FINAL INVESTIGATION REPORT ON SERIOUS INCIDENT TO AIR INDIA LTD. AIRBUS A-320 AIRCRAFT VT-ESI AT COCHIN ON 21.08.2014

COMMITTEE OF INQUIRY VT-ESI

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Foreword

In accordance with Annex 13 to the Convention on International Civil Aviation Organization (ICAO) and Rule 03 of Aircraft (Investigation of Accidents and Incidents), Rules 2012, the sole objective of the investigation of an accident/incident shall be the prevention of accidents/incidents and not apportion blame or liability.

This document has been prepared based upon the evidences collected during the investigation, opinion obtained from the experts and laboratory examination of various components. Consequently, the use of this report for any purpose other than for the prevention of future accidents/incidents could lead to erroneous interpretations.

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1.	Aircraft	Type	Airbus A-320
		Nationality	Indian
		Registration	VT-ESI
2.	Owner & Operator		Air India Ltd
3.	Pilot – in –Command		ATPL Holder
	Extent of Injuries		None
4.	Co-pilot		ATPL Holder
	Extent of Injuries		None
5.	No. of Passengers on board		169 (Pax) + 04 (Cabin Crew)
	Extent of Injuries		None
6.	Date & Time of Incident		21.08.2014; 15:36 UTC
7.	Place of incident		Cochin
8.	Last point of Departure		Cochin
9.	Intended landing place		Delhi
10.	Type of Operation		Scheduled Passenger Flight
11.	Phase of operation		Take-off Climb
12.	Type of Incident		In-Flight Shut Down (Uncontained Engine Failure)

(All timings in the report are in UTC unless otherwise specified)

SYNOPSIS

Air India Airbus 320 aircraft VT-ESI flight AI 047 (Cochin - Delhi) was involved in a serious incident of in-flight shutdown due uncontained failure of engine # 2 on 21-08-2014 at Cochin. The aircraft was under the command of a pilot an ATPL holder on type & Co-pilot also an ATPL holder. There were 04 cabin crew and 169 passengers on board the aircraft. There was no injury to any person on board the aircraft.

The aircraft was operating flight AI047 for Delhi and was cleared for take-off runway 27. The aircraft took-off at around 1535 UTC from runway 27. Soon after take-off while climbing the pilot heard a loud bang sound which was followed by engine # 2 fire warning. The pilot carried out ECAM actions and declared MAY DAY. The pilot informed ATC about the engine # 2 on fire and requested for priority landing runway 27. The aircraft was then cleared for landing runway 27. The pilot carried out overweight landing checklist and the aircraft then landed on runway 27 uneventfully. The aircraft was then parked at bay 11 and passengers were disembarked normally. Thereafter walk around inspection was carried out and it was observed that there were metal debris on engine #2 exhaust. The C-duct cowl was found punctured. There was no injury to any of the occupant on board the aircraft. The fire was confined to within engine only.

Ministry of Civil Aviation vide order No. AV 15029/118/2015-DG constituted a committee of inquiry to investigate the cause of the serious incident under Rule 11 (1) of Aircraft (Investigation of Accidents and Incidents), Rules 2012.

1. FACTUAL INFORMATION.

1.1 History of flight

Air India Airbus 320 aircraft VT-ESI was scheduled to operate flight AI 047 from Cochin to Delhi on 21.08.2014 under the command of pilot, an ATPL holder, qualified on type with Co-pilot also an ATPL holder, qualified on type. There were 04 cabin crew and 169 passengers on board the aircraft.

Prior to the incident flight the aircraft VT-ESI had operated flight AI 934 from Sharjah to Cochin. The aircraft landed at Cochin at about 1330 UTC. The flight was uneventful. There was no snag reported by the pilot after the flight. The aircraft was parked at stand # 4. Thereafter the aircraft was scheduled to operate flight AI 047 to Delhi. The ATC cleared the aircraft for take-off runway 27 and informed winds as 140^{o}/05 Kts. The aircraft took-off at 1535 UTC from runway 27. After about 01 minute 05 seconds of take-off a loud bang sound was heard by the cockpit crew which was followed by engine fire warning in cockpit. The co-pilot informs the PIC about engine # 2 on fire and both the crew then carried out ECAM actions. On being contacted by ATC for further clearance, the pilot declares MAY DAY due "engine # 2 fire" and informs that they are maintaining runway heading. The same was acknowledged by ATC and asked pilot about runway preference. The pilot informed ATC that they will prefer runway 27 for landing and the same was cleared by the ATC. Meanwhile cabin crew also informs pilot that the passengers saw fire in engine # 2 and they heard a loud bang sound from their respective position in cabin. The pilot informs cabin crew to standby for further instructions. Cockpit crew then carried out approach checklist. The pilot thereafter informs ATC that they are cancelling MAY DAY call and changing to PAN PAN as there is no fire now. The pilot then informs cabin crew that they have lost one engine i.e. engine #2 and landing back to Cochin in 05 minutes and advised cabin crew to prepare the cabin for landing. Cockpit crew then carried out overweight landing checklist and carried out uneventful overweight landing on runway 27. The ATC then cleared the aircraft for parking bay 11 via taxiway 'C' & 'B'. The pilot requested ATC for guidance to the bay and someone to look at the engine for fire. Pilot then requests ATC to inform the company for GPU (Ground Power Unit) and electrical. After reaching stand, the ATC confirmed with pilot if all operations are normal for which the pilot replied back as affirm and when asked for further assistance required, the pilot replied back as negative. The pilot then briefed passengers about the situation and thereafter confirms with cabin crew that there is no fire. After about 08

minutes of the aircraft reaching the bay, the step ladder was attached to aircraft to disembark the passengers. The passengers were disembarked normally.

Thereafter walk around inspection was carried out and it was observed that there were metal debris on engine #2 exhaust. The C-duct cowl was found breached (punctured). There was no injury to any of the occupant on board the aircraft. The fire was confined to within engine only.

1.2 Injuries to persons.

Injuries	Crew	Passengers	Others
Fatal	NIL	NIL	NIL
Serious	NIL	NIL	NIL
~~Minor~~/None	02+04	169	

1.3 Damage to aircraft.

The aircraft damage was confined to engine # 2. No damage was observed in the surrounding area of the engine (wing lower surface, flap, RH landing gear etc.). Following main damages were observed on the engine:

External Damages

1. Outboard C Duct
   - Outer Barrel found ruptured approximately 12 inches.
   - Inner Barrel Burn mark & rupture observed
2. Inner C Duct
   - Inner Barrel found burnt at 6 O'Clock position.
3. LPT (Low Pressure Turbine) stage 4 blades
   - more than 20% of blades found damaged
   - Most of the stage 4 NGV's (Nozzle Guide Vanes) found damaged.
4. Overheating was observed on all the latches.

Damage to C Ducts

Damages Observed after opening both the C Ducts

5. The turbine cooling air feed tube at 4 O' Clock position found ruptured.
6. HPT (High Pressure Turbine) case between 1 & 3 O' Clock position found ruptured open.
7. HPT case opened up and ruptured from 6 to 9 O'clock position shearing the 27 bolts on front side and 18 on rear side exposing entire HP turbine area.

The High Pressure Turbine case breached

Engine Rear View

8. All the turbine blades of stage 1 & 2 and stage 2 NGV's found missing.
9. Turbine cooling air feed tube at 7 O'clock position found damaged.
10. HPT ACC duct found ruptured.
11. Lot of metal debris found stuck at different locations of the engine.
12. No. 2 shaft seized.
13. The No.1 shaft was found stuck and found difficult to rotate.
14. Fire bottles were found discharged.

