitoring system (DMS) detectors are in the lubrication unit.

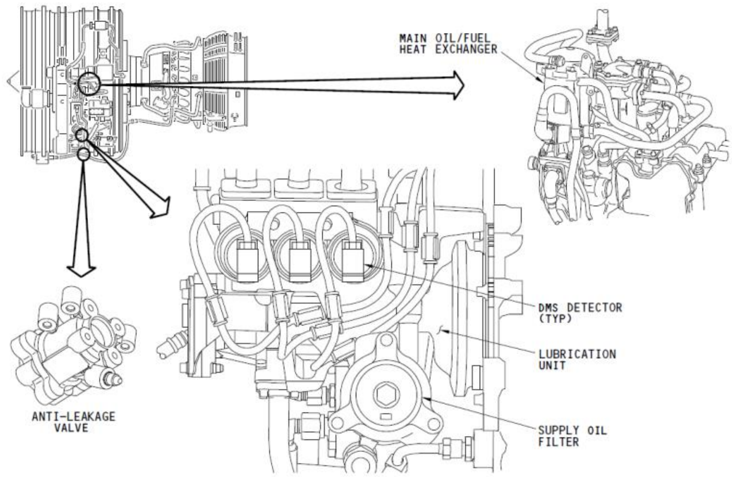


Figure 7: Lubrication Unit position (CFM56 ENGINES (CFM56-7) 737-600/700/800/900 Aircraft Maintenance Manual)

Purpose
The lubrication unit supplies pressurized oil to lubricate the engine bearings and gears. It also takes the oil that collects in the sumps and the gearboxes and sends it back to the oil tank.

Location
The lubrication unit is on the rear face of the accessory gearbox at the 6:00 position. You open the left fan cowl to get access to the lubrication unit.

Physical description
The lubrication unit contains these parts:
- Oil supply pump
- Supply oil filter
- Supply oil filter bypass valve
- Pop-out indicator
- Pressure relief valve
- Oil scavenge pump
- Debris monitoring system (DMS) detector.

A V-band clamp attaches the lubrication unit to the accessory gearbox.

Functional Description
The accessory gearbox turns the oil supply pump and the three scavenge pumps in the lubrication unit. The pumps are on a common shaft. The oil supply pump does not control the output pressure. When the engine speed changes, the oil pressure changes.

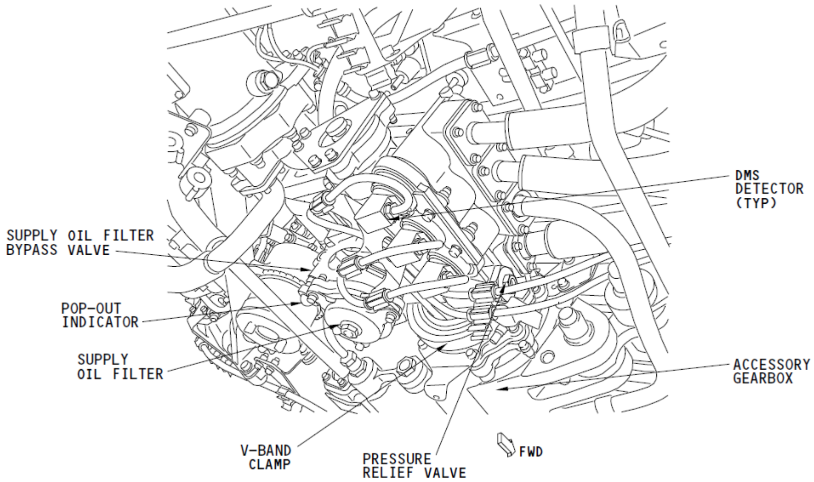


Figure 8: Engine Oil - Distribution - Lubrication Unit (CFM56 ENGINES (CFM56-7)- 737-600/700/800/900 Aircraft Maintenance Manual)

Purpose
The supply oil filter removes and holds unwanted material from the supply oil. The supply oil filter prevents the contamination of the downstream oil circuit.

Location
The supply oil filter is in the lubrication unit. The lubrication unit is on the rear face of the accessory gearbox at the 6:00 position. You open the left fan cowl to get access to the supply oil filter.

Physical Description
The supply oil filter is a paper filter cartridge. You discard the filter after use. The lubrication unit housing holds the supply oil filter. The cover keeps the supply oil filter in the housing. The oil filter housing cover has a drain plug.

Purpose
The debris monitoring system (DMS) detectors collect unwanted materials from the scavenge oil. This tells if there is a mechanical failure of an engine bearing or gear. The DMS detector magnets collect ferrous material. When there is sufficient ferrous material between the detector magnets, a message will show on the control display units (CDUs). A screen on each detector collects non-ferrous material larger than 800 microns.

There are three DMS detectors, one for each of these scavenge circuits:
• Forward sump
• Rear sump

• Accessory gearbox (AGB) and transfer gearbox (TGB).

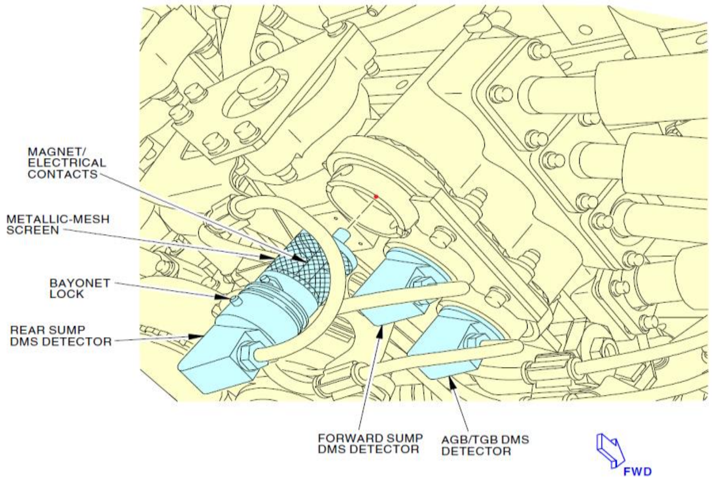


Figure 9: Engine Oil - Distribution - Debris Monitoring System (CFM56 ENGINES (CFM56-7)- 737-600/700/800/900 Aircraft Maintenance Manual)

Location

The lubrication unit housing holds the DMS detectors. They are at the inlet of the scavenge pumps. The lubrication unit is on the rear of the accessory gearbox at the 6:00 position. You open the DMS detectors/pressure relief door to get access to the detectors.

Physical Description

Each DMS detector has two magnets on a common post with a space between them. Each detector also has a metallic-mesh screen. Each detector attaches to the lubrication unit housing through a bayonet lock. There is an electrical connector on each detector. A check-valve in the lubrication unit housing prevents an oil leak when you remove a detector.

Functional Description

The two magnets on each detector collect ferrous material. The magnets are part of an electrical circuit that connects with the DMS box. The two magnets complete the circuit when they collect a sufficient amount of ferrous material to fill the space between them. With the circuit complete, a DMS message shows on the engine maintenance pages of the CDUs.

Purpose

The main oil/fuel heat exchanger uses fuel from the low-pressure fuel pump to decrease the temperature of the scavenge oil.

Location

The main oil/fuel heat exchanger attaches to the fuel pump assembly. The fuel pump assembly is at the 8:00 position. You open the left fan cowl to get access to the main oil/fuel heat exchanger.

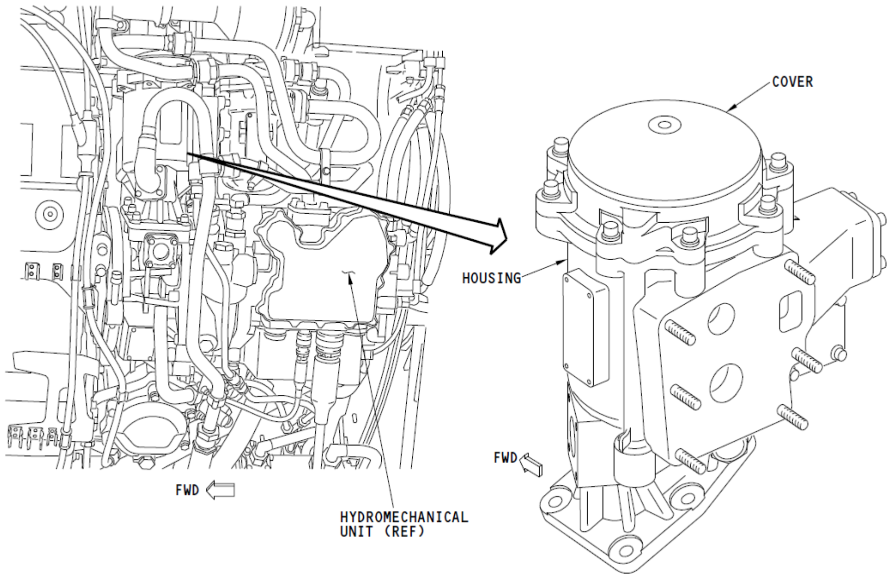


Figure 10: Engine Oil - Distribution - Main Oil/Fuel Heat Exchanger (CFM56 ENGINES (CFM56-7) 737-600/700/800/900 Aircraft Maintenance Manual)

Physical Description

The main oil/fuel heat exchanger has these parts:

• Exchanger core (inside the housing)
• Housing
• Cover.

The exchanger core is where the oil temperature decreases as the oil heats the fuel. The cover holds the exchanger core in the housing. The main oil/fuel heat exchanger has an oil bypass valve. The oil bypass valve opens when the exchanger core is clogged. This permits the oil to flow around the core exchanger. Thus, the oil temperature increases when the oil bypass valve opens. But the oil continues to flow.

Purpose

The scavenge oil filter assembly contains the scavenge oil filter and the scavenge oil filter clogging transmitter.

Location

The scavenge oil filter assembly is on the rear face of the accessory gearbox at the 7:00 position. You open the left fan cowl to get access to the scavenge oil filter assembly.

Scavenge Oil Filter Assembly

The scavenge oil filter assembly has a filter bowl and a body. The filter bowl holds the scavenge oil filter cartridge. A locking ratchet lever prevents rotation in the direction to loosen the filter bowl. In the body, an oil filter bypass valve opens when debris causes the scavenge oil filter to clog. The body also holds the scavenge oil filter clogging transmitter.

The scavenge oil filter removes debris from the three scavenge circuits. The scavenge oil filter prevents contamination of the oil circuit from one of these components if it becomes defective:
• Main engine bearing
• Gear
• Gear bearing
• Scavenge pump.

Supply Circuit
Oil from the oil tank goes through the anti-leakage valve to the lubrication unit. The oil supply pump pressurizes the oil. The pressure relief valve sends oil to the inlet of the AGB/TGB scavenge pump when the supply pressure is too high. The oil goes to the supply oil filter. The supply oil filter bypass valve monitors the pressure difference across the supply oil filter. If the filter clogs, the valve opens. The pop-out indicator shows a red button before the supply oil filter bypass valve opens. The oil flows through these supply lines:
• Rear sump
• Accessory gearbox (AGB)
• Transfer gearbox (TGB) and forward sump.
An oil pressure line from the rear sump supply line sends pressurized oil to the anti-leakage valve. That keeps the valve open.

Scavenge Circuit
From the engine sumps and gearboxes, the scavenge oil flows through three Debris Monitoring System (DMS) detectors. There is one DMS detector for each of these scavenge lines:
• Rear sump
• AGB and TGB
• Forward sump.
The check valves prevent leakage when you remove a detector. The DMS detectors send debris data through the DMS box to the Electronic Engine Control (EEC). The EEC sends this data to the FMC. The Flight Management Computer (FMC) shows debris messages in the EEC maintenance pages of the Control Display Unit (CDU). The oil goes to the three scavenge pumps. Each pump moves the oil in one scavenge line. The oil from the three scavenge lines goes to the scavenge oil filter. The scavenge oil filter bypass valve opens if the pressure difference across the scavenge oil filter is above limits. The filtered oil flows through the servo fuel heater then through the main oil/fuel heat exchanger. A bypass valve is in the main oil/fuel heat exchanger. If the heat exchanger clogs, the bypass valve opens and the servo fuel heater and the main oil/fuel heat exchanger are bypassed. The oil goes back to the servo fuel heater then to the oil tank.

Vent Circuit
A vent line connects the oil tank with the forward sump. Internally, the AGB and the TGB also connect with the forward sump. The forward sump and the rear sump vent out through the turbine exhaust plug at the rear of the engine.

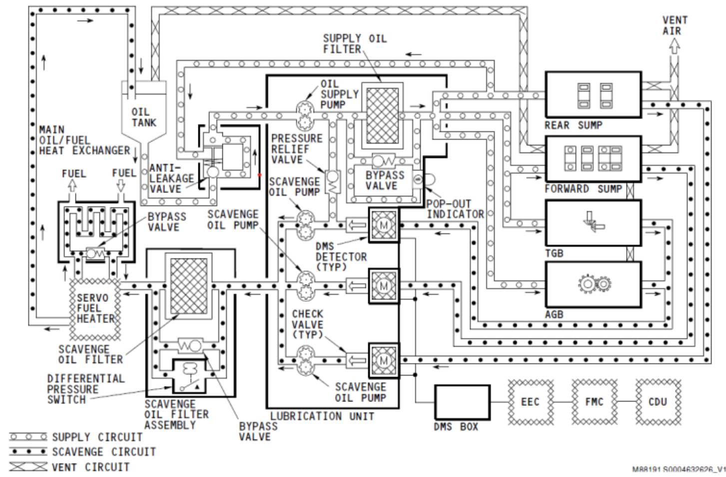


Figure 11: Engine Oil - Distribution - Functional Description (CFM56 ENGINES (CFM56-7)- 737-600/700/800/900 Aircraft Maintenance Manual)

1.7 Meteorological Information:

1.7.1 The weather information below was obtained from the Meteorological Routine Aerodrome Report (METAR) that was issued by the Oman Weather Service (OWS) recorded at MCT on 14th September 2022 at 0700Z.

