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**Investigation Report on Incident to
M/s Air India Airbus A321 aircraft VT-PPT operating
flight AI-807 at Delhi on 17.05.2024**

**GOVERNMENT OF INDIA
DIRECTORATE GENERAL OF CIVIL AVIATION**

FOREWORD

In accordance with the Aircraft (Investigation of Accidents & Incidents) Rules 2017, the sole objective of this investigation is to prevent aviation incidents and accidents in the future. It is not the purpose of the investigation to apportion blame or liability. The investigation conducted in accordance with the provisions of the above said rules shall be separate from any judicial or administrative proceedings to apportion blame or liability.

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

List of abbreviations used in the report

S. No.		
1	A/C	Aircraft
2	AIESL	Air India Engineering Services Ltd.
3	AME	Aircraft Maintenance Engineer
4	AMM	Aircraft Maintenance Manual
5	AMOS	Aircraft Maintenance and Operations System
6	AMP	Aircraft Maintenance Programme
7	APU	Auxiliary Power Unit
8	ARC	Airworthiness Review Certificate
9	ATC	Air Traffic Control
10	ATPL	Airline Transport Pilot License
11	BLD	Bleed
12	BMC	Bleed Monitoring Computer
13	C/O	Carried out
14	CAMO	Continuing Airworthiness Management Organisation
15	CFM	CFM International
16	CPL	Commercial Pilot License
17	CRC	Continuous Repetitive Chime
18	CRES	Corrosion Resistant Steel
19	CRS	Certificate of Release to Service
20	CSN	Cycles Since New
21	CSV	Cycles Since Shop Visit
22	CVR	Cockpit Voice Recorder
23	DFDR	Digital Flight Data Recorder
24	DGCA	Directorate General of Civil Aviation
25	ECAM	Electronic Centralised Aircraft Monitor
26	ECB	Electronic Control Box
27	ECS	Environmental control system
28	EDTO	Extended Diversion Time Operations
29	EFCS	Electronic Flight Control System
30	EGT	Exhaust Gas Temperature
31	EPR	Engine Pressure Ratio
32	F/CTL	Flight Controls
33	FCOM	Flight Crew Operating Manual
34	FCU	Fuel Control Unit
35	FDU	Fire Detection Unit
36	FLTN	Flight Number
37	FLX MCT	Flex Max Continuous Thrust
38	FO	First Officer
39	FR	Frame
40	FRTOL	Flight Radiotelephony Operator's License
41	FWD	Forward
42	GEN	Generator
43	GMT	Greenwich Mean Time

44	HQ	Headquarters
45	IFR	Instrument Flight Rules
46	IGV	Inlet Guide Vane
47	INOP	Inoperative
48	LC	Load Compressor
49	LCV	Load Control Valve
50	LOP	Low Oil Pressure
51	MCDU	Multipurpose Control And Display Unit
52	MEL	Minimum Equipment List
53	MES	Main Engine Start
54	MSN	Manufacturer Serial Number
55	NDT	Non Destructive Testing
56	NTM	Non Destructive Testing Manual
57	OEM	Original Equipment Manufacturer
58	P/B	Pushbutton
59	PF	Pilot Flying
60	PIC	Pilot In Command
61	PM	Pilot Monitoring
62	RWY	Runway
63	S/N	Serial Number
64	SCV	Surge Control Valve
65	SEC	Spoiler Elevator Computer
66	SID	Standard Instrument Departure
67	SOD	Staff On Duty
68	SOP	Standard Operating Procedure
69	SRM	Structural Repair Manual
70	SW	Switch
71	TAT	Total Air Temperature
72	TOGA	Take Off Go Around
73	TSN	Time Since New
74	TSV	Time Since Shop Visit
75	U/S	Unserviceable
76	UTC	Universal Coordinated Time
77	VABB	Mumbai
78	VABO	Vadodara
79	VAUD	Udaipur
80	VCBI	Colombo
81	VFR	Visual Flight Rules
82	VIDP	Delhi
83	VOBL	Bengaluru
84	VOMM	Chennai

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Investigation Report on Incident to M/s Air India Airbus A321 aircraft

VT-PPT operating flight AI-807 at Delhi on 17.05.2024

1. Aircraft
 - Type : Airbus A321-211
 - Nationality : INDIAN
 - Registration : VT-PPT
2. Owner : AIR INDIA LIMITED
 - Operator : AIR INDIA LIMITED
3. Pilot-in-Command : ATPL Holder
 - Extent of injuries : NIL
 - Co-Pilot/First Officer : CPL Holder
 - Extent of injuries : NIL
4. Date of incident : 17.05.2024
 - Time of incident : 12:02 UTC
5. Place of Incident : Delhi
6. Co-ordinates of incident site : 28.4997 N; 77.0078 E
7. Last point of Departure : VIDP (INDIRA GANDHI INTERNATIONAL AIRPORT, DELHI)
8. Intended place of Landing : VOBL (KEMPEGOWDA INTERNATIONAL AIRPORT, BENGALURU)
9. No. of passengers on board : 169
10. Type of operation : Scheduled Commercial Air Transport Operation
11. Phase of operation : Climb
12. Type of Incident : SCF-PP [SYSTEM/ COMPONENT FAILURE OR MALFUNCTION (POWERPLANT)]