1.4 Other damage: Nil

1.5 Personnel information:

1.5.1 Pilot – in – Command:

AGE	48 Years
License	ATPL
Date of License Issue and Valid up to	27/11/13 and 26/11/2015
Category	Aeroplane

Class	Multi Engine
Endorsements as PIC	C-152/PA-23,C-90, A320/A319/A321
Date of Joining Company	06/06/2001
Date of Endorsement as PIC on type	27/02/2006
Instrument Rating	06/11/2013
Date of RTR Issue and Valid up to	25/01/2013 & lifetime validity
Date of FRTOL issue & validity	24/10/2011 & valid upto 23/10/2016
Date of Med. Exam & validity	05/04/2014 & valid upto 04/04/2015
Date of Route Check	01/12/13 to 02/12/13
Date of Last Proficiency Check	25/04/2014
Date of English language Proficiency & Valid up to	24/01/2011 and Lifetime Validity
Date of last CRM	08/11/2013
Date of Dangerous Goods Awareness Training	11/11/2013
Date of last Refresher/Simulator	25/11/2013
Simulator Training for Critical Emergencies	25/04/2014
Total flying experience	10000 Hrs. (approx.)
Total Experience on type	7500 Hrs. (approx.)
Total Experience as PIC on type	4500 Hrs. (approx.)
Last flown on type	08/08/2014
Total flying experience during last 01 Year	596:31 Hrs
Total flying experience during last 180 days	380:56 Hrs
Total flying experience during last 90 days	203:05 Hrs
Total flying experience during last 30 days	46:00 Hrs
Total flying experience during last 07 Days	17:40 Hrs
Total flying experience during last 24 Hours	05:15 Hrs

1.5.2 Co-Pilot:

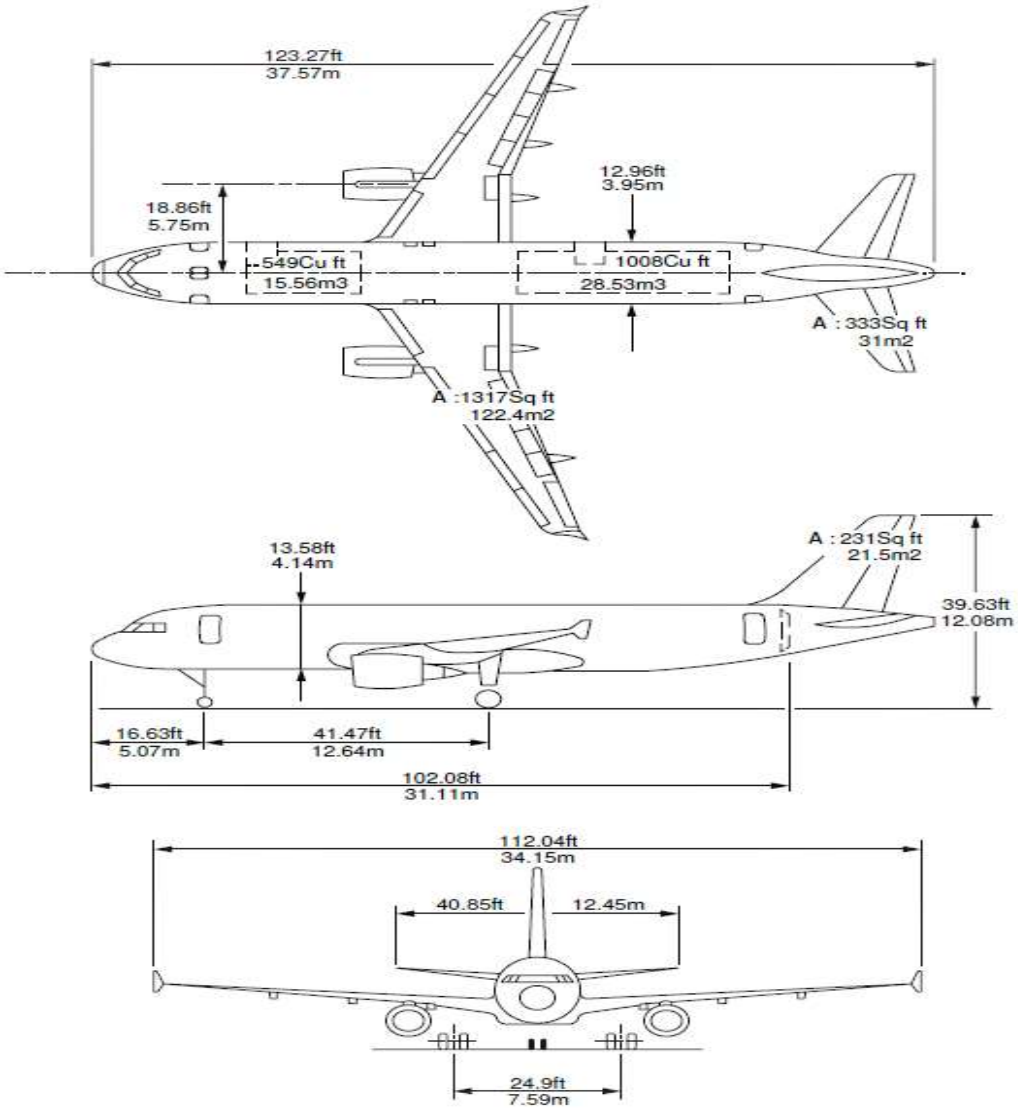
AGE	34 years
License	ATPL
Date of License Issue and Valid up to	20/06/2014 & Valid upto 19/06/2016
Category	Aeroplane
Class	Multi Engine
Endorsements as PIC	King Air C-90A/TB-20
Date of Joining Company	04/10/2012
Date of Endorsement as PIC on type	Co-pilot
Instrument Rating	21/09/2014
Date of RTR Issue and Valid up to	30/01/2000 and Lifetime Validity
Date of FRTOL issue & validity	09/06/2011 & Valid upto 08/06/2016
Date of Med. Exam & validity	24/06/2014 & Valid upto 23/06/2015
Date of Route Check	23/09/2013
Date of Last Proficiency Check	03/03/2014
Date of English language Proficiency & Valid up to	27/11/2013 & Valid upto 26/11/2019
Date of last CRM	06/06/2014
Date of last Monsoon training	June 2014
Date of Dangerous Goods Awareness Training	10/06/2013
Date of last Refresher/Simulator	06/06/2014
Simulator Training for Critical Emergencies	30/03/2014
Total flying experience	3564 Hrs. (approx.)
Total Experience on type	3314 Hrs. (approx.)
Total Experience as PIC on type	Co-Pilot
Last flown on type	13/08/2014
Total flying experience during last 01 Year	748:32 Hrs
Total flying experience during last 180 days	399:53 Hrs
Total flying experience during last 90 days	192:47 Hrs
Total flying experience during last 30 days	69:55 Hrs
Total flying experience during last 07 Days	25:40 Hrs
Total flying experience during last 24 Hours	05:15 Hrs

1.6 Aircraft Information

1.6.1 Airbus A320 Information

The Airbus A320 aircraft VT-ESI is a subsonic, medium-range, Civil Transport Aircraft. The aircraft has two high bypass turbofan engines manufactured by International Aero Engines AG, USA. The aircraft is designed for operation with two pilots and has passenger seating capacity of 168.

The aircraft is certified in normal (Passenger) category, for day and night operation under VFR & IFR. The maximum operating altitude is 39,100 feet and maximum Take-off weight is 73.5 tonnes. The maximum Landing weight is 64.5 tonnes. The aircraft length is 37.57 meters, wingspan is 34.15 meters and height of this aircraft is 12.08 meters. The distance between main wheel centers is 7.59 meters.



3 View Diagram of Airbus A 320 aircraft

A320 aircraft fuselage is a semi monocoque structure having five main section. The structure is primarily made of chemically milled skin panels attached with frames and stringers made of sheet metal. The fuselage has got total 80 No. of frames in which frame No. 1 is forward pressure bulkhead and frame No. 70 is rear pressure bulkhead. Frame No. 70 to 80 is unpressurised zone. In general standard frames have a common Z-shaped section made of formed sheet which provides continuous structural integrity to stringers and skin panels through sheet metal cleats.

Two wings on each side of the fuselage is attached through a center wing box at the middle of the fuselage. Wings are joined with the fuselage by means of Cruciform fittings at upper end and Triform fittings at lower end between center and outer wing box. Wing box are generally box structure having front and rear spar with number of ribs in between along each outer wing and the whole things are covered with skin panels. Wings carry the landing gear, engines and flight control devices. Wing also carries the fuel inside the box cavity.

Primary control surfaces are aileron on wings, elevator on trailing edge (T.E) horizontal stabilizer and rudder on trailing edge vertical stabilizer. Secondary control surfaces are flaps, slats and spoilers. All control surfaces are electrically control and hydraulically operated. Control surfaces are generally having box structure made of Carbon Fiber Reinforced Plastics (CFRP).

A320 aircraft VT-ESI is fitted with V 2500 – A1 engines manufactured by International Aero Engines (IAE).

The V 2500 – A1 engine is a dual rotor are variable stator high bypass turbofan engine. The engine is made of four primary modules.

The fan & LP (Low Pressure) compressor are supported by the fan frame which host forward engine mount. Five stages LP Turbine drives the forward fan and the four-stage booster compressor. LP turbine is supported by TRF which host rear engine mount. The high pressure rotor is made of ten stage HP compressor driven by two stage HP turbine. The annular combustion chamber is located between HPC & HPT and is equipped with ports for 20 fuel nozzles and ignitor plugs. The accessory gear box is located at the bottom of the fan case and is driven by HP rotor through transfer gear box. The fuel pump, oil pump, hydraulic pump and other accessories are driven by the gear box.