Wind Direction	VRB	Wind Speed	02knots	Visibility	8000 meters
Temperature	N/A	Cloud Cover	Nil	Cloud Base	Nil
Dew Point	N/A	QNH	N/A		

1.8 Aids to Navigation.

1.8.1 The aircraft was equipped with standard navigational equipment as approved by the DGCA, India. There were no records indicating that the navigation system was unserviceable prior to the serious incident.

1.9 Communications.

1.9.1 The aircraft was equipped with a standard communication system as approved by the DGCA, India. There were no recorded defects with the communication system prior to the incident. The radio communications between the flight crews and the ATC controllers were recorded, successfully retrieved and transcribed.

1.9.2 The ATC reported that on 14th September 2022 at 0725UTC, AXB442 B737-800 from OOMS to VOCI was cleared to take off from runway 08L from Yankee 3. While AXB442 was on the runway, the crew requested to vacate the runway due to technical problem. The crew was instructed to vacate the runway via Yankee 5 and hold at taxiway Whisky as OMA818 was 5 miles' final been instructed to go around due to traffic.

1.9.3 On taxiway Whisky, AXB442 advised that they have a technical problem on engine number 2 and will shut down the engine. The crew requested to go back to the stand and that the Aircraft Operating Control Centre (AOCC) been advised and stand given 312R. Smoke observed from engine number 1 and code 7 was initiated followed by crash alarm activation and all concerned were advised. OMA226 landed and the reported that they could see flame from engine number 2 of AXB442. The fire fighter vehicles had already started extinguishing the fire, pilot and fire fighters were advised.

1.9.4 At time 07:37 all passengers (PAX) evacuated from the aircraft. At time 0740 Rescue Fire Fighting Services (RFFS) advised category downgraded to CAT 8 and approach controller has been advice to broadcast the message to all aircraft. At 08:32, fire services category reported back to normal CAT 10. The aircraft was holding on taxiway Whisky and everything was under fire control while the fire services were waiting for the engineering to remove the escape slides. Code 7 downgraded to code 9. Aircraft been towed to stand 312R. Time 1104 code 9 closed.

1.10 Aerodrome Information:

Aerodrome Code	OOMS/MCT
Airport Name	Muscat International Airport
Airport Address	Muscat, Sultanate of Oman
Airport Class	Class C
Airport Authority	Civil Aviation Authority
Airport Service	Oman Airports
Type of Traffic Permitted	VFR/IFR
Coordinates	N 23.36.0, degrees E 058 17.0 degrees
Elevation	25ft/15m

Runway Length	4000 meters
Runway Width	60 meters
Category for Rescue Fire Fighting Services (RFFS)	10
Heading of Runway Used	08L
Surface of Runway Used	Asphalt
Approach Facilities	ILS, VOR, DME, RNP

1.10.1 Category 7-Aircraft Ground Incident (Information Sourced from Oman Airports-Airport Emergency Plan)

1.10.1.1 When an incident occurs involving an aircraft on the ground, which could affect the safety of that aircraft.

Note: Aircraft Ground Incidents involving other aircrafts, structures or ground equipment will be treated as either Code 1 or 7 according to the severity of the incident.

1.10.2 Code 9-Local Standby

1.10.2.1 When an aircraft in flight has developed or suspected to have developed a defect which should not create serious difficulty in affecting a safe landing.

1.10.3 Category 10- Weather Standby / Natural Disaster

1.10.3.1 A weather standby/natural disaster is where weather conditions deteriorate or have deteriorated to a point where conditions could or have affected the safety of aircraft operations at the airport.

1.11 Flight Recorders.

1.11.1 The aircraft was equipped with a digital flight data recorder (DFDR) and a Cockpit Voice Recorder (CVR) as required by the regulation to be fitted to the aircraft type.

1.11.2 The Flight Data Recording (FDR) system recorded all mandatory flight data parameters on: The Digital Flight Data Recorder (DFDR) as shown below.

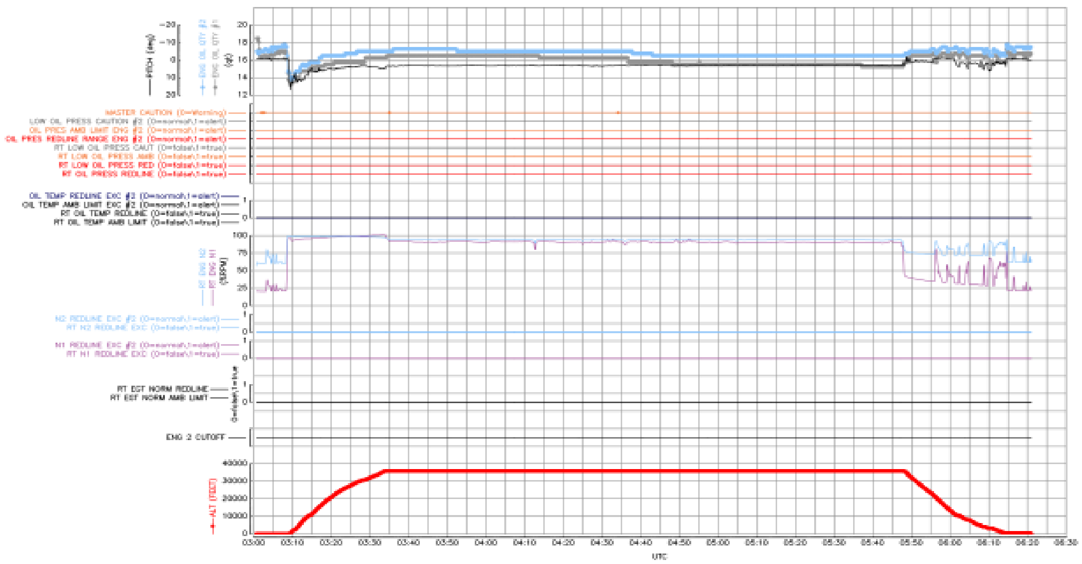


Figure 12 shows DFDR flight data from India to MCT the flight was uneventful

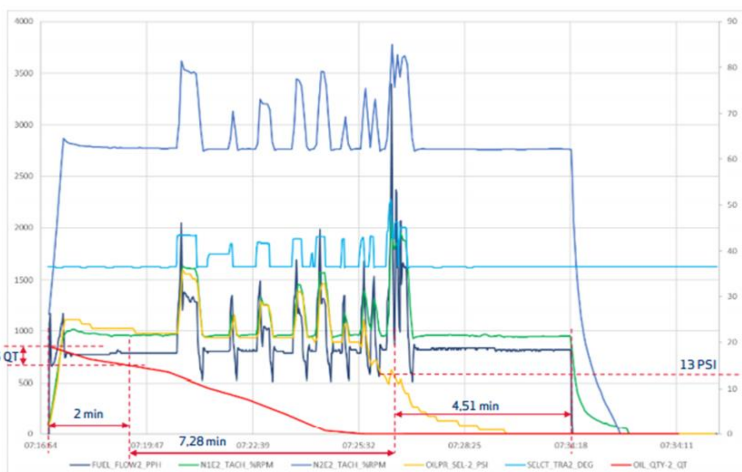


Figure 13 showing the recordings of the downloaded FDFR during taxi.

FDFR Oil loss rate analysis during taxi

FDR analysis

• Oil quantity decreasing since the engine start. 6 quarts oil loss in 2 min and the oil quantity continue to decrease until to 0 QT within7min.

• Oil pressure decreasing to zero few minutes later.

• The engine ran with an oil pressure below 13 PSI for than 4minutes.

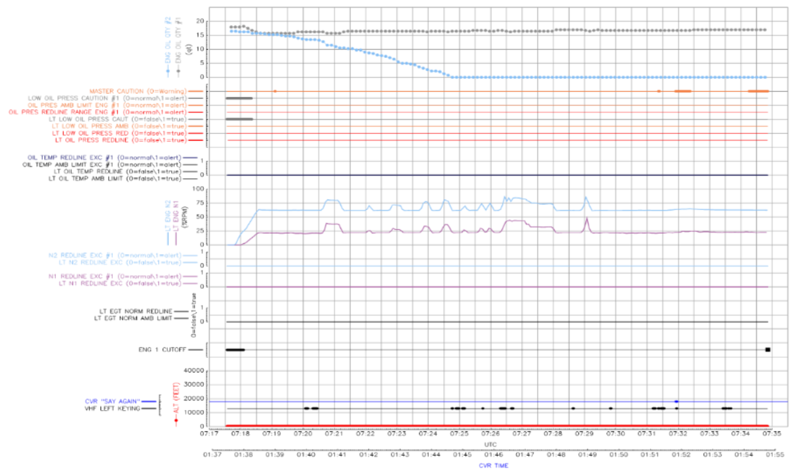


Figure 14 showing the oil quantity drop as per the DFDR downloads during taxi.

The following information was sourced from the CVR-communications between the Crew and the ATC:

TWR -AT 07:26 Express India 442 after airborne contact MCT radar 121.2 wind 030/08 knots AH. 08L cleared for takeoff have a good day.

CAPT - AT 07:26:15 ah…...tell him we have a problem

F/O-AT 07:26:17 and sir we have a problem ahh

CAPT- AT 07:26:18 technical problem issue and we have to vacate the runway.

F/O-AT 07:26:19 technical issue ahh…… have a technical issue we are unable to ahh to take off depart right now we have to vacate the runway Express India 442.

TWR-AT 07:26:28 roger copied that continue and vacate via taxiway Yankee 5, vacate taxi on the runway and vacate taxiway Yankee 5 expedite vacate.

CAPT- AT 07:26:36

F/O 07:26:37 expedite vacate via taxiway Yankee 5 and continue taxi on the runway for time being Express India 442.

F/O AT 07:26:44 ok taxi via Y5

CAPT 07:26:46 alright .... low oil press so right engine putting to idle.
F/O-AT 07:26:51 confirm sir checked
CAPT- AT 07:27:20 ahh contact on ahh private that frequency na

F/O-AT 07:27:23 yes Captain
CAPT-AT 07:27:24 tell them requesting ahh we are returning to the bay
F/O-AT 07:27:26 checked sir
F/O-AT 07:27:43 Oman Air operations Air India 442
F/O-AT 07:27:49 ahh yes sir we have a technical issue with the aircraft ahh we are returning to bay, request ahh engineering and stand number if possible.
CAPT-AT 07:28:10 JUST TELL ENGINEERING THAT'S ALL.
F/O-AT 07:28: just inform engineering 12 Express India 442
F/O-AT 07:28:18 sir back to vhf 1
CAPT-AT 07:28:19 yah
F/O-AT 07:28:20 vacating via .... taxiway Yankee5
CAPT-AT 07:28:24 yah.
07:28:30 – TWR: AXB442 take right on Whisky stand by for the stand
07:28:38 – F/O: Right on WHISKY standby for the stand AXB442
07:28:41- CAPT: right turn whiskey is immediately right?
07:28:42-F/O: affirm sir immediate right
07:28:43-CAPT: ok oil press is too low anytime engine can go out
07:28:47-F/O: check ahh
07:28:50 CAPT i am using only left
07:28:51 F/O: checked sir
07:28:57 F/O: and …(not clear)
07:29:00-CAPT: and oil quantity zero
07:29:02 F/O: affirm sir
07:29:04 CAPT: yahh ...that is the reason
07:29:13 CAPT: so should we stop and shut down here?
07:29:15 F/O: yes, sir we can do the checklist ahhh
07:29:18 CAPT: ok low oil quantity
07:29:34 F/O: low oil press
07:29:37 CAPT: low oil press
07:29:39 F/O: ah low oil .. low oil quantity. low oil quantity
07:29:46 – TWR: and confirm AXB442 do you need to go back to stand
07:29:50 – CAPT: affirm afirm
07:29:51 – F/O: affirm AXB442

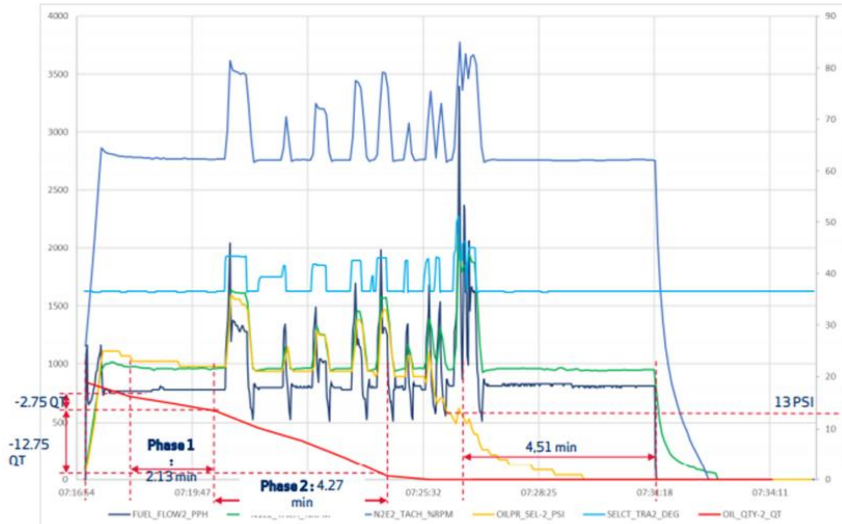


Figure 15 showing the recordings of the downloaded DFDR analysis on oil loss during taxi.