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

Synopsis:

On 17.05.2024 M/s Air India Airbus A321-211 aircraft VT-PPT operated a scheduled passenger flight AI-807 from Delhi to Bengaluru. The PIC was the Pilot Flying and the First Officer was the Pilot Monitoring. APU was ON and the APU bleed was used during takeoff and climb for air conditioning due to high ambient temperature.

During climb phase APU bleed was turned OFF and APU FIRE ECAM warning triggered and was active for about 28 seconds. Crew shutdown the APU and the agent was discharged. The fire warning was no longer active after ECAM actions and LAND ASAP appeared on ECAM. 'PAN PAN' call was made by the crew and the aircraft landed back at Delhi. There were a total of 177 people on-board (including crew) for the flight sector and nil injuries were reported. Black soot was observed in the upper portion of the APU compartment. Paint discoloration/ heat damage signs were observed on rear portion of the RH APU cowl door. No evidence of an actual fire has been detected in the APU compartment. No smoke was reported in the aircraft cockpit or cabin.

DGCA-India, vide Order No DGCA-15018(01)/10/2024-DAS dated 04.06.2024 instituted investigation of the incident under Rule 13 (1) of Aircraft (Investigation of Accidents and Incidents), Rules 2017 by appointing an Investigator-In-Charge along with a member to associate in the investigation.

The most probable cause of the incident was APU hot air leaks from load control valve & T-Duct - Scroll flange in combination with the ingestion of APU exhaust gases into the APU compartment, which would have increased the overall temperature over the triggering limits of the APU FIRE ECAM alert, causing the APU Fire indication.

Lack of effective control of M/s Air India CAMO on the maintenance activities being performed on the APU contributed to the incident.

1. Factual Information

1.1 History of flight:

M/s Air India Airbus A321-211 aircraft VT-PPT operated a scheduled passenger flight AI-807 on 17.05.2024, from Delhi to Bengaluru. There were a total of 177 people on-board (including crew) for the flight sector. The subject sector was the fifth sector of the date operated by VT-PPT. Both the cockpit crew members had undergone the pre-flight breath analyser test at Delhi prior to starting the first leg of the flight duty and the test result was 'negative' for alcohol consumption.

The subject sector was the first sector of the day for the operating flight crew. PIC (Pilo-In-Command) was the PF (Pilot Flying) and First Officer was the PM (Pilot Monitoring) for the subject sector. PIC prepared the cockpit for departure and the FO performed the walk-around of the aircraft prior to departure and there were no observations related to APU. MELs were cross checked by the crew and no performance limiting MEL was active. APU was switched on 15 minutes prior to take off. APU Bleed was switched ON for take-off as the cabin was hot due to high ambient temperature.

APU bleed followed by APU were put to OFF during the acceleration flow in climb. Immediately APU FIRE warning on ECAM along with continuous repetitive chime (CRC) was generated. Crew performed the ECAM actions and the APU FIRE push button was pushed by the crew and the agent was discharged. Crew carried out the ABNORMAL APU FIRE checklist.

Crew declared PAN PAN with ATC (approach radar) and requested to stop climb at FL070 and left heading. Crew discussed that they are overweight and burning fuel is a better option to land back. They then entered a hold and called a SOD crew into the cockpit to discuss the situation. They then decided to land back at Delhi. Crew reviewed the EMERGENCY AND ABNORMAL PROCEDURE checklist for APU FIRE and then the OVERWEIGHT LANDING checklist.

Crew reviewed the situation and communicated their intention of landing back at Delhi to the ATC. PIC briefed the forward galley cabin crew about the situation & the decision to land back at Delhi. First Officer informed Air India Dispatch about APU FIRE and the decision to land back in Delhi. Crew confirmed from the cabin crew that there were no signs of smoke or fire in the aft. Crew also reviewed the overweight landing checklist and decided that the packs to be put OFF for Landing. Crew informed passengers about returning to Delhi due to a technical issue. Aircraft landed back on RWY29L, Delhi at 13:08 UTC. No smoke was reported in the aircraft cockpit or cabin. No injury to any passenger or crew was reported.