1.6.2 General Information

Airbus A320 aircraft VT-ESI (MSN 0486) was manufactured in the year 1994. The aircraft is registered under the ownership of M/s. AIR INDIA LTD. The Certificate of registration No. 2618/3 under category 'A' was issued on 24.02.2011. As on 21.08.2014, the aircraft VT-ESI had logged 55849: 27 airframe hours & 34460 cycles since new and 4608:28 hours were logged since last C of A. Airworthiness Review Certificate (ARC) was initially issued on 10.04.2013 and was later extended on 09.04.2014 which was valid up to 10.09.2014.

The aircraft was holding a valid Certificate of Airworthiness Number 2106 issued under normal category sub-division passenger/ Mail / Goods by DGCA on 10.09.2013 and was valid till 10.09.2014. The aircraft is holding aero mobile License No. A-014/048-RLO/NR and was valid on the day of incident. This aircraft was operated under Scheduled Operator's permit No. S-09 and is valid till 30.06.2018. Prior to flight the aircraft was holding a valid Certificate of Flight Release.

The aircraft was last weighed on 16.07.2014 at Delhi, weight schedule was prepared and duly approved by the office of DAW, Delhi. As per the approved weight schedule the Empty Weight of the aircraft is 39909.26 kgs. Maximum usable fuel quantity is 18730 kgs. Maximum payload with full fuel tanks is 10681 kgs. Empty weight CG is 18.76 meters aft of datum. The next weighing was due on 15.07.2019.

Computerized Load & Trim sheet was made for VT-ESI operating flight AI-047**.** The Details of basic weight schedule were as follows:-

Weight	**Maximum Permissible (Kg)**	**Actual Weight (Kg)**
Take-off weight	73500	72800
Landing weight	64500	71800

Dry Operating weight for the flight was 44089 Kgs. The c.g of the aircraft was within the operating limits.

The aircraft and Engines were being maintained under continuous maintenance as per maintenance programme consisting of calendar period and flying Hours/Cycles based maintenance approved by O/o DGCA, Delhi dated 06.09.2013. The last Major Inspection '4A check' inspection was carried out at 55397:46 hours / 34156 cycles on 01.07.2014.

Subsequently all lower inspections (Pre-flight checks, Service Checks, Weekly Checks) were carried out as and when due before the incident.

Engine	Serial No.	Time Since New (TSN)	Cycle Since New (CSN)
#1	V0299	42828 hrs	28189
#2	V0118	41505 hrs	27772

The last engine # 2 overhaul was carried out on 31.03.2012 at 33341:37 engine hours. The engine had logged 8163:23 Hours since last overhaul. The engine # 2 was released from the shop on 31.03.2012. On 31.03.2012 the engine V0118 was released from shop and installed on VT-EPH on 03.04.2012.

On 13.09.2012 the engine was removed from VT-EPH and installed onto VT-ESC. On 11.05.2014 the engine was removed from VT-ESC due "repeated high EGT" warning and was later installed onto VT-ESI (#2 position) on 18.05.2014.

The last fuel microbiological test was done on 24.02.2014 at Delhi by Air India Ltd. During 2A check and the colony count was within acceptable limits.

1.6.3 Lapping Procedure of Bearing Front Seal Seat (Seal Plate)

Long Soak Cleaning: The One Step Alkaline rust remover procedure.

- Aqueous Degrease the component.
- Soak the component in one of the alkaline rust remover solutions at the applicable temperature for 30 to 60 minutes.
  - The operating temperature range of the solution is 88-93^{o}C.
- Flush the component with cold water.
  - Remove the component from the alkali tank. Use a cold water spray to flush the alkaline solution from the component. Do this over the tank.
  - Pressure spray rinse to remove scale, corrosion, and oxides & put the component fully in a cold water tank.
  - Remove the component from the cold water tank and then use cold water spray to flush the component again.
- Do an inspection of the component to make sure that component is clean.
- Flash dry the component with hot water.

- Put the component fully in to hot water at a temperature of 66-93^{o}C until the temperature of the component is at the water temperature. Remove the component from the hot water & flash dry.

➢ Apply the corrosion inhibitor, as necessary to prevent corrosion of component.

Bearing front seal seat- Inspection

➢ Ensure that the component is cleaned before inspection.
➢ Examine component for cracks (Fluorescent Penetrant Inspection) as per Standard Practices Manual (SPM) Task. Accept or repair if required.
➢ Examine the seal seat for chipped hardface. Accept or repair if required.
➢ Examine the seal seat for hardface that is pitted, scratched or gone. Repair if required. Accept or repair if required.
➢ Examine the seal seat for nicks, dents, scratches & pits on areas other than the hardface. Accept or repair if required.
➢ Pilot inside diameter. Accept or repair if required.
➢ Axial dimension. Accept or repair if required.
➢ Measure the thickness of the hardface. Accept or repair if required.
➢ Preserve the part as per SPM Task.

Bearing Front seal seat (Seal plate) - Lap the seat.

➢ The lapping procedure
- The basic lapping equipment is available from one of the sources that follow: Lapmaste, Supfina, peter Walters of America or their equivalent or their equivalent. The machine must give the specified surface finish and must be satisfactory for used with diamond lapping compounds.
- Use a lap plate made of gray cast-iron or Meehanite - GA50. The lap surface must contain serrations or grooves, with a 90^{O} shape.
- The diamond lapping compound must be fully included in the lap. Push the CoMat 05-118 DIAMOND LAPPING COMPOUND, SLURRY, SPRAY, OR SUSPENSION, or an equivalent, into the lap: by lapping with a hard steel, or linde flame plated disk which has a weight of approximately 20 psi. The disk must be put in the conditioning rings, the same as the part.
- Apply a thin coating of CoMat 10-061 STODDARD SOLVENT to the lap. Run the lap almost dry, until its surface looks iridescent. The lap must have a matt

finish and not look wet, as when too much solvent is used. The lap surface must be very dark, when fully charged.

- Lap the part at approximately 1 psi (6.9 kPa) and at a rate of 100 to 300 surface feet a minute (31 to 91 surface meters a minute); as measured at the average diameter of the area to be lapped.
- It is only necessary to charge the lap again, when the lap time has increased by more than 50 percent; of that used for a fully charged lap. When the correct load is applied to the part, the necessary finish will be completed in less than 25 minutes; if all the operational conditions are satisfactory.
- Examine the lapped surface.
- Clean the parts as per SPM task. Parts put into storage before they are cleaned must be kept wet with CoMat 10-061 STODDARD SOLVENT so that the lapping compound will not become dry.

- Special procedure used to clean the seal plate and spacer (As per Long Soak Cleaning SPM Task).
- Examine the Seal Seat after Lap repair
  - Examine the front seal seat for the surface finish, flatness and the axial dimensions of the seal seat face.

1.6.4 Oil Consumption History for V0118 Engine.

As mentioned earlier the Engine was installed on 3 different airframes, oil consumption trend was reviewed from April 2012 to August 2014 which reveled following:

- From February 2013 to August 2014 oil consumption indicates upward trend.
- Acceptable & stable trend was observed between April 2012 and February 2013.
- Maximum consumption observed was 0.258 qt/hr which is less than 0.30 qt/hr threshold.
- No reported evidence of external oil loss (TEC wetting, etc.)

Oil Consumption showed increasing trend but was within limits.

1.7 Meteorological information:

The weather at Cochin during the time of incident was:

Time in UTC	Wind Direct-ion	Speed (K)	Vis (m)	Weather	Clouds	Temp (°C)	Dew Point (^{o}C)	QFE hPa	QNH hPa	Trend
1500	100	06	4000	Hz	SCT 450 m	26	24	1006	1007	NOSIG
1530	120	05	4000	Hz	SCT 450 m	25	24	1006	1007	NOSIG

1.8 Aids to navigation:

Cochin airport is equipped with VOR, DME, NDB, and ASDE. PAPI & ILS Cat- II is installed on Runway 27 & 09.

1.9 Communications:

There was always two way communications between the aircraft and the ATC.

1.10 Aerodrome information.

Cochin Airport is an international airport located in Cochin, Kerala. The IATA location Identifier code is COK and ICAO location Indicator code is VOCI. The airport is operated by Cochin International Airport Limited (CIAL). The elevation AMSL of airport is 9.14 m (30 ft). The airport is licensed by DGCA No. AL/Public /005 for both IFR and VFR traffic. The airport reference code is 4E.