Oil loss rate analysis during taxi:

Phase 1: stabilized idle after start, from time 07:18:14 to 07:20:22

• Duration: 2:08 min = 2.13 min

• Average N2: 62,4 % – Calculated oil volume delivered to the Aft sump (nominal @100 N2 ≈ 500 liter/hr ≈ 530 QT/hr): 530 x 0.624 x 2.13/60 = 11.74 QT

• Oil loss from DFDR reading: 16.25 - 13.50 = 2.75 QT (i.e. -1.3 QT/minute) ¬ About 23 % of injected oil flow is lost (77 % is still scavenged back to the oil tank) Phase 2: taxi-out with 5 throttle advance, from time 07:20:22 to 07:24:38

• Duration: 4:16 min = 4.27 min

• Average N2: 67 % – Calculated oil volume delivered to the Aft sump (nominal @100 N2 ≈ 500 liter/hr ≈ 530 QT/hr): 530 x 0.67 x 4.27/60 = 25.27 QT

• Oil loss from DFDR reading: 13.50 - 0.75 = 12.75 QT (i.e. -3 QT/minute)

About 50 % of injected oil flow is lost (50 % is still scavenged back to the oil tank

Understanding (assumptions) Aft sump oil scavenge is partially impaired

• Assumption: partial clogging in Aft sump scavenge line

• % of clogging increases at time 07:20:22: a change of OIL_QTY-2 decrease rate is observed (from - 1.3 QT/min to -3 QT/min).

• An oil coke deposit fragment in the TRF scavenge line has broken apart and partially clogs the scavenge tube

– At time 07:20:22 the fragment moves in a more adverse position

Oil level consumption from DFDR analysis is consistent with oil leakage due to oil system malfunction.

1.12 Wreckage and Impact Information

1.12.1 After take-off clearance before the starting of takeoff roll in Muscat, Oman, the crew received a fire indication warning on the right-hand engine. They aborted the takeoff at low speed, taxied off the runway, shut down the engines, and evacuated the airplane using the inflatable slides.

1.12.2 The aircraft sustained damages on engine number 2, exhaust cone heat damage, pylons areas heat damaged, flap fairing heat damaged, bottom wing surfaces signs of after burns effects.

Figure 16 showing the aircraft after it came to a stop with all 4 slides were deployed

Figure 17 showing the damages to #2 engine thrust reverser thermal blankets

Figure 18 showing damages and soot of the fire

Figure 19 showing the oil level (empty) on the engine 2 sight gauge


Figure 20. showing the damages to the engine #2 pylon

1.13 Medical and Pathological Information.

1.13.1 There was no evidence that physiological or psychological factors, nor incapacitation, had affected the performance of both flight crews.

1.14 Fire.

1.14.1 There was evidence of smell, smoke and fire on engine number 2 as reported by the Tower through the PIC. This prompted the deployment of RFFS to the aircraft. Firefighting used Monnex high performance dry powder systems and FFFP foam to extinguish the Engine no.2 fire.

1.15 Survival Aspects.

1.15.1 The following was reported by RFFS OIC's Actions Taken – Chief Fire Officer:

On 14th of September 2022 Red Watch were on day duty. The crew distributed into four stations, South Station, Royal Oman Police Station, Marine Station, and North Fire Station which covering the Runway. When the tower activated code 7, the fire vehicles respond from North Fire Station fire 7 and 3 and Terminal Building (where code 8 was activated) fire 11.

At 07: 30 Code 7 activated, Chief Fire Officer informed by radio at stand 401

07:31 Fire Command and Fire 7 in attendance, Air India Express B737-800, registration number VTAXC, number 2 engine fire, On Scene Commander (Chief Fire Officer) instructed Fire 7 to extinguish the number 2 engine fire

07:34 Fires 3 and 6 assisting to extinguish engine number 2 following re-ignition with Monnex

07:34 Requested ATC to instruct the aircraft captain to switch to VHF 121.6 so that a situation report could be given to him and request he does not initiate an evacuation as the fire situation under control

07:36 No response from aircraft captain on VHF 121.6

07:37 Full evacuation of the aircraft initiated by the aircraft captain, fire staff deployed to all evacuation chutes to assist passenger evacuation

07:40 PEMS and PRC requested to be activated

07:50 All passengers and crew safely evacuated, BA team committed to the aircraft to ensure all persons have safely evacuated

07:51 Fire category downgraded to category 8, ATC and EOC informed

07:52 Report of injured passengers at the PRC, request the clinic to attend

Figure 21 showing RFFS positions and deployment of slides

07:55 Emergency recall of fire staff to support restoring the fire category

08:01 Oman Air engineering requested to check engines number 2 and 1 for any signs of residual fire, confirmed as safe

08:24 FCV in attendance and a silver command meeting held by the On-Scene Commander (OSC) with the CAA, Oman Air Engineering and Royal Oman Police (ROP) to agree the OTSB preservation of evidence and agreements to remove personal belongings from the aircraft cabin

08:32 Fire Category 10 restored, ATC and EOC informed

09:50 Code 7 downgraded to code 9

11:01 Aircraft safely parked on stand 312R, permission given to Transom to remove hold baggage

11:04 Code 9 Incident closed

1.15.2 **Emergency Evacuation Routes**

Emergency evacuation may be accomplished through four entry/service doors and four overwing escape hatches. Flight deck crewmembers may evacuate the airplane through two sliding flight deck windows.

Emergency Evacuation Routes

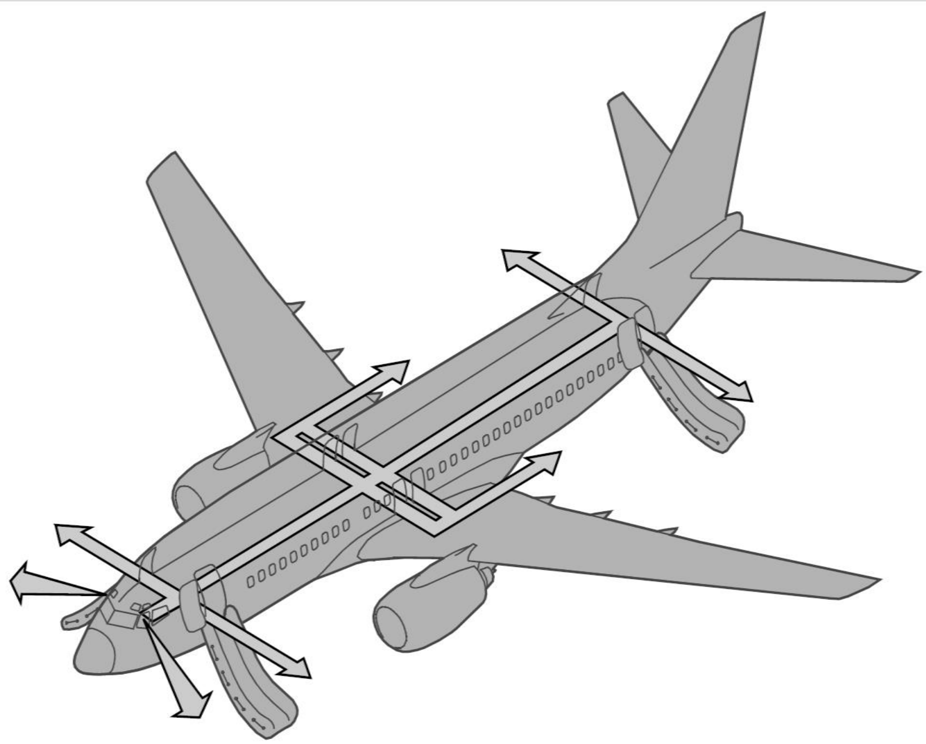


Figure 22. showing the positions of 4 slides which were used during the evacuation

1.15.3 **Emergency Exit Doors:**

Four Type III emergency exits are located in the passenger cabin over the wings. These are canopy-type doors and are held in place by mechanical locks and airplane cabin pressure. The overwing exit doors can be opened from inside or outside of the airplane by a spring–loaded handle at the top of the door. The 28 Volt DC flight lock system is designed to ensure that the flight lock will automatically lock during takeoff, in-flight, and landing and unlock on the ground to allow for opening of the door in emergency situations. Commands for the flight lock to lock and unlock are dependent upon engine speed, thrust lever position, air/ground mode status, and the open/closed status of the doors. The overwing emergency exits lock when:

• three of the four Entry/Service doors are closed and
• either engine is running and

• the airplane air/ground logic indicates that the airplane is in the air or both thrust levers are advanced. The overwing emergency exits unlock when any one of the above conditions is not met or DC power is lost.

1.16 Tests and Research.

1.16.1 AI Engineering Services Limited- Mumbai:

The OTSB performed a teardown inspection of the engine in Mumbai, India, with CFM present. During the teardown, they noted debris in the area of the accessory gearbox where the engine driven hydraulic pump (EDP) mounts to it.

The following was established during the teardown:

Engine number 2 computer (EEC) download analysis carried out and did not provide any information relating to root cause of the incident.

Engine number 2 borescope inspection carried out and did not provide any information relating to root cause of the incident.

The Engine Driven Pump (EDP) was removed from quarantine storage and the box opened. Residual oil from the Case Drain was captured as well as oil in the shipping box that had leaked out. The following observations were noted when visually inspecting the unit once removed from the shipping box:

- Debris on the External Driveshaft which was observed during the removal of the EDP from the engine was no longer present when the pump was examined.
- Safety wire in certain areas on the unit was not original- Parker uses safety cable.
- The Compensator Plug had only a remnant of safety cable.
- The pump rotated freely by hand.
- No FOD was observed in the inlet, discharge, or case drain ports.

The Solenoid electrical connector pins were undamaged, but there was minor thread damage to the connector shell. The External Driveshaft was removed from the pump and found to have excessive black residue near the tip, and on the mating Internal Driveshaft deep within the internal spline drive. This black residue was captured for analysis. This residue was later determined to likely be hydraulic fluid that was exposed to high temperatures. The EDP was subjected to an extended static proof pressure test of 52psi for 5 minutes. There was no leakage or wetting noted. The EDP was then successfully tested per CMM 29-11-34. No abnormal performance was noted. No external leakage was noted.

The pump was then completely disassembled, and each part visually inspected by the investigation Team. No abnormalities were noted.

Discussion:

This Engine Driven Pump (EDP) SN 660874798 was returned to Parker from Air India for investigation as a result of an engine fire on aircraft VT-AXZ during takeoff roll. Review of FDR data did not indicate any loss of hydraulic fluid quantity or pressure during this event. The EDP was visually examined after removal from the shipping box, and debris was noted on the end of the EDS and inside the mating IDS. This debris was captured and analyzed by the Parker M&P Lab. This residue was later determined to likely be hydraulic fluid that was exposed to high temperatures.

The pump turned freely by hand and there was no debris noted in any of the ports, so the decision was made to mount the EDP to the test stand and pressurize it for a static leak test.

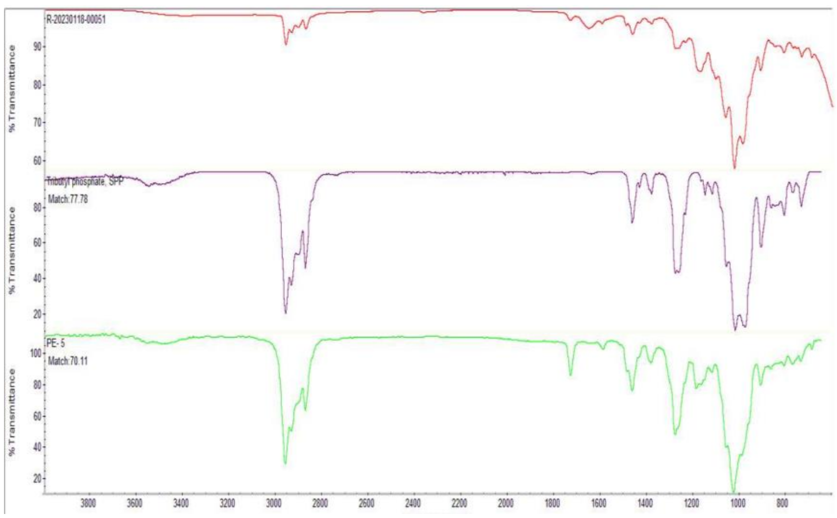


Figure 23. shows the test results of the EDP

The unit was held at 52 psi for 5 minutes and exhibited no leakage or wetting at any location. The EDP was then performance tested per CMM 29-11-34 where it passed all requirements without exception. Based on visual inspection and the testing, this unit was deemed "No Fault Found". The pump was then completely disassembled and each component visually inspected and photographed. No abnormalities were noted on any of the components.

- EDP was sent to Parker for investigation: Parker results received on 2 February 2023 (cf. K220326 Eng Report.pdf):

- Pump investigation witnessed by Boeing/FAA FSDO/NTSB on Jan 11 2023

- First observations:
- The were debris on the External Driveshaft

•Evidence of hydraulic fluid exposed to high temperature

• Safety wire in certain areas on the unit was not original- Parker uses safety cable.
• The Compensator Plug had only a remnant of safety cable.
• The pump rotated freely by hand.
• No FOD was observed in the inlet, discharge, or case drain ports
• The Solenoid electrical connector pins were undamaged, but there was minor thread damage to the connector shell.
• Static proof pressure test (52 psi for 5 min): no leakage nor wetting
• Total disassembly: no anomalies (see below figure).