1.2 Injuries to persons:

Injuries	Crew	Passengers	Others
Fatal	Nil	Nil	Nil
Serious	Nil	Nil	Nil
Minor/None	Nil / 08 (02 Cockpit crew and 06 Cabin Crew)	Nil/ 169	

Total Persons on Board : 177

1.3 Damage to aircraft:

Black soot was observed in the upper portion of the APU compartment. Paint discoloration/ heat damage signs were observed on rear of RH APU cowl door structure. Air inlet diffuser on tapping shows signs of debondings. Exhaust bellow found torn.

Operator has consulted OEM Airbus post the subject incident and based on OEM suggestion NDT inspection (eddy current conductivity test) of the APU cowl door was performed and the conductivity of the RH APU cowl area was not within acceptable limits. However, Airbus confirmed that APU door with conductivity values beyond limits is acceptable as is with High Speed tape application as per SRM guidelines.

1. The R/H APU door damage was found beyond NTM 51-10-12 limits, the R/H APU door has been replaced.
2. The APU hoist fittings (QTY 3) have been inspected as per NTM 51-10-12, only the lower fitting has been found damaged beyond limits and replaced.

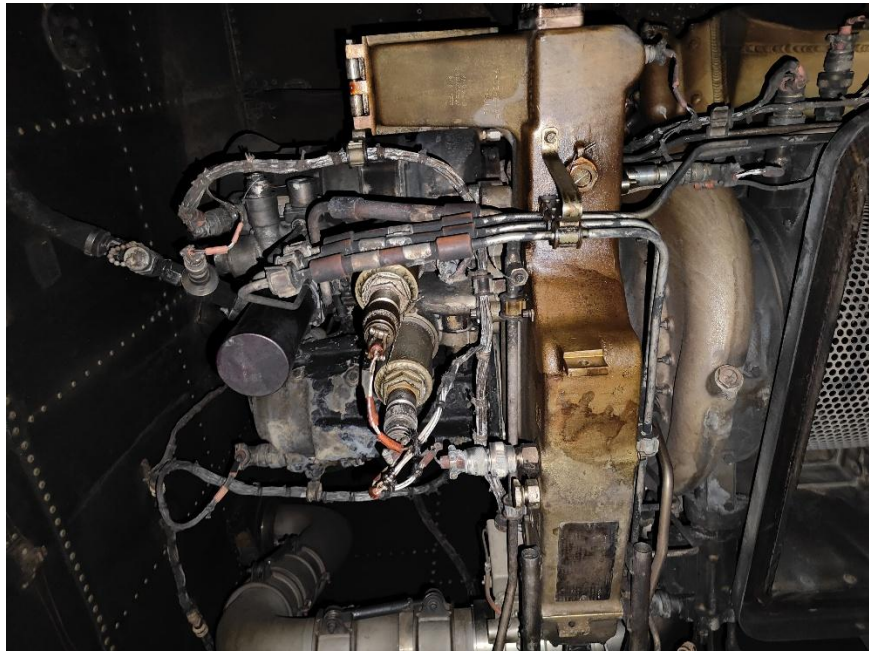
The APU fire loop and Fire extinguisher bottle have been replaced.

The damaged APU (S/N: P4438) has been removed and replaced by a serviceable and fully equipped APU.

Airbus has also confirmed that the APU compartment structure is still capable of sustaining certified loads.



APU compartment (in fuselage tail cone) and access doors on the bottom of the tail cone [Post incident]



APU and view inside APU compartment [Post incident]

1.4 Other damages:

Nil

1.5 Personnel information:

Cockpit was manned at the time of incident by Crew of M/s Air India. The details of the licences and ratings are as detailed below: -