The airport has one runway. The Runway specification is as under:

- Orientation: 27/09
- Runway Length: 3400 m
- Runway Width: 45 m
- Runway Shoulder Width: 7.5 m (on both sides)
- Strength: PCN 60
- Parallel Taxiway: 3400 m

The Airport Reference point is 10°09'13.8"N 072°51'58"E. Runway has marking for Designation, THR, TDZ, Centreline, Rwy Edge and is lighted for THR, Edge, End, TDZ, and Centreline. The Airport Rescue and Fire Fighting Services is Category ‘9’ (Nine).

1.11 Flight recorders.

The aircraft was fitted with Solid State CVR & DFDR manufactured by L-3 Communications, USA. The CVR & DFDR were removed from the aircraft after the incident & data from CVR & DFDR were downloaded and analysed.

CVR

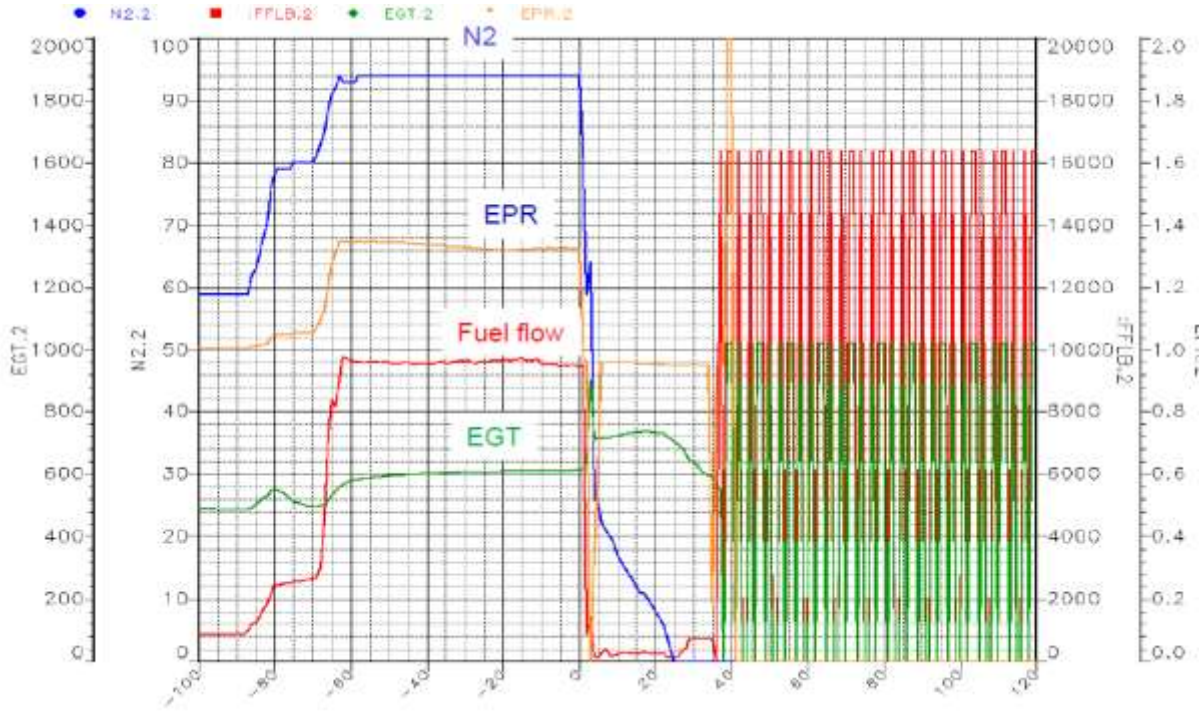
A total of last 02:03:23 hrs audio data was available in CVR. Salient observations made from the CVR tape transcript are given below:

- The ATC cleared aircraft for take-off runway 27 and informed winds as 140^{o}/05 Kts.
- Soon after about 01 minute 05 seconds of take-off a loud bang sound was heard followed by Engine fire alarm sound in cockpit.
- The co-pilot immediately told PIC that "Engine # 2 on fire".
- The PIC then calls for ECAM actions and the same was carried out.
- On being contacted by ATC for further clearance, the pilot declares MAY DAY, informs ATC about "engine # 2 fire" and maintaining runway heading.
- The ATC confirms the MAY DAY call and asks pilot for runway preference.
- The pilot informed ATC that they will prefer runway 27 for landing.
- The cabin crew then informs cockpit crew that they heard a loud bang sound.
- The pilot informs cabin crew to standby for further instructions.
- ATC again confirm with pilot about reason for MAY DAY and the same was acknowledged by the pilot.
- Cabin crew again informs pilot that the passengers saw fire in engine # 2 and they heard a loud bang sound from their respective position in cabin.
- Cockpit crew then carried out approach checklist.
- The pilot then informs ATC they are cancelling MAY DAY call and changing to PAN PAN as there is no fire.
- The pilot then informs cabin crew that they have lost one engine i.e. engine #2 and landing back to Cochin. He further advised cabin crew if the cabin is ready for landing.
- Cockpit crew then carried out overweight landing checklist.
- The aircraft touched down (landed back) after about 13 minutes post engine fire.
- The ATC then clears the aircraft for parking bay 11 via taxiway 'C' & 'B'.

- The pilot requests ATC for guidance to the bay and someone to look at the engine and confirms it's the right engine i.e. #2 engine.
- Pilot then requests ATC to inform to the company for GPU and electrical.
- ATC confirms for all operations normal, and ask for any further assistance for which the pilot replied back as negative.
- The pilot then briefs passengers about the situation and thereafter confirms with cabin crew that there is no fire.
- After about 08 minutes of the aircraft reaching the bay, the step ladder was attached to aircraft to disembark the passengers.
- Thereafter the pilot was heard discussing about engine C-duct breach with one of the ground personal.

DFDR analysis was carried out and following observations were made:-

- The aircraft took-off at 15:35:49 UTC heading 270.
- After about 65 seconds of take-off i.e. 15:36:54 UTC, the Engine # 2 N2 decreases from 93 to 78, probably the time of incident.
- In another 30 seconds the Engine # 2 TLA (Thrust Lever Angle) was changed from 34 to 0.



Engine # 2 parameters vs time with the time of incident taken at t=o.

- Engine #2 EGT over limit sustained for approximately 30 seconds ranging from 637^{o}C to a maximum of 735^{o}C.
- The engine # 2 fire warning sustained for about 131 seconds.
- High engine # 2 N2 vibrations for 04 seconds.

1.12 Wreckage and impact information.

The aircraft sustained damages to the core engine and the engine C-duct.

1.13 Medical and pathological Information:

Both the Cockpit crew had undergone pre-flight medicals / Breath analyzer test and were found to be negative.

1.14 Fire:

The fire was confined to engine # 2 only.

1.15 Survival aspects:

The incident was survivable.

1.16 Tests and research:

1.16.1 Engine Strip Examination

The involved engine ESN V0118 was brought to Delhi and strip examined at JEOC, Air India by NTSB (Technical experts from IAE) in the presence of Committee of Inquiry and representatives from Airbus Industries. The engine was stripped and some of the damaged engine parts were transported to NTSB (IAE/ Prat & Whitney) for further detailed examination.

Observations made during the strip examination of the damaged engine are as follows:

General:

All location references are aft looking forward (ALF) and the numbering convention is by analog clock position.

The engine data identified the engine as V0118. The low pressure compressor (LPC) fan case module was verified as serial number 320118. The electronic engine control (EEC) was verified as serial number 25/29/31/32. The high pressure turbine (HPT) module was verified as serial number 450087. The low pressure turbine (LPT) module serial number was unable to be verified as it was illegible due to significant oxidation on the data plate.

The engine was found with the Common Nozzle Assembly (CNA) attached. There were indication of fire damage at the 12'O clock position on the CNA, and the damage extended axially from where the CNA attaches to the engine, to the aft most point on the CNA, and on the external surface at 12'O clock position where the CNA mates with the aft –most portion of the engine pylon. The internal damage consisted of a charred and sooted surface measuring approximately 12 inches by 12 inches and the external surface was lightly covered in black soot and discoloration in an area measuring 12 inches wide by 16 inches long.

Sooting was present at the 12'O clock location on the LPT case, and on the main turbine case cooling (TCC) supply line.

All accessory components were found still installed on the engine.