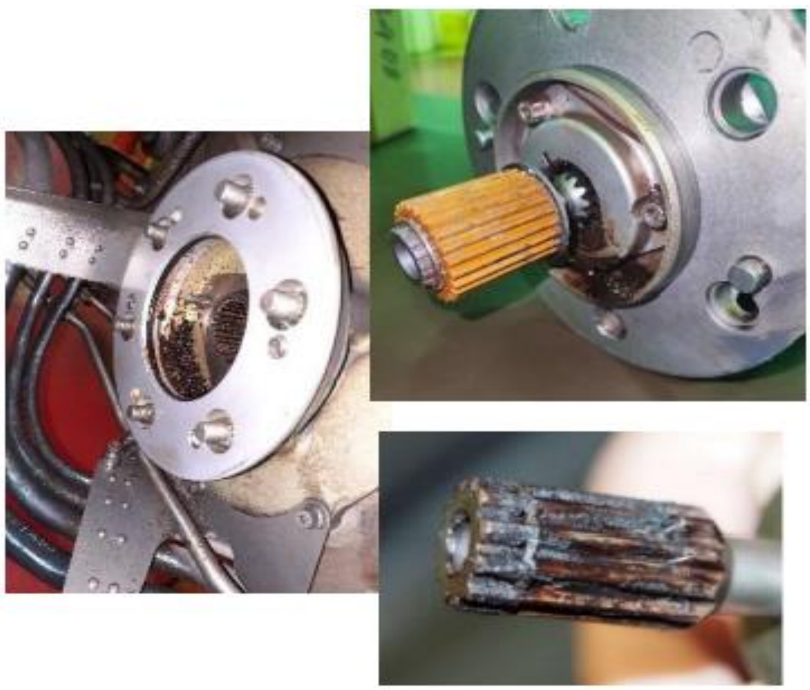


Figure 24 showing black debris and the leak of the skydrol at the base of the EDP

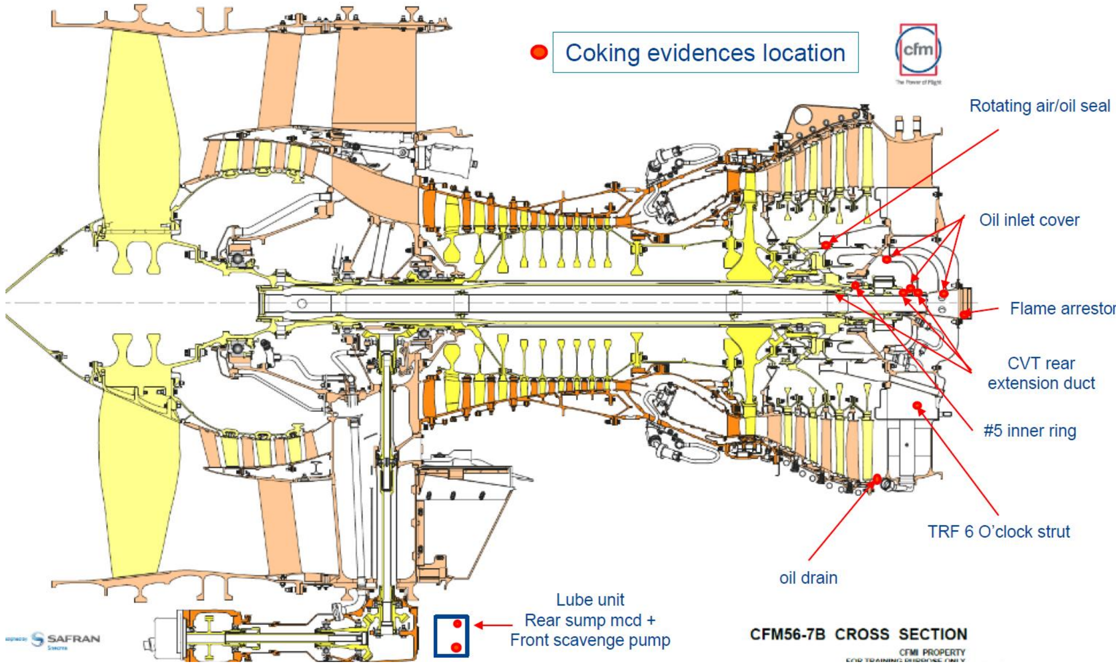


Figure 25. showing coking evidences, locations, #5 inner ring and oil seal, oil inlet cover and flame arrester (Source; CFM)

Figure 26. showing abnormal coking at seal teeth location and seal teeth wear

Figure 27. showing a Center Vent Tube (CVT) rear extension duct

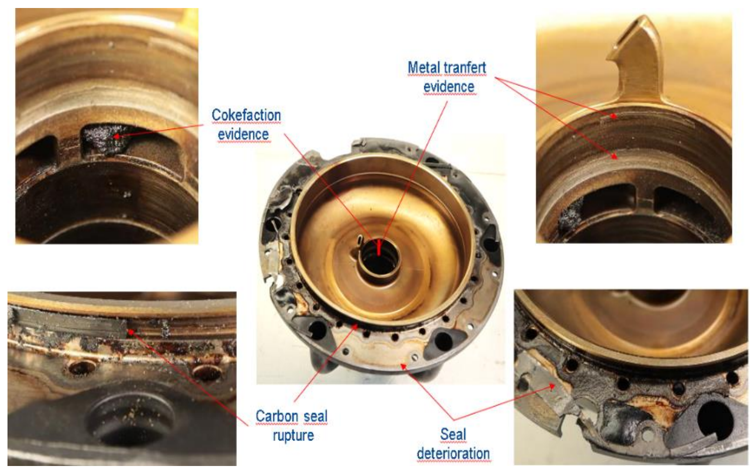


Figure 28. showing damaged seal and evidence of carbon seal rupture

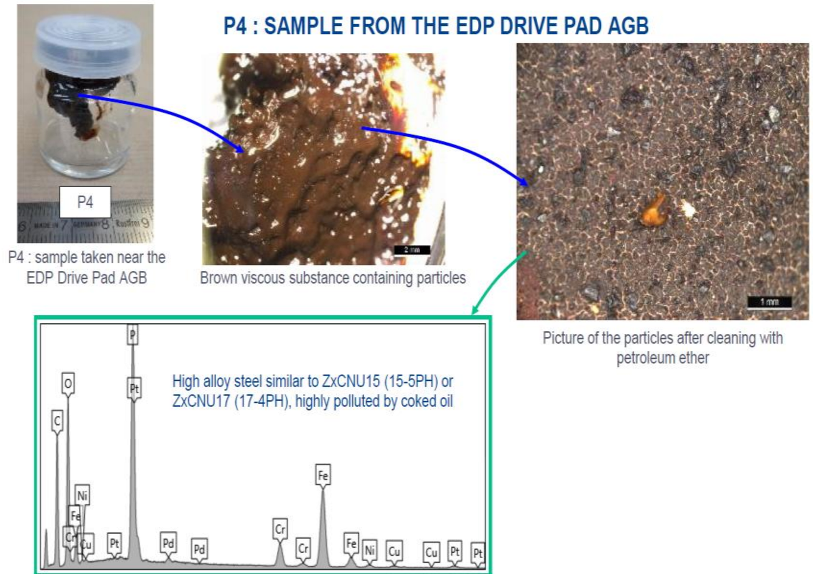


Figure 29. shows a brown viscous substance taken near the EDP Drive pad

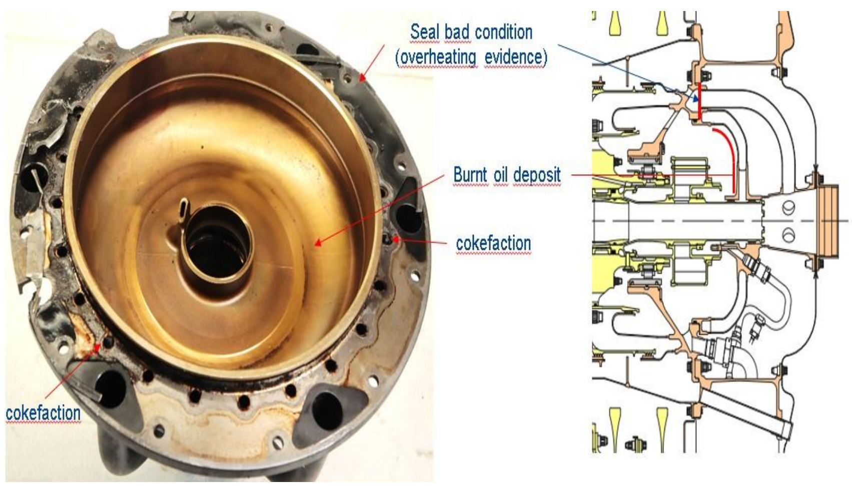


Figure 30. showing a damaged seal conditions and evidence of overheating

Oil sampling chemical analysis confirmed that the oil is not a typical "Mobil jet 2": unusual aspect, unusual odor and contained foreign product (origin not identified):

- This unusual oil with abnormal presence of solvent could have led to create abnormal amount of coke found in the engine:

• Large amount of abnormal coking detected in several locations (but where oil is present in normal operation without generating coke), with big pieces up to 11mm, including in scavenge MCD of lube unit.
• Most probably low time of functioning in this condition (should this coke be present on previous flights, other detections or distresses may have occurred).
• Coke generation (linked with specific oil composition): quantity and #5 bearing (BRG) support groove (see figure below) coking most probably come from the soak back phase of previous flights.

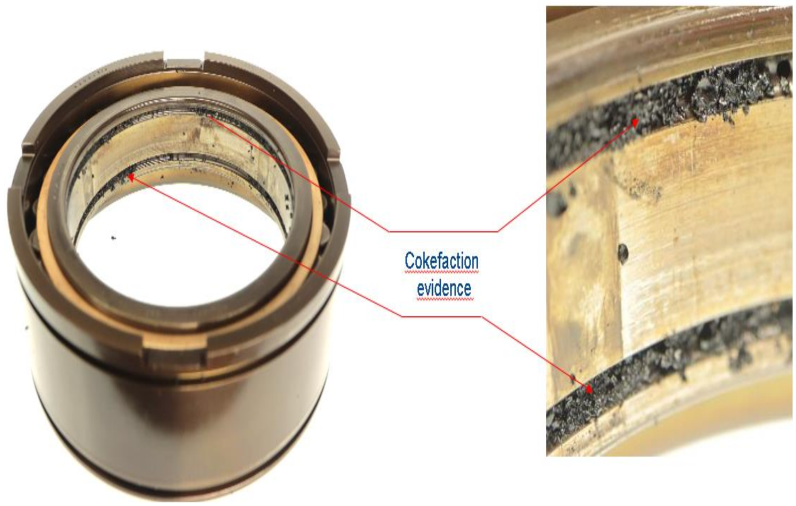


Figure 31. showing bearing #5 damages and coke faction evidence on bearing number #5

• This abnormal coking (linked with specific oil composition) may block oil flows, could have led to oil scavenge system clogging, generating quick and massive overfill of local sumps, leading to external leakages.
• Oil was evacuated thru rear sump oil drain and flame arrestor.
Rear sump seal wear could have contributed to oil evacuation in the exhaust plug.

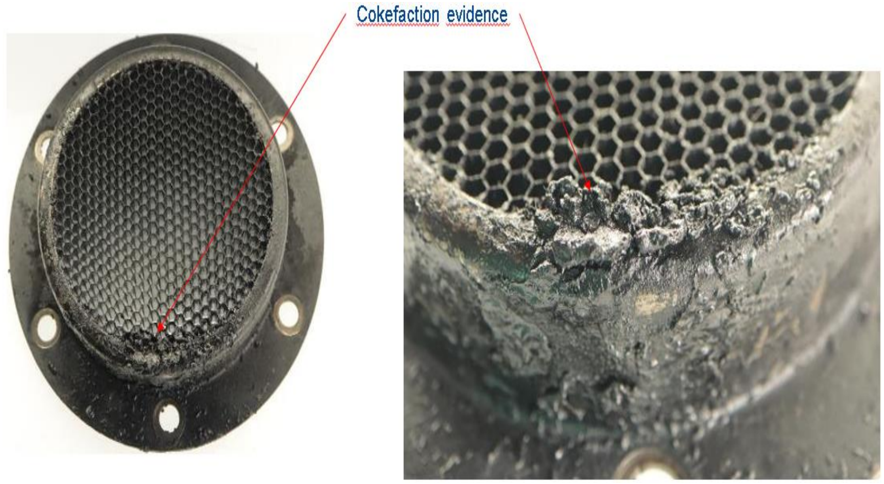
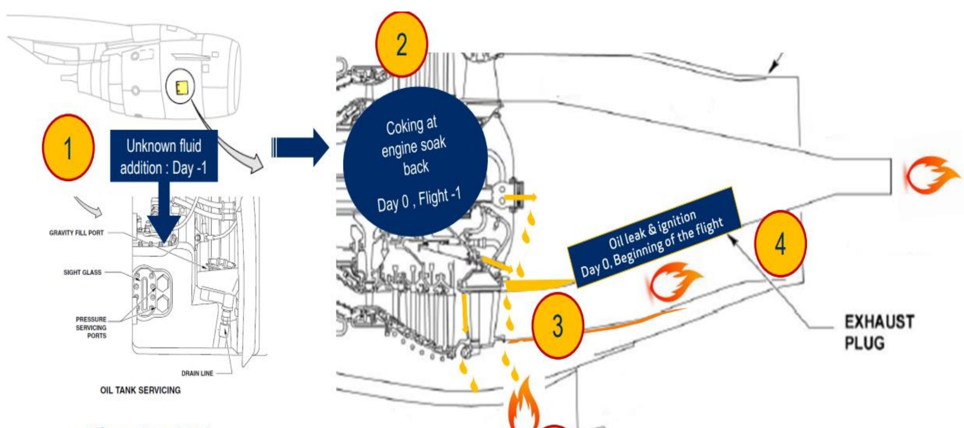


Figure 32. showing coke faction evidence on the flame arrester

- Oil located in the plug/ exhaust has created the smoke /fire seen during the event. Fire most likely facilitated by abnormal oil composition (unexpected components are excellent fuels).