There was oil present in the main engine oil tank, but a quantity was not measured. The integrated drive generator (IDG) oil level was found to be in the green band of the sight glass indicator.

All engine mounts were found still installed and intact with no obvious damage observed. The pins located on the aft mount on the LPT were difficult to remove, had some oxidation present and exhibited radial scoring along their load bearing surface upon removal.

Fan / Low Pressure Compressor Module:

The fan and spinner were intact with 22 blades present and numbered. The fan was able to rotate freely, and also rotated the LPT. Fan blade#1 had a cropped area at the leading edge of the tip. Fan blade#21 had a cropped area at the tailing edge of the tip. The fan rub strip located on the inner diameter (I.D.) of the fan case in the plane of fan rotation had a rub 360^{o} around the circumferences, with heavier rub marks at the 2'O clock and 10'O clock locations. All external hardware was present on the outside of the fan case with no damage noted. The inlet guide vanes for the low pressure compressor (LPC) were intact and present with no damage noted. The fan exit guide vanes (FEGV) were intact and present with no damage noted.

The forward bearing compartment (FBC) which is comprised of the #1, #2 and #3 bearing compartments and associated hardware was not examined.

High Pressure Compressor Module:

The high pressure compressor (HPC) was intact with no damage noted. Powder-like residue from the fire extinguisher agent, which was coloured white, covered nearly the entire HPC assembly the Variable Guide Vanes (VGV) on the HPC were positioned in a near fully open position. All visible VSV hardware was intact and undamaged. All the VSV hardware was intact and undamaged. The I.D. of the HPC shaft showed evidence of a rub from contact with the LPT shaft. The area of the rub covered approximately 180 degrees of the shaft I.D. and was 7 inches long axially towards the front of the engine.

The HPC was examined by borescope and showed indications of a rub on the 3rd and 4th stages. A dust- like material was present throughout this location in the HPC. This dust-like material resembled liberated abraidable coating material from the HPC casing. There was no obvious wetting towards or presence of fluids in, on, or around the 3rd and 4th HPC stages.

Diffuser Module:

The diffuser case was intact with no external damage noted. Powder-like residue from the fire extinguishing agent, which was coloured white, covered the external surface and hardware of the diffuser case in random locations. The diffuser case was examined via borescope. Domestic object debris (DOD) was found inside the diffuser case, within the combustor liners at the 2'O clock position. The 1st stage Nozzle Guide Vanes (NGV) were eroded at both the leading and trailing edges, with impact damage at location at 10'O clock and 2'O clock, DOD was found speared and lodged through the 1st stage NGV's in a forward direction, at the 3'O clock position.

Coked oil was found on the HPC shaft at the interface of the carbon seal and the shaft circumference on the aft side of the #4 bearing compartment.

High pressure Turbine Module:

The HPT Module had four locations where the case was damaged in a manner consistent with material having penetrated through the case. These four locations are referred to as un-containment location. Two un-containment locations were at 11'O clock in the plane of the 2nd stage NGVs. Each of these two holes were approximately 2 inches long in the

circumferential direction and 1inch long in axial direction. Another un-containment location consisted of the HPT case being torn open aft of M-flange and forward of N-flange from approximately the 9'O clock to the 6'O clock position. M-flange was separated at the 6'O clock position, and N-flange was separated at the 7'O clock position. Of the 100 nuts and bolts that should be present at M-flange, 28 were missing. Of the 100 nuts and bolts that should be present at N-flange, 20 were missing.

The tear in the HPT case originated at approximately 9'O clock position, just forward of N-flange, and extended circumferentially towards approximately 6'O clock position. The widest point of the tear was approximately 2 inches. At 6'O clock position the tear was nearly the entire width of the HPT case, approximately 6 inches the tear extended past the fractured M-flange location at 6 inches, and transitioned into an approximately 1 inch wide elongated and non-uniform hole, which terminated at approximately 5'O clock position, the remaining un-containment location was present between1'O clock and 3'O clock. It was an elongated, non-uniform hole that was 2 inch wide at its widest location and 0.5 inches wide at its narrowest width axially.

A quantity of ten 2nd stage Blade Outer Air Seals (BOAS) were found intact and in place and showed impact damage at the 1'O clock to 4'O clock positions. The rest of the BOAS were unable to be identified or located at disassembly.

A quantity of five 2nd stage outer diameter (O.D.) vane platforms, were in place and significantly damaged with approximately 90% of total material missing. A quantity of two 2nd stage O.D. vane platforms were dislodged and located against the case between 1'O clock and 3'O clock position, just forward of the 2nd stage BOAS, which were in place.

A quantity of ten 1st stage BOAS supports were found intact and in place beginning at the 12'O clock position and progressing counter-clockwise (CCW) towards the 6'O clock location. The BOAS support flange located just forward of the O.D. case rail was not in place with some material remaining. It was bent forward from the 3'O clock to 9'O clock position. A quantity of 33 BOAS were liberated from the engine. One BOAS was recovered in a box of debris which arrived with the engine.

The HPT nut was removed by normal means. The indicated breakaway torque of the HPT nut was approximately 1750 ft-lbs.

A section of the HPT 1st stage seal was cut at 6'O clock and 8'O clock position in order to permit further hardware removal.

The 1st stage blades were fractured near or at the platform, while the 2nd stage blades retained 25% of their original length nearly uniformly around 360^{o} of the circumference of the rotor. The 2nd stage blades had a fracture surface similar to the profile of the under barrel of the 2nd stage seal. The remnants of the 1st stage HPT blades were found retained in their disk attachment location. The 2nd stage HPT blades around 20 in number were displaced forward by approximately ¼ inch. The 1st stage near HPT air-seal were all damaged. Around 13 seals were liberated from their installed locations. The disk attachment teeth located on the aft side of the 1st stage disk were sheared off in the region of the missing seals. The 2nd stage NGV's were liberated from their installed locations. The 2nd stage HPT retention tabs were intact and in place with no damage noted.

The aft side of the 1st stage HP disk showed impact marks and scoring. All 12 air metering plugs were intact and in place with no damaged noted. The front side of the 2nd stage HPT disk showed impact marks and scoring, consistent with the diameter of the inner bore of the 2nd stage seal.

The HPT 2nd stage air-seal assembly was damaged and detached from its mounting location. The inner bore and bore to web transition fillet of the 2nd stage seal was fully intact and was found resting on the bores of the 1st stage disks. The 2nd stage air-seal assembly was fractured on the O.D. of the web. There were two regions where the fracture extended inwards towards the bore. These fractures terminated at approximately the bore to web transition fillet, and were approximately 120^{o} apart.

Four pieces of the outer barrel of the 2nd stage air-seal assembly were recovered. The largest piece measured approximately 38 inches in length and was found lodged inside the combustor between the 11'O clock and 5'O clock position on the 4th and 5th rows of the outer combustor liner segments. The next largest piece measured approximately 16 inches in length and was found lodged in the combustor assembly from 1'O clock and 3'O clock and laying against the HPT case between the 1st and 2nd HPT rotors. The largest piece measured approximately 14 inches in length and was found at the 3'O clock position protruding outward through the 1st stage NGV's and aft towards N-flange. The final and smallest piece was approximately 2 inches by 2 inches and was found lodged between two 1st stage NGVs at the 9'O clock position.

Coked oil was present at the forward inner snap diameter location of the 1st stage HPT, 360^{o} around the circumference. Thickness or width could not be determined.

Low Pressure turbine Module / Turbine Exhaust Case:

The LPT module was intact and visible rotating hardware was found damaged. There were no uncontained penetrations visible through the LPT case. The LPT shaft showed signs of contact approximately 4 inches long and its widest point and was in the plane of the 2nd stage HPT rotor. Just forward of P flange on the LPT and extended 360 degrees around the circumference of the shaft at this location. At a location approximately 14 inches forward from where the LPT shaft is necked to a larger diameter, a contact mark approximately 1 inch long and ½ inch wide at its largest point was present.

All 3rd stage LPT vanes exhibited impact damage, with vane trailing edges most significantly damaged at 3'O clock location. Liberated HPT hardware was also found lodged at this location. At 12'O clock, two LPT 3rd stage inner transition ducts were found dislodged from their intended position. Additional HPT hardware was found loosely lodged in the 3rd stage LPT vanes and in the case, predominantly at the 6'O clock location.

The 7th stage LPT rotor blades were all present, but all also exhibited impact damage in varying forms. The damage varied from a blade which had approximately 30% of its span missing to blades which had trailing edge damage only and to blades which were missing their outer shroud. The 7th stage blade outer air-seal was distressed, with minimal honeycomb seal material remaining and indication of machining damage, in the form of a distinct groove which extended 360^{o} around the circumference of the inner barrel. The 7th stage stator vanes in the LPT were able to be partially viewed. Missing material in varying dimensions and locations was observed on every vane.

The #5 bearing compartment and associated components located in the LPT module showed no signs of distress. The #4 weep tube port, which is located at approximately between 5'O clock & 6'O clock position on the turbine exhaust showed no signs of oil leakage. The exhaust plug which interfaces with the I.D. of the TEC showed no signs of damage.

Externals:

The turbine cooling air (TCA) feed tube which interfaces with the HPT case at 4'O clock was found 75% severed around its diameter and showed signs of impact damage. The majority of the damage was located on the outboard portion of the tube, forward of m-flange. The TCA

tube which interfaces with the HPT case at 8'O clock had the outboard portion of the tube which bends inward toward the HPT case dented. The dent was approximately 3 inches long along the surface of the tube and 1 inch wide at the widest point. The depth of the dent was approximately 25% of the tube diameter. The air cooled air cooler (ACAC) located at 7'O clock between M and N-flange showed signs in the form of dents from impact damage on the inboard side of the assembly which faces the HPT case.

The turbine case cooling (TCC) tubes located at the un-containment locations on the HPT case had signs on impact damage and were crushed or bent. The forward most TCC tube on the HPT at 3'O clock had a piece of metal approximately 4 inches long by 25 inches wide at the widest point speared through the centre of the tube body. Tubes which were located between 5'O clock and 7'O clock in the plane of un-containment on the HPT case had peppering and slight impact damage.

The remainder of externals located other than in the planes of un-containment on the HPT case elsewhere on the engine were found installed and impact with no obvious damage observed.

Nacelle:

The inboard and outboard nacelle assemblies installed at the time of the event were available for review. All nacelle and access panel latches were in place and appeared undamaged. The outboard nacelle had damage at 5'O clock position in the form of a tear which is approximately 14 inches in length and 2 inches wide at the widest point. The tear originates 6 inches above an access panel at this location, and continues down at the approximate 45^{o} angle relative to an installed position, and terminates at the forward most bottom edge of the access panel. The inner diameter of the inner barrel of the outboard nacelle had impact damage at 3'O clock position and evidence of thermal damage and sooting between 1'O clock and 3'O clock. the inner diameter of the outer barrel of the outboard nacelle had impact damage at 3'O clock and a piece of DOD of an undeterminable dimension, penetrated into this location. The wall at this location was bulged inward towards the engine centreline just aft of this location. Accurate dimensions could not be determined.

The inboard nacelle outer surface which faces towards the airframe was intact and showed no areas of un-containment. The inner diameter of the inner barrel of the inboard nacelle was thermally damaged and material missing. The abatable coating was damaged and honeycomb material crumbled when touched. Accurate dimensions could not be determined. The outer

diameter of the inner barrel had two un-containment locations at approximately the 6'O clock location. Accurate dimensions could not be determined.

1.16.2 Seal Plate Lapping Process Review

After the strip examination of the involved engine S/N V0118 at JEOC, Air India, some of the damaged engine parts were sent to NTSB (IAE/ Prat & Whitney), USA for detailed metallurgical testing. The damaged engine parts like fractured HPT 1-2 seal and other damaged parts were analysed for probable root cause of engine fire/failure. No. 4 seal plate of engine # 2 (V0118) was analysed and it was observed that the weep grooves and holes of the seal plate were mostly blocked with lapping debris. In order to confirm the same, on site, lapping process review was carried out at JEOC overhaul shop by IAC Personnel.

Observations

A review of the shop processing procedures and records for a typical seal plate was conducted. To accomplish this, a used seal plate was provided by IAE. The seal plate part number was 2A3432, which is representative of a front seal plate used in the #4 compartment in the V2500 engine. No serial number or other identification markings were present on this seal plate. It was observed that the JEOC seal plate lapping process matches with the IAE Engine Manual (EM) and Standard Practices Manual (SPM). The process sheet follower was properly signed off as per standard JEOC procedures. The JEOC process sheets utilized during this review were provided.

The entire lapping process was observed from beginning to end as per the JEOC process sheets. Before lapping, the IAE supplied seal plate used in the review was processed through the pre-lapping cleaning procedure. After this initial cleaning process, carbon and staining were removed but the grooves had black residue remaining. See image #1.

After cleaning and prior to the lapping process, the subject seal seat was dimensionally and visually inspected. Instead of performing a Magnetic Particle Inspection (MPI), JEOC performs a Fluorescent Penetrant Inspection (FPI) via a waiver which was not documented, granted by IAE. FPI was not carried out in the interest of time as this was a demonstration article and was not germane to the intent of this process review. The seal seat was examined for a chipped hard face condition, deep scratches or pits, and blocked oil slots.

The first step as per the process before physical lapping was to clean the table. This involved wetting the table with a locally available product consistent with the EM recommendation,

and then wiping the lapping table surface with a cloth while rotating the table. The intent of cleaning procedure is to ensure that all lapping residue from previous operations is removed. See image #2.

Debris was found in the sump or area underneath and beside the lapping table surface where lapping medium collects as a result of the process. A sample was obtained for analysis by IAE in order to provide some history of past lapping constituents.

When the table cleaning process was completed, the lapping tooling was installed and diamond lapping paste applied to the table. See image #3. The machine was run for 5 minutes to distribute the diamond paste as per normal JEOC practice.

After the diamond paste was distributed, the subject seal seat was placed on table. See image #4. The positioning tooling was then installed and a weight consisting of a 28kg steel disc was placed on top of the seat. See image #5. The seat was lapped for 10 minutes. Additional solvent was added in small quantities during the process when the table appeared too dry to the operator performing the process.

After lapping, the seal plate was removed from the machine. There was lapping residue deposited in the lubrication slots and holes present in the seal plate as depicted in image #6. The seat was run through the cleaning process and coated with preservation oil as per the EM. Subsequently, the seal plate was presented to IAE as being in a clean condition and ready for use in an engine as per the JEOC process sheets and the IAE EM. See image #7.

Visual inspection showed that lapping residue had not been completely removed from external surfaces. Visual inspection of the slots and lubrication holes was difficult and could not be performed.

A business card of one of the IAE personnel present was run along a slot of the seal plate, allowing for a collection of lapping debris on the card. Debris was raised out of the slot during this procedure. A sample of this debris was retained, analyzed, and compared to the debris acquired from the V0118 seal plates. See images #8 & #9.

After this observation was made, JEOC personnel then physically removed as much material as possible with plastic picks and ran the part through the cleaning cycle a second time. Another business card was inserted and debris was present again but to a lesser degree than the original attempt to check for debris. See image #10.

Image #1 – Demonstration seal plate after cleaning and before lapping.

Image #2 - Cleaning the Table with Hicrolap solvent prior to lapping.

Image #3 - Tooling Installed and Diamond Lapping Paste Applied (yellow streaks).

Image #4 - Placement of seal plate for lapping.

Image #5 – Seal plate installed in lapping machine with 28kg weight installed.

Image #6 – Post lapping condition of the demonstration seal plate.

Image #7 – Post cleaning condition of the demonstration seal plate.

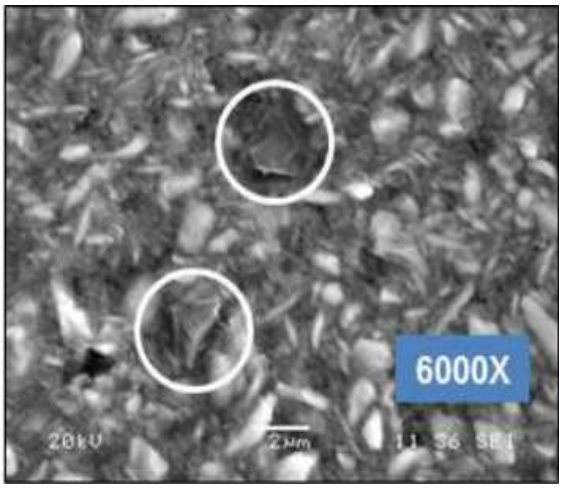
Image #8 – Lapping debris removed from demonstration seal plate slot.

Image #9 – Debris removed from demonstration seal plate groove after process complete.