- Two locations of fire, entertained in spite of permanent airflow (Significant oil leakage) necessary to feed fire, consistent with low oil quantity alarm and remaining oil in flow path and internal to plug (See figure below).



13/09/2022	IX-477	2,5
13/09/2022	IX-478	0,5
14/09/2022	IX-443	1
14/09/2022	IX-442	0

Figure 33. showing possible sequence of events from oil maintenance to the incident

-Oil sampling Chemical analysis confirmed non-common Mobil Jet 2 oil: unusual aspect, unusual odor: polysiloxane + 2- pentanone,4-hydroxy-4-methyl + tributylphosphate

- Unusual coking inside Rear Sump with some coke parts above 11mm + coke locations not in CFM experience

- Last oil servicing (~1l) occurred the night before flight IX443. Distress flight was the 2nd flight of the day.
- Rear sump chip detector contaminated by coke + metallic particles
- Oil inlet cover seal rupture + some seal teeth wear ◊ leakage possible

- Oil consumption (oil tank empty) is consistent with oil leakage due to oil system malfunction
- Remaining oil in plug
- Sister engine #1: oil normal

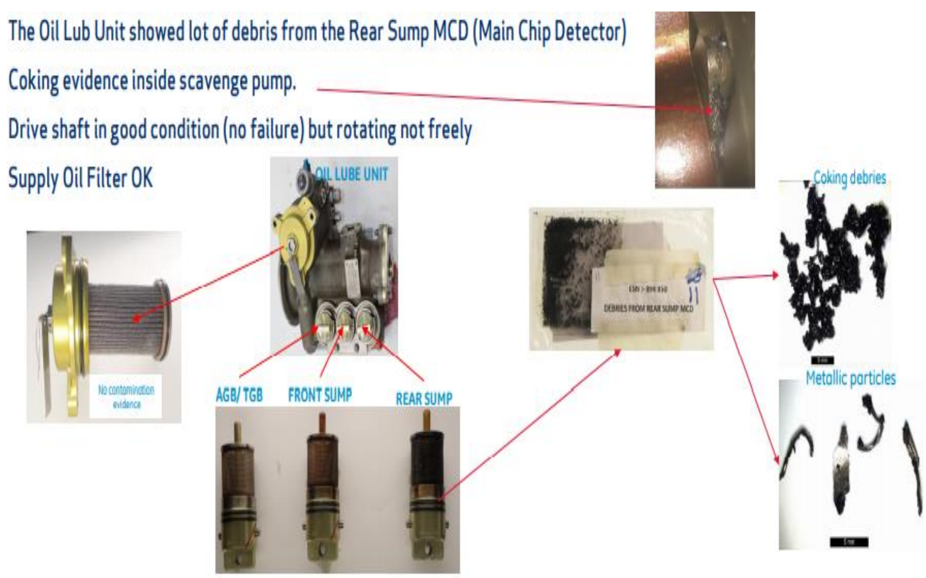


Figure 34. shows oil lubrication unit with debris from the rear sump main chip detector (MCD)

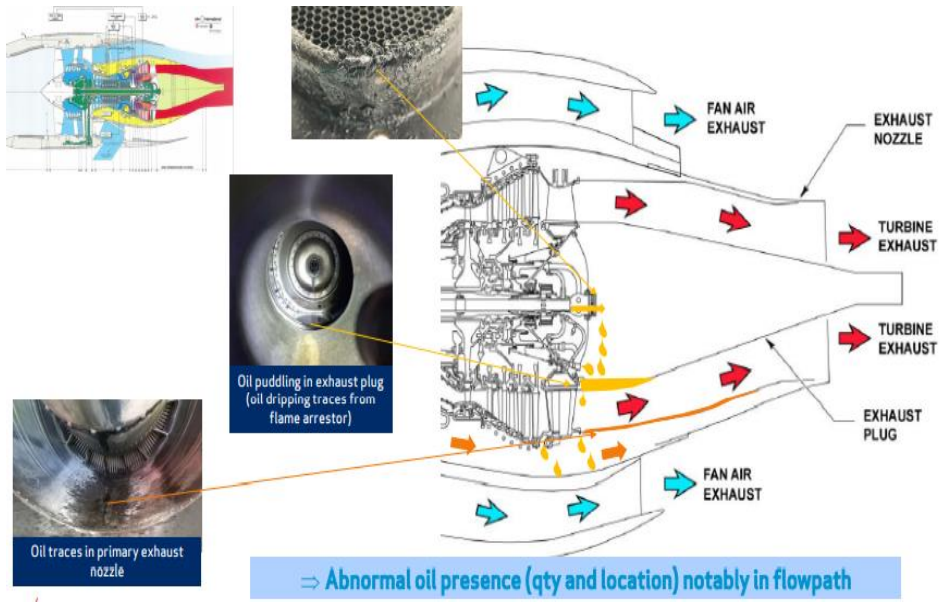


Figure 35. shows traces of oil in primary exhaust nozzle and dripping from flame arrestor

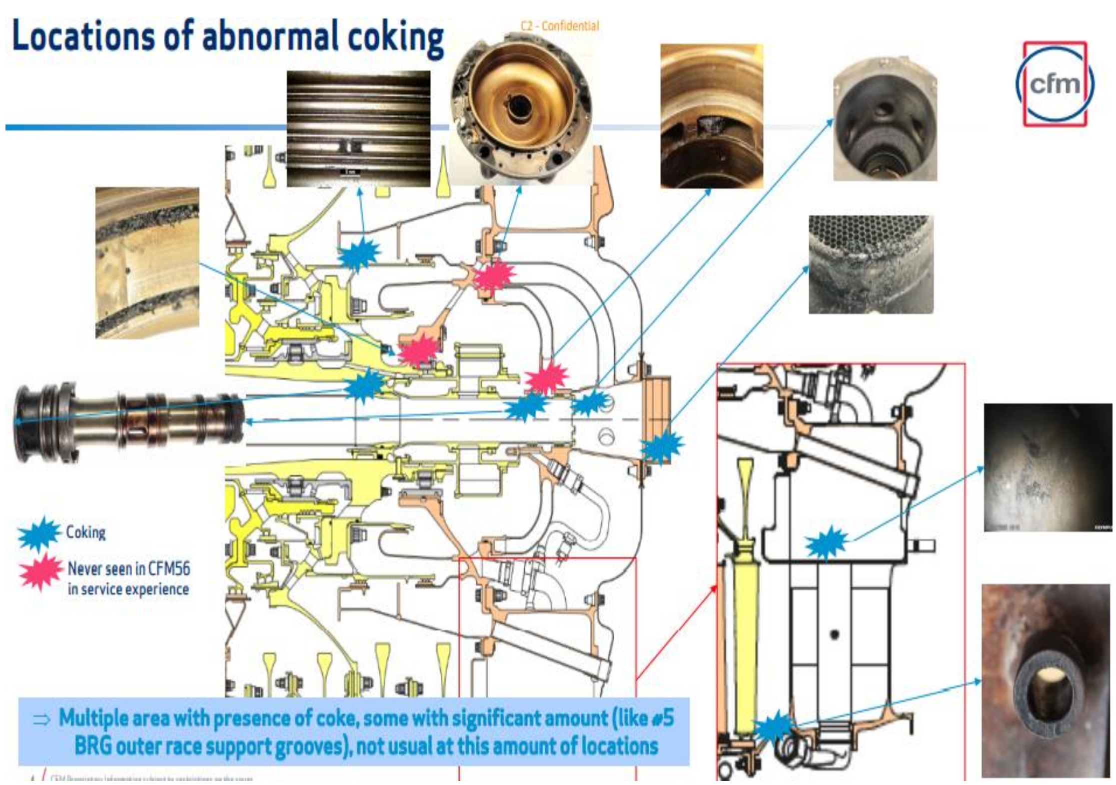


Figure 36. showing locations of affected abnormal coking

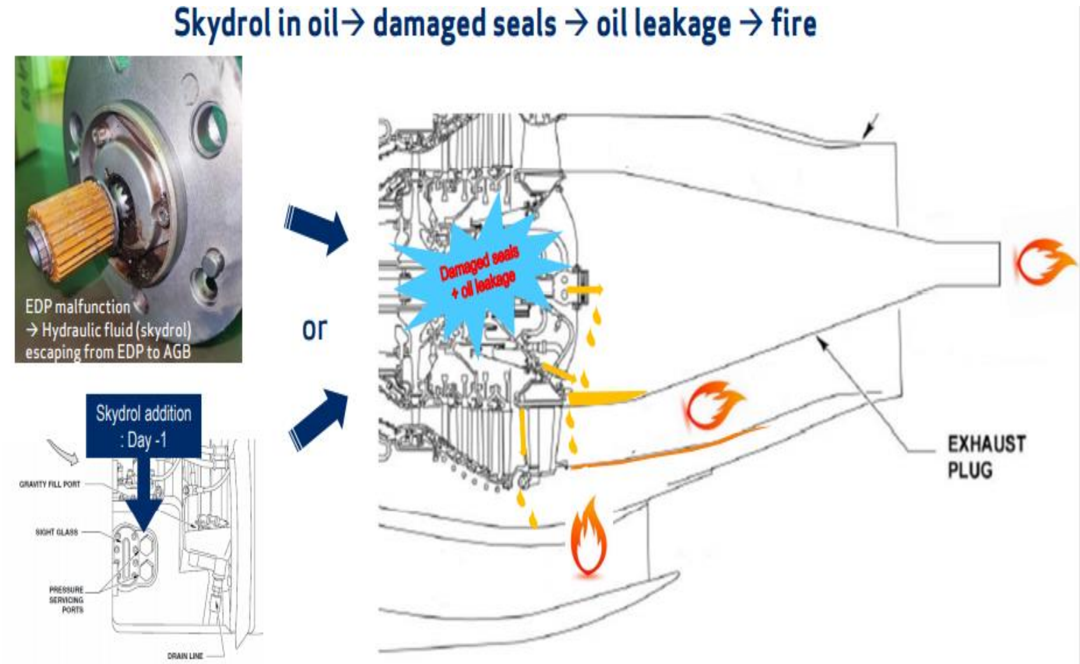


Figure 37. showing hydraulic fluid leaks and escapes from EDP

Hypothesis: Big amount of coke entering Lube Unit and generating pump malfunction due:

◊ Unusual coking

◊ Lube Unit malfunction

◊ overfill of rear sump

◊ oil leakage

◊ fire)

Hypothesis shows coke entering the lubrication unit, generated EDP malfunction, overfill the rear sump, leading to a leak into the fire arrestor and subsequently causing fire.

- Oil sampling Chemical analysis confirmed non-common Mobil Jet 2 oil

- Unusual coking inside Rear Sump with some coke parts above 11mm + coke locations not in CFM experience
- Last oil servicing (~1l) occurred the night before flight IX443. Distress flight was the second (2) flight of the day.
    - Rear sump MCD contaminated by coke
    - Few amount of coke seen inside scavenge pump
    - Drive shaft not rotating freely

- Oil inlet cover seal rupture + some seal teeth wear ◊ leakage possible
  - Oil consumption (oil tank empty) is consistent with oil leakage due to oil system malfunction
- Remaining oil in plug

Figure 38. showing the oil sample from oil tank.Figure 28 showing comparisons of the oil sample from oil tank and the Mobil Jet Oil 2

Hypothesis: « Skydrol (hydraulic fluid) » leakage from EDP to AGB due to (Skydrol in oil

◊ damaged seals

◊ oil leakage

◊ fire)

Hypothesis shows skydrol leakage from EDP to AGB due to skydrol in oil which damaged the seals which caused the oil leak and subsequently causing fire.

- Malfunction of EDP known as possible: seen in the past
- Skydrol is known as very damaging for seals
- Oil sampling chemical analysis confirmed non-common Mobil Jet 2 oil
- Tributylephosphate present in Skydrol
- Oil inlet cover seal rupture + some seal teeth wear ◊ leakage possible
- Oil consumption (oil tank empty) is consistent with oil leakage due to oil system malfunction
- Remaining oil in plug

- Sister engine: oil normal

- EDP investigated by Parker: "No Fault Found (NFF) and EDP not the cause of the engine fire event on aircraft VT-AXZ"

1.17 Organizational and Management Information

1.17.1 This was a scheduled international flight from Oman to India with 6 crew members and 147 passengers on-board, operated under Part 121 Air Operating Certificate issued by Indian Civil Aviation Authority.

1.17.2 The operator was initially issued an Air Operating Certificate (AOC) by the State of Registry and State of Operator, India, on 22 April 2005 with a re-issue on 28 June 2021 with an expiry date of 21 April 2023.

1.17.3 OTSB released the aircraft to the operator on 26 September 2022 after completing the investigation, as the aircraft was no longer needed.