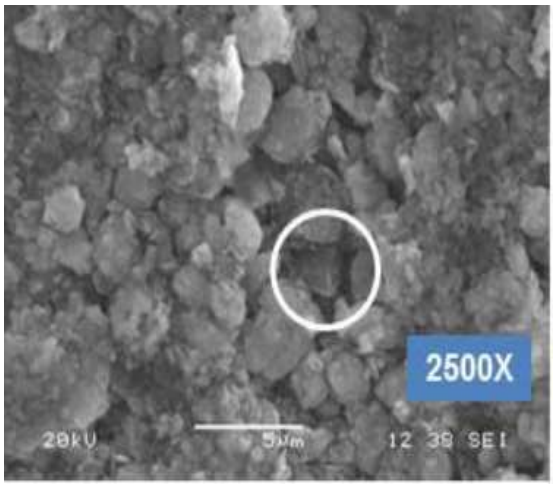
Image #10 – Debris removed from demonstration seal plate after second cleaning cycle.

Findings

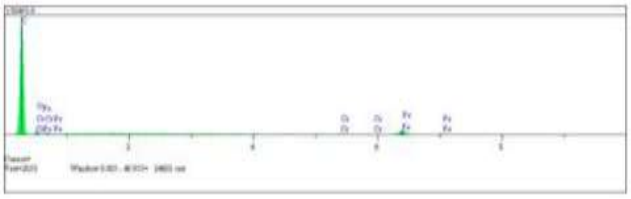
- Diamond particles found in anti-weep grooves of Both V0118 event seal plates & JEOC Demonstration seal plate.

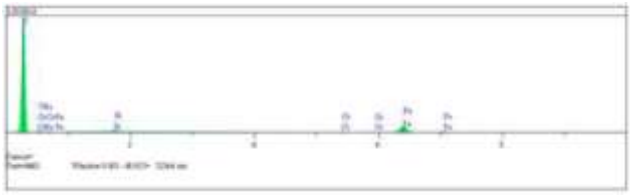


Debris from V0118 seal plate

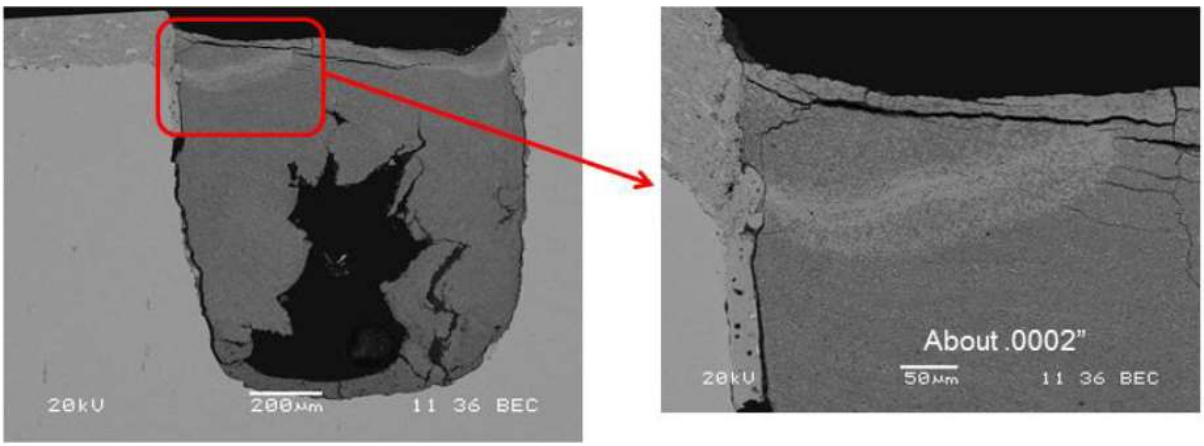


Debris from JEOC Demonstration Seal plate

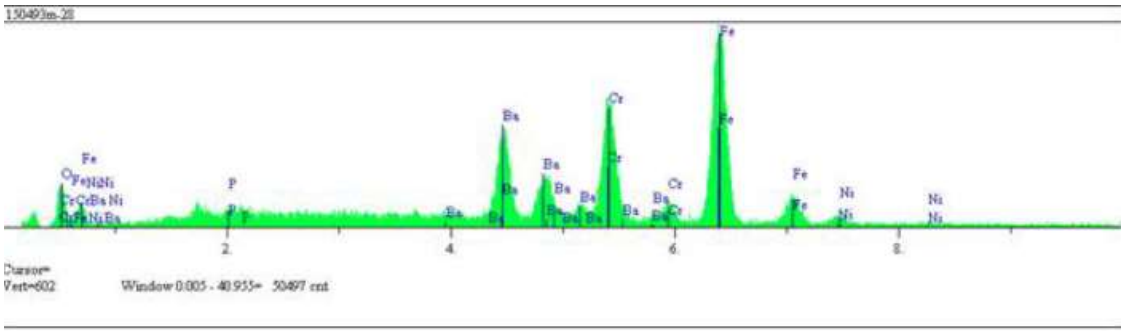




- Chemistry and aspect ratio of metallic Debris & Diamond particles matches OEM lapping Debris.
- Diamond particles not found in environmental debris
- Barium found in anti-weep grooves of both V0118 event seal plates & JEOC demonstration seal plates; source identified as preservation fluid (AeroShell Fluid 12).



Cross section of V0118 seal plate Anti-weep Groove



- *Barium was not found outside of V0118 Anti-Weep Groove, Therefore it was not environmental.*

1.17 Organizational and management information:

Air India Limited is a Scheduled Airlines and operates a fleet of Airbus and Boeing aircraft. The airline was issued Air Operator's Permit (AOP) No. S-9 in Category "Passenger and Cargo" by DGCA and was valid at the time of incident. The Airline IATA Code is "AI", ICAO code "AIC" and call sign "Air India". The airline operates a fleet of 113 aircraft includes 24 Airbus A319-100 aircraft, 28 Airbus A320-200 aircraft, 20 Airbus A321-200 aircraft , 05 Boeing 747-400 aircraft, 15 Boeing 777 aircraft and 21 Boeing 787 aircraft. Air India is having 02 Subsidiaries as Air India Express & Air India Regional which have separate permit. The airline operates at 84 destinations (48 Domestic + 36 international) and having approx. 28000 employees. The airline has headquarter in New Delhi. Its primary hub is at Indira Gandhi International Airport, New Delhi, and secondary hub at Chhatrapati Shivaji International Airport, Mumbai.

1.18 Additional information*:* Nil

1.19 Useful or effective investigation techniques*:* NIL

2. ANALYSIS

2.1 SERVICEABILITY OF THE AIRCRAFT

2.1.1 Airbus A320 aircraft VT-ESI (MSN 0486) was manufactured in the year 1994. The Certificate of registration was valid at the time of incident. As on 21.08.2014 the aircraft had logged 55849: 27 airframe hours and 34460 cycles since new and 4608:28 hours were logged since last C of A. Airworthiness Review Certificate (ARC) was valid up to 10.09.2014.

The aircraft was holding a valid Certificate of Airworthiness. The aircraft was holding valid aero mobile License. This aircraft was operated under Scheduled Operator's permit No. S-09 valid till 30.06.2018. Prior to incident fight the aircraft was holding a valid Certificate of Flight Release.

The aircraft and Engines were being maintained under continuous maintenance as per maintenance program consisting of calendar period based maintenance and flying Hours/Cycles based maintenance as per maintenance program approved by O/o DAW, Delhi. The last Major Inspection '4A check' was carried out at 55397:46 hours / 34156 cycles on 01.07.2014. Subsequently all lower inspections (Pre-flight checks, Service Checks, Weekly Checks) were carried out as and when due before the incident.

Engine	**Serial No.**	**TSN**	**CSN**
#1	V0299	42828 hrs	28189
#2	V0118	41505 hrs	27772

The last engine # 2 overhaul was carried out on 31.03.2012 at 33341:37 engine hours. The engine had logged 8163:23 Hours since last overhaul. On 11.05.2014 the engine was removed from VT-ESC due "repeated high EGT" warning and was later installed onto VT-ESI (#2 position) on 18.05.2014.

The last fuel microbiological test was done on 24.02.2014 and the colony count was within acceptable limits.

The load and trim sheet was prepared before flight and c.g. of the aircraft was within the operating limits. There was no snag reported on the aircraft prior to the incident flight.

2.1.2 After the strip examination of the involved engine S/N V0118 at JEOC, Air India, some of the damaged engine parts were sent to NTSB (IAE/ Prat & Whitney), USA for detailed metallurgical testing. The damaged engine parts like fractured HPT 1-2 seal and other damaged parts were analysed for probable root cause of engine fire/failure.