1.18 Additional Information.

1.18.1 The following information was extracted from Boeing 737-600/-700/-800/-900 AIRPLANE FLIGHT MANUAL

ENGINE OIL SYSTEM Minimum oil pressure is 13 psi. If engine oil pressure is in the yellow band with takeoff thrust set, do not takeoff. Maximum oil temperature limit for continuous operation is 140°C. Maximum oil temperature is 155°C. Operation between 140°C and 155°C is limited to 45 minutes. The approved oil is designated in the CFM56-7 Service Bulletin 79-001(see Appendix D), as revised. See Non-Normal Procedures, Section 2, for oil pressure below 13 psi.

1.18.2 The following information was extracted from aircraft quick reference handbook (QRH):

Engine High Oil Temperature

Condition: The engine oil temperature is high.

1 Choose one Temperature is at or above the redline:

Go to the Engine Failure or Shutdown checklist on page

Temperature is in the amber band:

Go to step 2

2 Auto throttle (if engaged) …………………. Disengaged

3 Thrust lever

(affected engine) …………..Confirm……………. Retard slowly until the engine oil temperature is within the normal operating range or the thrust lever is closed.

4 Choose one:

Oil temperature is in the amber band for 45 minutes or less:

Note: Turn the affected engine at a thrust setting that keeps the engine oil temperature within the normal operating range.

Do not use FMC performance predictions.

Transponder mode selector……………..TA ONLY

This step prevents climb commands which can exceed reduced thrust performance capability.

Oil temperature is in the amber band for more than 45 minutes:

Go to the Engine Failure or Shutdown checklist on page.

Oil Quantity Indicator:

-Shows usable oil quantities in (Option) quarts, liters, or % (0-100)

-for low oil quantity, video is reversed and LO (white) is displayed the LO message shows –-the LO message shows when the oil quantity is <4 quarts

-indicated oil quantity may decrease significantly during engine start, take off and climb out

-if it occurs, engine operation is not impacted and the correct oil quantity should be indicated during level flight

-an oil quantity indication as low as zero is normal if windmiling N2 RPM is below approximately 8%

-the oil quantity indicating system sends data to the DEUs

-wing dihedral causes the oil tank for engine 2 to hold more oil than engine 1

Oil Quantity

100% =21.3 quarts/20.2 liters/5.34 gallons
75%=16 quarts/4.0 gallons
60%=minimum dispatch/12 quarts/11.4liters
50%=10.6 quarts/2.7 gallons
25%=5.3 quarts/1.3 gallons

LO=<18.8% or 4 quarts

Average oil consumption of all 737s is 1 US gallon per hour #2 Engine holds 21.6 quarts/20.4 liters because of the dihedral of the wings.

Oil Tank:

- the oil tank access is at the 3 o'clock position on the fan case
- it has an oil level sight gauge

The following information has been extracted from 737-800 Flight Crew Operations Manual

Take-off Procedure (SB Changes YL462 - YL478)

Pilot Flying	Pilot Monitoring
Pilot Flying and Pilot Monitoring Before entering the departure runway, verify that the runway and runway entry point are correct.	
	When entering the departure runway, set the STROBE light switch to ON. Use other lights as needed. Set the transponder mode selector to TA/RA.
Verify that the brakes are released. Align the airplane with the runway.	
Verify that the airplane heading agrees with the assigned runway heading.	
	YL462 - YL478 When cleared for take-off, set the FIXED LANDING light switches to ON. YT571 - YT578 When cleared for take-off, set the LANDING light switches to ON.
Advance the thrust levers to approximately 40% N1. Allow the engines to stabilize.	
Push the TO/GA switch.	
Verify that the correct take-off thrust is set.	
	Monitor the engine instruments during the take off. Call out any abnormal indications. Adjust take-off thrust before 60 knots as needed. During strong headwinds, if the thrust levers do not advance to the planned take-off thrust, manually advance the thrust levers before 60 knots. Call "THRUST SET".

After take-off thrust is set, the captain's hand must be on the thrust levers until V1.	
Monitor airspeed. Maintain light forward pressure on the control column.	Monitor airspeed and call out any abnormal indications.
Verify 80 knots and call "CHECK."	Call "80 KNOTS."
Verify V1 speed. Verify the automatic V1 callout or call "V1."	Verify V1 speed. Verify the automatic V1 callout or call "V1."
At VR, rotate toward 15° pitch attitude. After lift-off, follow F/D commands.	At VR, call "ROTATE." Monitor airspeed and vertical speed.
Establish a positive rate of climb.	
	Verify a positive rate of climb on the altimeter and call "POSITIVE RATE."
Verify a positive rate of climb on the altimeter and call "GEAR UP."	
	Set the landing gear lever to UP.
Above 400 feet radio altitude, call for a roll mode as needed.	Select or verify the roll mode. Verify VNAV engaged.
At thrust reduction height, verify that climb thrust is set.	

1.18.2 OIL - General (79-00-00) - Approved Oils for CFM56-7B Engines

Approved Oils

A. Service Requirements

(1) The engine must be serviced only with the approved oils listed in Table 1(See appendix 5.4) of the paragraph (2.B. Tabulation of Oils). There are no known incompatibilities among oil brands, provided they are of the same type and specification. However, mixing of two different approved brands of oil is only permitted once per month.

NOTE: When changing oil from Turbonycoil 600 to Eastman Turbo Oil 2197 (ETO 2197) or when changing oil from Eastman Turbo Oil 2197 (ETO 2197) to Turbonycoil 600 remove and inspect the oil filters (supply and scavenge (if applicable) oil filters) on the two first engines reaching 500 hours.

Oil consumption and oil pressure have to be carefully monitored during this period, in order to detect supply or scavenge tubes clogging.

(2) Fleet changeover from one approved brand to another approved brand of the same type may be accomplished by adding the new oil at the time of service (Topping off). Fleet changeover from one approved brand to another approved brand of a different type may be accomplished after total draining of the oil tank.

(3) In case of accidental mixing of a non-approved oil brand or a different oil type brand the following action must be taken:

- If less than 10% by volume (2 Quarts or less) has been dispensed in to the oil tank, no action is required.

- If more than 10% by volume (more than 2 Quarts) has been added in the oil tank, the tank must be drained and refilled with the specified oil brand prior to next flight.

(4) Type 2 oil brands are limited to a minimum oil temperature of -40 °F (-40 °C) for engine starting.

(5) Type 1 oil must be limited to revenue service operation that could potentially encounter extreme cold temperature below -40 °F (-40 °C) and must not be used for extended periods of time.

(6) Lubrication system servicing, draining and flushing must be done as specified in the Aircraft Maintenance Manual.

Engine Maintenance

The engines must be maintained as follows:

(a) Scheduled engine maintenance inspections and condition monitoring evaluations must be made in accordance with the airline operators established practices and schedules and the CFM56 maintenance program.

(b) Inspection of the engine lubricating system particle traps, magnetic chip detectors and filter elements must include documentation of any findings during the initial servicing and any subsequent inspections. Unusual or excessive material collection must be analyzed by the airline operator and the results must be included in reports to CFM International. Findings indicating an oil incompatibility with the engine must be reported immediately to CFM International.

c) An accurate record of oil consumption must be maintained and must include notation of any engine maintenance that could affect the accuracy of oil consumption computations.

1.18.3 Crew Duties (737 Flight Crew Operations Manual)

Preflight and postflight crew duties are divided between the captain and first officer. Phase of flight duties are divided between the Pilot Flying (PF) and the Pilot Monitoring (PM). Each crewmember is responsible for moving the controls and switches in their area of responsibility:

• the phase of flight areas of responsibility for both normal and non-normal procedures are shown in the Area of Responsibility illustrations in this section. Typical panel locations are shown.

• the preflight and postflight areas of responsibility are defined by the “Preflight Procedure - Captain” and “Preflight Procedure – First Officer.” The captain may direct actions outside of the crewmember’s area of responsibility. The general PF phase of flight responsibilities are:

• taxiing

• flight path and airspeed control

• airplane configuration

• navigation.

The general PM phase of flight responsibilities are:

• checklist reading

• communications

• tasks asked for by the PF

• monitoring taxiing, flight path, airspeed, airplane configuration and navigation. PF and PM duties may change during a flight. For example, the captain could be the PF during taxi but be the PM during takeoff through landing. Normal procedures show who does a step by crew position (C, F/O, PF, or PM):

• in the procedure title, or

• in the far right column, or

• in the column heading of a table

The mode control panel is the PF's responsibility. When flying manually, the PF directs the PM to make the changes on the mode control panel.

The captain is the final authority for all tasks directed and done.

1.18.4 Preliminary Preflight Procedure – Captain or First Officer

The Preliminary Preflight Procedure assumes that the Electrical Power Up supplementary procedure is complete.

A full IRS alignment is recommended before each flight. If time does not allow a full alignment, do the Fast Realignment supplementary procedure.

IRS mode selectors .... OFF, then NAV

Verify that the ON DC lights illuminate then extinguish.

Verify that the ALIGN lights are illuminated.

The UNABLE REQD NAV PERF-RNP message may show until IRS alignment is complete.

VOICE RECORDER switch ....As needed

Verify that the following are sufficient for flight:

• oxygen pressure

• hydraulic quantity

• engine oil quantity

Do the remaining actions after a crew change or maintenance action.

Note: The following oxygen pressure drop test only needs to be performed at one crewmember or observer station.

1.19 Useful or Effective Investigation Techniques.

1.19 Not applicable.

2 Analysis

2.1. General

From the available evidence, the following analysis was made with respect to this incident. This shall not be read as apportioning blame or liability to any organization or individual.

2.2. Flight Operations

The captain was qualified to act as pilot-in-command with a valid ATPL and class 1 medical certificate. The PIC was issued with a B737 rating to act as a pilot-in-command or co-pilot. The first officer was qualified to act as co-pilot with a valid CPL and class 1 medical certificate. The First Officer was issued with a B737 rating to act as a co-pilot only. The crew was properly licensed and qualified to operate the aircraft and the crew followed the established operations procedures in collaboration with other parties to safely secure the aircraft and the passengers.

After clearance by ATC to take off the crew reported that they experienced a low oil pressure warning followed by the fire indication warning on the right-hand engine followed by engine oil low pressure. After communicating with ATC, the crew followed and executed the “ENGINE

FIRE or Engine Severe Damage or Separation" checklist, the number two engine Oil Filter Bypass Light illuminated which led the crew to follow the ENGINE FIRE or Engine Severe Damage or Separation" checklist and carried out a precautionary shutdown of number two engine in accordance with the ENGINE OIL FILTER BYPASS checklist from the QRH. The crew aborted the takeoff at low speed, taxied off the runway, shut down the engines.

2.3 Aircraft

The operator performed the aircraft last inspection "weekly check" on the 11th September 2022 at 46334 airframe hours. The aircraft had accumulated an additional 34 airframe hours in operation since the last inspection. The aircraft was issued Certificate of Release to Service (CRS) with an expiry date of 25 August 2022. On-site investigation and further post-incident inspection of the wreckage (airframe and engine) revealed no pre-existing failures prior to the incident; all damage was caused during the serious incident fire event. The aircraft maintenance records made available by the operator shown that the aircraft was airworthy and there were no recorded defects prior to the incident flight. There was a recorded differential oil pressure of engine number 2 on the aircraft tech log, the differential pressure was approximately 5psi when compared to engine number 1.

The aircraft, experienced a fire indication warning followed by low oil pressure indication light on the right-hand engine. As the flight progressed after being given the clearance, the number two engine oil filter bypass light came on. This was an indication of a clogged scavenge oil filter element and an impending filter bypass. The crew followed relevant QRH and shut the number two engine during taxing. The oil quantity started decreasing from 6 quarts oil loss in 2 minutes and continued to decrease to 0 quarts within 7minuntes and subsequently oil pressure decreased to zero for few minutes and later followed by the engine running with an oil pressure below 13 PSI within 4minutes.

During the disassembly of the EDP the manufacturer established that there were some debris on the external drive shaft, indicating hydraulic fluid exposed to high temperatures and there was also minor thread damage to the connector shell. It was also established that the safety wire in certain areas of the EDP was not original as the manufacturer uses different safety wires than those found on the EDP. Although the EDP appeared to have been repaired prior to the incident, the records made available by the operator indicated that there was no maintenance conducted on the EDP prior to the incident flight. Therefore, OTSB could not establish as to when was the maintenance or repairs were carried out on the EDP. It is most likely that there was some maintenance or repairs done on the EDP since the safety wires were not original safety wires used by the EDP manufacturer.

The manufacturer performed test and disassembly of the EDP, the EDP was found not to be leaking, and no fault found with the EDP. The EDP manufacturer concluded that EDP was not the cause of engine fire event on aircraft VT-AXZ. the DFDR analysis did not show any loss of hydraulic fluid quantity or pressure during the event, several flights are needed to damage seals and Skydrol is not known to create big coke.

OTSB noted the EDP manufacturer's conclusion on EDP, that it was not the cause of engine fire event on aircraft VT-AXZ. However, the presence of hydraulic fluid (skydrol) debris on external drive shaft of EDP, indicating hydraulic fluid exposed to high temperatures could not be explained or determined by the EDP manufacturer that how it happened that hydraulic fluid (skydrol) is found in the area where there should not be any hydraulic fluid. The properties of skydrol are resembled on the oil taken from engine number 2. The substance found in engine number 2 oil, had properties that resemble skydrol.

OTSB conclude that, it is probable that, the hydraulic fluid, that was exposed to high temperature on the external drive shaft of the EDP, it may have entered the oil system through the Accessory Gear Box (AGB) resulting in oil contamination of the oil system causing oil system malfunctioning.

The investigation established that oil from the engine number 2 and the Mobil jet 2 oil had different aspects, engine serial number 894850 oil was found to be elastic aspect, "gum" type texture and Mobil jet 2 oil part of the oil was found to be sticky like caramel and the other had a varnished aspect. Flash point determination was carried out in a closed cell, no significance, differences between the two oils: Mobil jet 2 (new): 252°C versus oil from engine 894850: 246°C.

The engine number 1 oil analysis (ESN 894401) was found to be consistent with common Mobil Jet 2 oil. Based on the number 1 engine oil analysis results it does appear that the records of the last five flights oil upliftment from the operator was done using the correct Mobil Jet 2 oil, however this doesn't take away that oil analysis of engine number 2, established that the engine number 2 oil was contaminated with unknown substance. OTSB conclude that it is probable that the source of the unknown substance found in the oil system of engine number 2 could be from the hydraulic oil (skydrol) that was found on the external drive shaft of the EDP which resulted in oil system malfunctioning.

It should be noted that the evidence presented to OTSB investigation team, suggest that both engine number 1 and engine number 2 were serviced with the same Mobil jet 2 oil, and it is only engine number 2 oil that was found contaminated and not engine number 1 oil system. Although the oil of engine number 1, was tested few months after the incident, there were no reported defects of engine number 1 oil system malfunctioning prior to the incident and post the incident. Therefore, this suggest that both engine number 1 and engine number 2, were both serviced with normal Mobil jet 2 oil, as per the evidence records provided by the operator. The oil contamination of engine number 2 is improbable that it was due to maintenance error of oil upliftment using none approved oil to replenish both engine number 1 and engine number 2 as this could have affected both engines and not only engine number 2. Therefore, OTSB concluded that based on the oil upliftment maintenance records, both engine number 1 and engine number 2 were serviced with the correct Mobil jet 2 oil.

Oil sampling chemical analysis confirmed that the oil found in engine number 2 is not a typical "Mobil jet 2 ", unusual aspect, unusual odor and contained foreign product origin not identified but suspected hydraulic oil due to the presence of hydraulic oil on the external drive shaft of EDP. OTSB established that the likely hood is that due to the presence of hydraulic oil on the external drive shaft of the EDP, the skydrol possibly leaked to the AGB causing oil system malfunctioning resulting in the coking of oil and clogging of the oil system. This led to the malfunctioning of Oil Lubrication Unit causing scavenge sump to be flooded and vent out through the rear vent system.

According to the CFM engine Aircraft Maintenance Manual (AMM): The lubrication unit (LUB Unit) supplies pressurized oil to lubricate the engine bearings and gears. It also takes the oil that collects in the sumps and the gearboxes and sends it back to the oil tank. The investigation found that the lubrication unit was found with debris on the drive shaft which contributed to the malfunction of the LUB Unit.

It should be noted that the manufacturer ruled out that the EDP was the cause of the fire event on aircraft ZT-AXZ., this is because no fault found was established with EDP. However, it has not been established or determined that how did the skydrol entered the external drive shaft that connects to the AGB, Therefore OTSB concluded that although the manufacturer confirmed no fault found with the EDP, the presence of hydraulic oil on the external drive shaft of EDP, may have entered the AGB causing oil system malfunctioning on engine number 2.

OTSB requested records of the oil used and the maintenance records on the oil upliftment. The evidence provided by the operator suggest that the operator has been using the correct oil as recommended by the manufacturer. The operator provided documentation evidence of their storage checklist which included the batch numbers which matched that of the manufacturer oil specification recommended for this type of engines. Based on this information, OTSB determined that there was no evidence that incorrect oil was uplifted during the servicing of the flight the night before the incident flight. And this is further based on the fact that, engine number 1 which was uplifted using the same oil used for engine number 2, therefore engine number 1 never experience oil system malfunction prior to the incident and even post the incident.

The engine manufacturer suggested that the most likely scenario which lead to this incident is that the amount of coke entered lubrication unit and generated lubrication unit malfunctioning (lubrication unit was not turning freely, found with debris and this caused possible malfunctioning). This may have blocked oil flows, could have led to oil scavenge system clogging and flooding, generating quick and massive overfill of local sumps, leading to external leakages through the air vents. This led to the oil evacuating through rear sump oil drain and flame arrestor. The rear sump seal wear lead to the oil evacuation into the exhaust plug and the oil located in the plug/ exhaust created the smoke /fire seen during the event.

Although the oil sample of engine number 1 was only tested few months after the incident, no defects were recorded by the operator, prior to the incident and even after the incident about the oil system malfunctioning of engine number 1. This therefore suggest that both engines were serviced with recommended Mobil jet 2 engine oil.

OTSB further made enquiry with the engine manufacturer on the welding points of the oil supply tube. The manufacturer indicated that the 4 damaged welding points which the manufacturer described as design intent welding points were not as a result of a repair of the oil supply tube, but rather they are design intent to protect the oil supply tube. Therefore, it was concluded that there was no maintenance conducted on the oil supply tube welding points.
The manufacturer reported that the most likelihood of the deformation of the oil supply tube could be related more on a mechanical deformation during the assembly or disassembly and that the deformation existed on the tube when the manufacturer received the TRF with the tube inside.

OTSB further conclude that the 4 welding points connect and attach the thermal shield to protect the oil supply tube from excessive high temperatures during the operation of the aircraft, therefore the breakage and failure of the welding points, exposed the oil supply tube to the excessive high temperature which could have led to the deformation of the oil supply tube since the thermal shield was found moved backwards and the oil supply tube exposed to excessive high temperature without any protection.

It is therefore concluded that following the failure of the 4 welding points which could have happened over time caused the oil supply tube to be exposed to high temperatures and possible deformation which had an effect on the oil system cooling mechanism. The operators flight logs reports revealed that the engine number 2 oil system pressure was consistently high by approximately 5psi when compared to engine number 1.

2.4 Human Factors

On 14th September 2022, the flight crew of India Express flight (AXB442) a Boeing 737-800, VT-AXZ) was scheduled for the second sector (MCT-COK), after been given clearance to enter Runway 08L and cleared for take-off and as the aircraft was entering the runway, the crew alert box blinked followed by the right engine (#2 engine) low oil pressure. ATC was contacted and informed that they are unable to take off due to technical problem. The flight crew was asked to vacate the runway via Yankee 5 and turn right on Whisky (W) taxiway.

After stopping the aircraft at taxiway Whisky (W), the engine low oil pressure Non-Normal Checklist (NNC) was carried out. Oil pressure was observed to be dropping and also the oil quantity level indication, which eventually read zero. Then another aircraft reported smoke from the engine number #2. Smoke was also observed from the cockpit and fire was also reported. Engine fire or separation memory item was carried out as per the aircraft quick reference hand (QRH) book. Since fire was reported, fire extinguisher bottle was activated. Thereafter, NNC was carried out. Since fire was still reported, the second fire extinguisher bottle was also activated. The review of NNC directed the crew to go to evacuation checklist which was followed successfully.

DFDR and CVR analysis: The incident occurred about few seconds after the flight crew was cleared for take-off. The incident flight was not the first that paired the captain and the copilot. Crew coordination during emergency is very important however in this occurrence based on the DFDR and CVR recordings, the first warning light appeared at 07:19 however the crew started engaging with the ATC on the matter at 07:26. Therefore it took the crew approximately 7 minutes to engage with ATC after receiving the engine fire warning. It is possible that the crew continued with the taxi after the first warning indication while they were coordinating, including continuous crosschecking and monitoring of instruments prior to engaging ATC.

The engine number 1 oil analysis (ESN 894401) by the manufacturer was found to be consistent with common Mobil Jet 2 oil. Based on the number 1 engine oil analysis results the manufacturer determined that it does appear that the records of the last five flights oil upliftment were done using the correct Mobil Jet 2 oil. However, they couldn't determine the source of the unknown substance found in the oil system of engine number 2. The report further indicated that the oil analysis of engine number 2 was found with unknown substance. There was no conclusive determination from the manufacturer of what caused or how the unknown substance got to the oil tank and/ or oil system of engine number 2. However, the investigation established that the was presence of hydraulic oil (skydrol) on the external drive shaft of the EDP, this could have leaked to the AGB causing the oil system contamination and damage to the seals.

OTSB reviewed records from the operator and found that the operator has been using the correct Mobil Jet 2 oil and the oil analysis conducted from the oil drained from the two engines proved to be that of Mobil Jet 2 oil. OTSB further reviewed and analyzed the technical report from the manufacturer. The first observations were the debris on the External Driveshaft and the hydraulic fluid (skydrol) which seemed to have been exposed to high temperature.

It was also established that it is probable that the skydrol that was present in the external drive shaft of the EDP leaked to the AGB resulting in the engine number 2 oil system contamination and resulting in the oil system malfunctioning.

It is therefore concluded that following the failure of the 4 welding points which could have happened over time caused the oil supply tube to be exposed to high temperatures and possible deformation which had an effect on the oil system cooling mechanism. The operators flight log reports revealed that the engine number 2 oil system pressure was consistently high by approximately 5psi when compared to engine number 1.

2.5 Survivability

Rescue fire service response: There was services provided of Rescue fire, which helped the crew to evacuate the passenger’s safety and timeously and successfully. Firefighting used Monnex high performance dry powder systems and FFFP foam to extinguish the Engine no.2 fire.

Analysis of injuries and fatalities: The 20 passengers who suffered minor injuries during the evacuation were treated by the airport clinic. All injured passengers were treated by the emergency services and never hospitalized. The whole incident evacuation duration took 58 minutes from the commencement of the evacuation until the last person was evacuated.

Survival aspects: The incident was survivable by the crew and passengers, although there were some minor injuries during the evacuations, the passengers were safely evacuated and taken to the clinic for further checkups on their minor injuries and they were released immediately after the checkups were completed.

2.6 Weather

The crew stated that during the clearance for the take-off, ATC also reported the wind direction was light and variable with a wind component of at 02kts. Therefore, OTSB determined that weather was not a factor to this incident.

2.7 Cabin Crew and Cockpit Crew Operations Procedures

The cabin crew were on their first flight of the day from OOMS and the crew had adequate rest prior to undertaking to conduct the flight. The flight and the evacuations were handled as per the operator’s Standard Operating Procedures (SOP) requirements.

3 Conclusions

3.1 General

From the available evidence, the following findings, causes and contributing factors were made with respect to this incident. These shall not be read as apportioning blame or liability to any organization or individual.

To serve the objective of this investigation, the following sections are included in the conclusion heading:

- Findings — are statements of all significant conditions, events, or circumstances in this incident. The findings are significant steps in this incident sequence, but they are not always causal or indicate deficiencies.
- Causes — are actions, omissions, events, conditions or a combination thereof, which led to this incident.
- Contributing factors — are actions, omissions, events, conditions or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the incident occurring, or would have mitigated the severity of the consequences of the incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2. **Findings**

3.2.1 The Captain (Capt) was in possession of an Airline Transport Pilot License (ATPL). According to the evidence provided by the operator, the pilot had flown a total of 7333.40 hours, of which 2202.34 hours were on the aircraft type.

3.2.2 The captain was properly licensed and medically fit to operate the flight.

3.2.3 The FO was in possession of a Commercial Pilot License. According to the evidence provided by the operator the pilot had flown a total of 998.53 hours, of which 698.26 hours were on the aircraft type.

3.2.4 The FO was properly licensed and medically fit to operate the flight.

3.2.5 The senior cabin crew was initially issued with a cabin crew competency card on 29th September 2008 in accordance with the Indian Civil Aviation Law, Civil Aviation Regulations and with Annex 1 to the Chicago Convention, as amended. The last license validation was on 1st November 2021 with an expiry date of 31st October 2022.

3.2.6 There were 3 cabin crews working under and or with the senior cabin crew. All were rated on Boeing B737, issued with competency card and received the following trainings: DGR, AVSEC TRG, DITCHING DRILL, FIRE DRILL, EMERGENCY EXIT TRAINER, ESCAPE SLIDE DRILL, CRM/JTCRM and MEDICAL CHECK. The flight cabin crew was properly licensed and medically fit to operate the flight.

3.2.7 The Air Traffic Controller was initially issued with an air traffic licence on 21st October 2003 in accordance with the Oman Civil Aviation Law, Civil Aviation Regulations and with Annex 1 to the Chicago Convention, as amended. His last license validation was on 31st March 2022 with an expiry date of 6th April 2024. The ATC controller was issued a Class 3 medical certificate on 31st March 2022 with an expiry date of 6th April 2023. The controller was properly licensed, medically fit and correctly rated to provide the service.

3.2.8 The aircraft was first registered with the current owner on 6th November 2020. The aircraft had a valid CoA issued on 1st November 2021 with an expiry date of 31st October 2022 and the aircraft was re-issued a CRS on 13th October 2021. The last weekly check maintenance inspection was carried out on 11th September 2023 at 46334 airframe hours.

3.2.9 The operator was initially issued an Air Operating Certificate (AOC) by the State of Registry and State of Operator, India, on 22 April 2005 where by it was re-issued on the 28th June 2021 with an expiry date of 21st April 2023.

3.2.10 The Operator had a valid Aircraft Maintenance Organization (AMO) approval certificate issued with the aircraft type endorsed.

3.2.12 According to available records, the incident engine was replaced with the serviceable engine following the incident, functionally tested for performance and was found satisfactory and the aircraft was ferried to India. The incident engine was shipped to India where the engine was inspected and disassembled in the presence of OTSB investigating team for further analysis.