No. 4 seal plate of engine # 2 (V0118) was analysed and it was observed that the weep grooves and holes of the seal plate were mostly blocked with lapping debris. In order to confirm the same, on site, lapping process review was carried out at IAC overhaul shop by IAC Personnel. IAC personnel performed lapping process demo using IAE provided

V2500, #4 seal plate. After lapping, cleaning and preservation, it was observed that, seal plate weep grooves contained residual lapping debris or "slurry". The slurry was analysed and was found to be matching with V0118 # 4 seal plate debris.

Both samples contained:

- Diamond particles- consistent with lapping paste.
- Barium- consistent with Aero-Shell 12, used for preservation.
- Iron particle size- consistent with lapping table.

The Anti weep circuit prevents the oil from escaping the compartment during sub idle conditions. V0118's # 4 seal plate weep grooves and holes which were mostly blocked with lapping debris, allowed the oil release from #4 bearing compartment at the sub idle condition during start and shutdown.

The #4 seal plate lapping was carried out during the #2 engine overhaul and inadequate cleaning and inspection of Seal Plate after lapping resulted in most of the seal plate groove and holes getting blocked with lapping debris. This allowed the oil to escape # 4 compartment at engine sub-idle and getting ignited at increased engine power.

In view of the above it is inferred that serviceability of the aircraft engine is a factor to the incident.

2.2 WEATHER:

At the time 1530 UTC, the visibility was reported to be 4000 meters with winds 120/05 kts, temp 25°, Dew point 24 QFE 1006 hPa, QNH 1007 and clouds not significant.

In view of the above the weather at the time of incident was fine and is not a contributory factor to the incident.

2.3 PILOT FACTOR

Both the cockpit crew were qualified to operate the subject flight**.** The PIC and the co-pilot both were holding a valid ATPL license and were qualified on type. Both the crew were current in all the trainings and ratings as per the requirements. The pilot had total flying experience of about 10,000 hours with approximately7500 hours on type and about 4500 hours as PIC on type. The co-pilot had total flying experience of about 3564 hours and approximately 3314 hours on type as P2.

The ATC cleared the aircraft for take-off runway 27. The pilot carried out pre take-off checklist and the aircraft took-off at around 1535 UTC from runway 27. After about 01 minute 05 seconds of take-off a loud bang sound was heard by the cockpit crew which was followed by engine fire warning in cockpit. The co-pilot immediately informed the PIC about engine # 2 on fire and as per procedure they carried out ECAM actions. The pilot declared MAY DAY and informed ATC about "engine # 2 fire". The pilot then informed ATC that they will prefer runway 27 for landing. Both the cockpit crew then carried out approach checklist. The MAY DAY call was cancelled by PIC and was replaced by PAN PAN as the fire warning went off afterwards. The pilot then informs cabin crew that they have lost one engine i.e. engine #2 and landing back to Cochin. The Cockpit crew then carried out overweight landing checklist and carried out uneventful overweight landing on runway 27. The pilot requested ATC for guidance to the bay and someone to look at the engine for fire. Pilot then requests ATC to inform the company for GPU and electrical.. After reaching stand, the pilot briefed the passengers about the situation.

2.4 CIRCUMSTANCES LEADING TO THE INCIDENT

Engine # 2 was overhauled at engine overhaul shop. During the overhaul process lapping of the No. 4 bearing seal was carried out. During the process, the anti-weep grooves which prevent the oil from escaping the compartment during sub idle conditions were not adequately cleaned and inspected which resulted into most of the grooves blocked with lapping debris. This allowed the oil to escape the No. 4 bearing compartment and migrate to the HPT (High Pressure Turbine) at the sub idle condition during start and shutdown. The oil migration to the HPT resulted into the oil ignition in the HPT during the power ON condition. This might have resulted into formation of crack in the HPT 2nd stage air-seal at high temperatures. The crack may have propagated and eventually developed into low cycle fatigue fracture of 2nd stage air-seal located in the HPT module and subsequently to engine fire. The damaged parts of air seal at high temperatures then damaged the HPT blades which subsequently breached the HPT casing and engine C-ducts.

3. CONCLUSIONS:

3.1 FINDINGS:

1) The certificate of Airworthiness, Certificate of Registration, and CRS of the aircraft was valid on the date of incident.

2) The PIC & Co-pilot had undergone the requisite pre-flight medical examination and were certified as not being under the influence of alcohol.
3) The CG of the aircraft was within the prescribed limits. There was no sang reported on the aircraft prior to the incident flight.
4) All navigation and approach aids were functional and were operating normally at the time of incident.
5) The PIC had a total flying hours of about 10,000 Hrs of which 7500 hrs were on type. Co-Pilot had a total flying experience of 3564 hrs and 3314 hrs as P2 on type. Both the cockpit crew were qualified to operate the subject flight.
6) Prior to the incident flight the aircraft had operated Dubai – Cochin flight and the flight was uneventful.
7) The ATC cleared the aircraft for take-off runway 27 and the aircraft took-off at 1535 UTC from runway 27.
8) After about 01 minute 05 seconds of take-off a loud bang sound was heard by the cockpit crew which was followed by engine fire warning in cockpit.
9) The co-pilot informs the PIC about engine # 2 fire and they carried out ECAM actions.
10) The pilot declares MAY DAY and informs ATC about "engine # 2 fire".
11) The pilot informed ATC that they will prefer runway 27 for landing and the ATC cleared the aircraft for priority landing.
12) Cabin crew also informed pilot that the passengers saw fire in engine # 2 and they heard a loud bang sound from their respective position in cabin.
13) Cockpit crew carried out approach checklist and informed ATC that they are cancelling MAY DAY call and changing to PAN PAN as there was no fire afterwards.
14) The pilot then informs cabin crew that they have lost one engine i.e. engine #2 and landing back to Cochin.
15) Cockpit crew then carried out overweight landing checklist and an uneventful overweight landing on runway 27.
16) The ATC then cleared the aircraft for parking bay 11 via taxiway 'C' & 'B'. The pilot requested ATC for guidance to the bay and someone to look at the engine for fire.
17) Pilot then requests ATC to inform the company for GPU and electrical.

18) After reaching stand, the ATC confirmed with pilot if all operations are normal for which the pilot replied back as affirm and when asked for further assistance required, the pilot replied back as negative.
19) The pilot then briefed passengers about the situation.
20) After about 08 minutes of the aircraft reaching the bay, the step ladder was attached to aircraft to disembark the passengers. The passengers were disembarked normally.
21) Thereafter walk around inspection was carried out and it was observed that there were metal debris on engine #2 exhaust. The C-duct cowl was found breached (punctured) along with the HPT casing.
22) There was no injury to any of the occupant on board the aircraft.
23) The fire was confined to within engine only.
24) At the time of incident visibility was 4000 meters and winds 120/05 kts.
25) During teardown inspection of engine HPT stage 2 air seal was found substantially damaged along with the HPT blades.
26) Inadequate cleaning and inspection of No. 4 bearing seal after lapping, during the overhaul of Engine # 2 at engine overhaul shop resulted into most of the anti-weep grooves blocked with lapping debris.
27) This blocked anti-weep groove allowed the oil to escape the No. 4 bearing compartment and migrate to the HPT (High Pressure Turbine) at the sub idle condition during start and shutdown.
28) The oil migration to the HPT resulted into the oil ignition in the HPT during the high power condition and this resulted into low cycle fatigue fracture to 2nd stage air-seal at high temperatures.
29) The damaged parts of air seal at high temperatures then damaged the HPT blades which subsequently breached the HPT casing and engine C-ducts.

3.2 PROBABLE CAUSE OF THE INCIDENT:

Non adherence to the stipulated lapping procedure of cleaning and inspection of #4 seal plate during overhaul of engine # 2 resulted in blocking of anti-weep groove which allowed the oil to escape # 4 compartment and enter the HPT during sub-idle conditions. This oil seepage got ignited at increased engine power which eventually resulted into low cycle fatigue fracture to HPT 2nd stage air-seal.

4. SAFETY RECOMMENDATIONS:

1. M/s Air India Ltd. and other operators operating with IAE V2500-A1 engines should strictly adhere to the service bulletin V2500-ENG-72-0670 (Engine Oil Consumption Monitoring and No. 4 Front and Rear Seal Seat Replacement) issued by the engine manufacturer IAE post incident and mandated by the FAA Airworthiness Directive dated 05.09.2016.

K. Ramachandran

(K Ramachandran)
Air Safety Officer, AAIB
Member, CoI to VT-ESI

(Raje Bhatnagar)
Assistant Director, AAIB
Member, CoI to VT-ESI

Date: 09.11.2017
Place: New Delhi