3.2.13 The aircraft had accumulated an additional 34.0 airframe hours in operation since the last inspection and no major defects were recorded on the aircraft.

3.2.14 The meteorological routine aerodrome report (METAR) for Muscat International Airport on 14 September wind direction was reported light and variable with wind speed of 02 knots. Therefore, weather was considered not a factor in this occurrence.

3.2.15 AT 07:26 and after being cleared for a take-off the Captain instructed the First Officer to inform the ATC that they have a technical problem and had to vacate the runway.

3.2.16 The crew followed the non-normal checklist procedure at 07:32:04, which was 6 minutes and 4 seconds after the occurrence was first identified or reported by the crew. According to the DFDR master caution light came on 07:19 and the crew actioned the non-normal checklist after 07:26 which was 7 minutes after the first warning light.

3.2.14 According to available records made available to OTSB Investigation team, the last oil servicing occurred in India, the night before flight IX443, the distress flight was the second flight back to India and first of the day.

3.2.15 According to work order no: EWO-000545-17 in 2017, the engine was sent to the engine overhaul facility due to EGT issues, OAP, MUMBAI. Engine was repaired, reassembled and tested for performance and was found satisfactory. Post engine test, borescope inspection was carried out and the engine was found satisfactory.

3.2.15 Engine number 2 computer Electronic Engine Control (EEC) was downloaded and analysis was carried out and did not reveal any anomaly, which could have contributed to the incident.

3.2.16 Engine number 2 borescope inspections carried out and did not reveal any anomaly which could have contributed to the incident.

3.2.17 AI Engineering Services Limited- Mumbai carried out the disassembly of the engine and there were no anomalies found however several components including Engine Driven Pump (EDP), Oil Lubrication Unit and oil sampling were taken and recommended for further tests and analysis.

3.2.18 The Engine Driven Pump (EDP) was further tested and examined based on the visual inspection and test results, no anomalies were found that could have contributed to the engine fire incident. However, there was evidence of hydraulic oil (skydrol) on the external drive shaft of the EDP which could not be explained how it happened.

3.2.19 The manufacturer reported that the safety wires found in certain areas on the EDP was not original, as the manufacturer (Parker) only uses safety wires different from what was found on the EDP. However, the investigation could not establish the last maintenance on the EDP to confirm if the safety wire was replaced or not. The operator was consulted and there were no records that the maintenance was carried out on the EDP prior to the incident.

3.2.20 The Oil supply tube is an on-condition item. The review of the maintenance data of the Engine 894950 reveals that no maintenance was carried out on the oil supply tube of the mentioned engine. Scrutiny of documentation of the shop visit of the Engine 894850 did not reveal any repair carried out on the oil supply tube.

3.2.21 The oil supply tube which was found installed on engine 894950, was found with 4 damaged welding points which the manufacturer calls design intent as per Engine Shop Manual to repair welding spots (REP036). Oil supply tube which was found on the engine was damaged and deformed. The manufacturer reported that the deformation of the oil supply tube could be related more on a mechanical deformation during the assembly or disassembly and that the deformation existed on the tube when the manufacturer received the TRF with the tube inside. Therefore, OTSB concluded that following the failure of the 4 welding points which could have happened over time caused the oil supply tube to be exposed to high temperatures and possible deformation.

3.2.23 The manufacturer reported that the hypothesis on the Oil Supply Tube damage could be linked to the vibration which happened over time in service resulting in the breakage of the 4 design intent welding spots of the thermal shield that could have created a movement of the thermal shield and deformation of the oil supply tube.

3.2.24 The 894850-engine oil was found to be very viscous and consists of two phases at rest which are: the color of the oil is similar to that of a regular one and the oil's smell is quite different from the oils that are usually analyzed at SAE lab.

3.2.25 Oil sampling chemical analysis confirmed that the oil tested was not a typical "Mobil jet 2 ", unusual aspect, unusual odor and contained foreign product origin not identified, and the properties of skydrol are resembled on the oil taken from engine number 2.

3.2.26 The manufacturer established that Skydrol is known as very damaging for seals and the oil sampling chemical analysis confirmed non-common (Skydrol) Mobil Jet 2 oil. This unusual oil with abnormal presence of solvent could have led to create abnormal amount of coke found in the engine. This is evidenced by seals damaged, the coking clearly articulate damaged seals in the oil system and the number #5 bearing.

3.2.27 The engine number 1 oil was tested, analyzed and found to be normal and matching with that of Mobil jet 2 oil. Although the engine number 1 oil was tested few months after the incident occurred, no defects relating to the oil system malfunction were recorded for engine number 1 prior to the incident and post the incident.

3.2.28 Review of digital flight data recorder (DFDR) data indicated that the oil quantity started decreasing from 6 quarts oil loss in 2 minutes and continued to decrease to 0 quarts within 7minuntes and subsequently oil pressure decreased to zero few minutes later followed by the engine running with an oil pressure below 13 PSI within 4 minutes.

3.2.29 The Engine Driven Pump (EDP) was visually examined after removal from the shipping box, and debris were noted on the end of the Energy Dispersive Spectroscopy (EDS) and inside the mating Instruction Detection System (IDS). This debris was captured and analyzed by the manufacturer (Parker M&P Lab). This residue was later determined to likely be hydraulic fluid (Skydrol) that was exposed to high temperatures.

3.2.30 The pump turned freely by hand and there was no debris noted in any of the ports, so the decision was made to mount the EDP to the test stand and pressurize it for a static leak test and no anomalies were found.

3.2.31 Particles found in the oil inlet cover correspond to coked oil and particles found in the Rear Sump Main Chip Detector (MCD) are a mix of a sharp edge from a high alloy steel or a particle probably coming from a plasma deposited coating, and some coked oil particles. A brown viscous substance has been found near the engine driven pump (EDP) drive pad of the AGB (Accessory Gear Box).

3.2.32 The 4 welding points failed resulting on the thermal shield not protecting the oil supply tube as expected to ensure that the oil is not exposed to the excessive heat and is able to lubricate the oil systems.

3.2.33 The investigation established that one of the possible contributing factors could be oil coke deposit fragment in the TRF which partially clogged the scavenge tube, and subsequently causing lack of lubrications to the oil system.

3.2.34 The abnormal coking may have blocked oil flows, could have led to oil scavenge system clogging and flooding, generating quick and massive over fill of local sumps, leading to external leakages. Oil evacuated through the rear sump oil drain and flame arrestor. Due to the rear sump seal wear, the oil leaked into the exhaust plug which resulted into the smoke/fire reported.

3.2.35 The manufacturer report finding shows oil inlet cover seal had ruptured and some seal teeth wear. Also, the report showed that oil sampling chemical analysis confirmed non-common Mobil Jet 2 oil and due to oil chemicals contaminated which contributed on changing the oil characteristic. This contributed into unusual coking inside rear sump with some coke parts above 11mm. This may have caused the malfunctioning of the oil lubrication unit which led into, causing scavenged oil flooding in the rear sump, leading to external oil leakage through the air vent system.

3.3. Probable Cause/s:

3.3.1 The amount of coke entered lubrication unit and generated lubrication unit (LUB Unit) malfunctioning, (LUB Unit was not turning freely, found with debris and this caused malfunctioning). This may have blocked oil flows, could have led to oil scavenge system clogging and flooding, generating quick and massive overfill of local sumps, leading to external leakages through the air vents. This led to the oil evacuating through rear sump oil drain and flame arrestor. The rear sump seal wear lead to the oil evacuation into the exhaust plug and the oil located in the plug/ exhaust created the smoke /fire seen during the event.

3.4 Contributing factors:

3.4.1 The foreign substance most probably like skydrol in the oil system contaminated the oil and caused the oil system malfunctioning and unusual coking and clogging.

3.4.2 The presence of hydraulic oil (skydrol) on the external drive shaft of the EDP, could have entered the AGB resulting in engine number 2 oil system contamination and malfunctioning.

3.4.3 The Oil Lubrication Unit, may have malfunctioned due to debris found inside the Unit, causing scavenged oil flooding in the rear sump, leading to oil leakage. The unit was not freely turning by hand.

4. Safety Recommendations

4.1 General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report. The OTSB expects that all safety issues identified by the investigation are addressed by the receiving States and organizations.

4.1.1 Due to the fact that this occurrence has happened before according to the manufacturer, and considering that this occurrence almost happened in flight where engine number 2 was undoubtedly going to be switched off. In the interest of safety OTSB recommend the following:

4.1.1.1 The operator to conduct detailed inspection on the 737-800 fleet on the oil supply tube 4 welding points for security and conditions.

4.1.1.2 The operator to conduct detailed inspection on the 737-800 fleet EDP for possible leakage into the AGB, this follows abnormal debris found in the EDP external drive shaft which resemble the properties of hydraulic oil (skydrol).

5. Appendices:

5.1 Appendix A: Significant Comment from Bureau d'enquêtes et d'analyses pour la sécurité de l'aviation civile (BEA) France.

Appendix A

Significant Comment from BEA:

In line with ICAO Annex 13 standard 6.3, OTSB here by append the comments received from BEA where there was disagreement between the parties.

Below is technical comments as received from BEA,

Significant comment B – Theme B: Skydrol (hydraulic fluid)

As described in CFM document "Root cause analysis / Probable scenario" dated 11 June 2023, the probability that Skydrol played a role in this event was determined to be extremely low. As a result, scenarios with Skydrol involved were discarded (see page 18 of the CFM document).

The two scenarios involving the Skydrol that were considered were:

- **Scenario Skydrol #1**: A leak of Skydrol due to a malfunction of the EDP, then the Skydrol polluted the oil of the engine. This scenario was classified as highly unlikely due the fact that no fault has been found during the examinations of the EDP by Parker.

- **Scenario Skydrol #2**: Addition of Skydrol by error in the oil tank. This after several flight could have damaged the elastomere seals which could have led to oil leakage and then fire. This scenario was classified as highly unlikely, due to the following refuting facts:

o The phosphorus content measured in the oil was not high enough. In previous cases of oil pollution by Skydrol, the content of phosphorus was much higher.

o No fault found during the examination of the EDP by Parker.

o The DFDR analysis showed that there was no drop in hydraulic fluid pressure or quantity during the event.

o Skydrol is not known to create big coke.

In addition, abnormal coking debris were found at bearing #5 level in inner ring lubrication groove, but no damage to the bearing itself was identified during examination.

This level of coking (debris size up to 11 mm and debris present at multiple locations) was never encountered before this event in all CFM56-7B fleet. Therefore, from CFM experience, it is not correct to say that this type of occurrence happened before.

Therefore, the BEA disagrees with the following findings, contributive factors and safety recommendations:

3.2.25 Oil sampling chemical analysis confirmed that the oil tested was not a typical "Mobil jet 2 ", unusual aspect, unusual odor and contained foreign product origin not identified, and the properties of skydrol are resembled on the oil taken from engine number 2.

3.2.26 The manufacturer established that Skydrol is known as very damaging for seals and the oil sampling chemical analysis confirmed non-common (Skydrol) Mobil Jet 2 oil. This unusual oil with abnormal presence of solvent could have led to create abnormal amount of coke found in the engine. This is evidenced by seals damaged, the coking clearly articulate damaged seals in the oil system and the number #5 bearing.

3.4 Contributing factors:

3.4.1 The foreign substance most probably like skydrol in the oil system contaminated the oil and caused the oil system malfunctioning and unusual coking and clogging.

3.4.2 The presence of hydraulic oil (skydrol) on the external drive shaft of the EDP, could have entered the AGB resulting in engine number 2 oil system contamination and malfunctioning.

4.1 Safety recommendation

4.1.1 Due to the fact that this occurrence has happened before according to the manufacturer, and considering that this occurrence almost happened in flight where engine number 2 was undoubtedly inevitably going to be switched off. In the interest of safety OTSB recommend the following:

4.1.1.1The operator to conduct detailed inspection on the 737-800 fleet on the oil supply tube 4 welding points for security and conditions.

4.1.1.2The operator to conduct detailed inspection on the 737-800 fleet EDP for possible leakage into the AGB, this follows abnormal debris found in the EDP external drive shaft which resemble the properties of skydrol.

BEA most likely scenario

Based on all information collected during the investigation (parts examination, oil chemical analysis, maintenance history that CFM and BEA became aware of during the investigation), the most likely scenario supported by the BEA and CFM is recalled below.

Based on the examinations performed by CFM, main findings on engine #2 are:

- Oil sampling from oil tank analyses confirm that the oil is not typical “Mobil jet 2”.

- Oil has been contaminated by a product containing polysiloxane, 2-pentanone,4-hydroxy-4-methyl and tributylphosphate. The origin of the pollution has not been determined.

- Large amount of abnormal coking (big pieces up to 11 mm) has been found in/on numerous parts

CFM determined that the most likely scenario was the following: the exhaust fire was caused by an oil leakage, the latter caused by an abnormal amount of coking itself due to the polluted oil. Rear sump seal wear could have contributed to oil evacuation.

Indeed, the unusual oil with abnormal presence of solvent could have led to create abnormal amount of coke found in the engine. This abnormal coking may have blocked oil flows and could have led to oil scavenge system clogging, generating quick and massive overfill of local sumps, leading to external leakages. Oil consumption (oil tank empty) seems consistent with this hypothesis.

Oil was evacuated in the plug / exhaust and created the smoke / fire seen during the event. Fire was facilitated by abnormal oil composition because the pollutants found in the oil are known to be excellent fuels.

Other scenarios were considered during the investigation but determined as less likely or unlikely with refuting arguments listed in CFM document titled “Root cause analysis / Probable scenario.