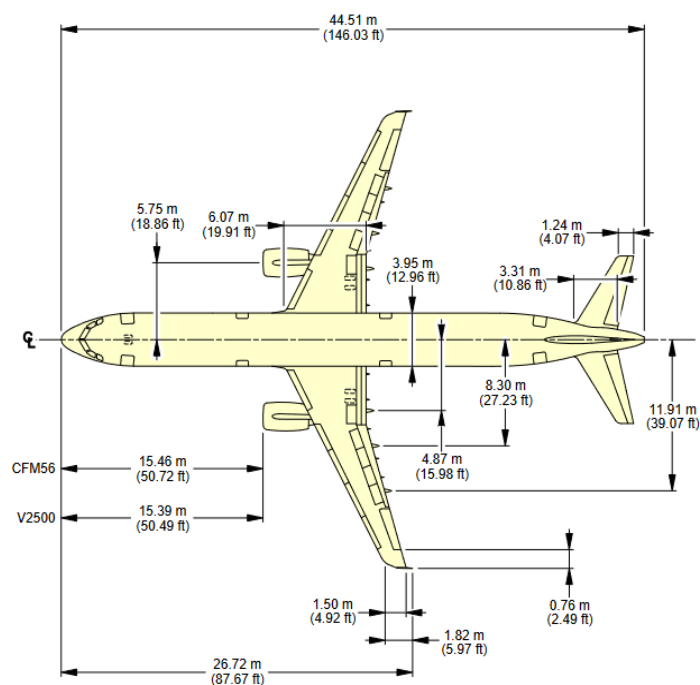
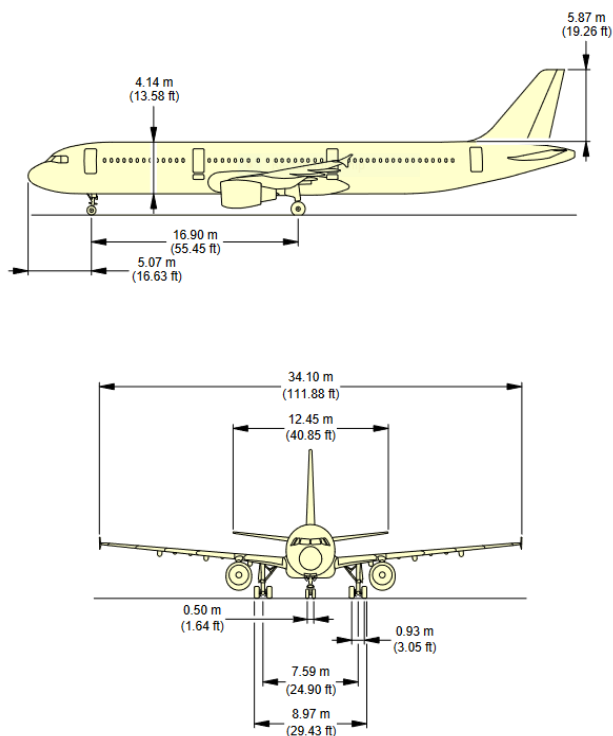
Flight Crew details:		
	PIC	First Officer
a) Type of license	ATPL holder	CPL holder
b) Valid up-to	25.07.2027	11.10.2026
c) Date of Initial issue	26.07.2022	12.10.2021
d) Class of license	ATPL	CPL
e) Category of license	AIRPLANE	AIRPLANE
f) Age	40 years	26 years
g) Aircraft Ratings	C172, A320, BE76	C172, C310, A320
h) Date of Endorsement as PIC (on type)	11.01.2023	-
i) Date of last Medical Exam	15.05.2023	10.05.2023
j) Medical Exam validity	24.05.2024	27.05.2024
k) FRTOL Valid up to	18.05.2025	12.10.2026
l) Instrument Rating (valid upto)	14.09.2024	15.09.2024
m) Date of last Route check	28.02.2024	06.02.2024
n) Date of last Proficiency Check	28.02.2024	06.02.2024
o) Total flying experience	5198:12 hrs	959:39 hrs
p) Experience on Type	4930:52 hrs	759:39 hrs
q) Experience as PIC on Type	917:40 hrs	-
r) Last flown on Type	16.05.2024	15.05.2024
s) Total flying experience in last 180 days (prior to incident)	442:27 hrs	290:58 hrs
t) Total flying experience in last 30 days (prior to incident)	72:49 hrs	42:29 hrs
u) Total flying experience in last 7 days (prior to incident)	12:54 hrs	21:43 hrs
v) Total flying experience in last 24 hrs. (prior to incident)	Nil	0
w) Rest before duty	23 hrs	47:29 hrs

1.6 Aircraft information:

Airbus A321-211 is a twin engine aircraft fitted with CFM 56 5B engines manufactured by CFM International. The aircraft is certified in Normal category, for day and night operation under VFR & IFR. The aircraft is fitted with a Honeywell APU. The aircraft was flying as a Non-EDTO aircraft since induction.

1.6.1 Aircraft data:

Manufacturer	AIRBUS
Type	A321-211
Owner	AIR INDIA LIMITED
Operator	AIR INDIA LIMITED
Manufacturer Serial no.	4078
Year of Manufacture	2009
Certificate of Airworthiness issue date and validity	30-10-2009 (Initial issue)
Airworthiness Review Certificate issue date and validity	ARC issued on 15.02.2024, Expiry date: 17.02.2025
TSN	44281:12 hrs
CSN	25659 Cycles
Time since last ARC	782:07 Hrs
Cycles since last ARC	462 Cycles
Category	Normal
Certificate of Registration and validity	No. 4036/4 Category 'A' dated 05.08.2014 [Entered in the register of India w.e.f 30.10.2009]
Minimum Crew Required	02
Maximum All Up weight	89000 kgs
Last Major inspection	A check performed on 15.05.2024
Last inspection	A check done on 15.05.2024 + weekly check
A/C Hrs & cycles on 13.05.24	44266:34 hrs /25649
A/C Hrs & cycles since replacement of LCV	14HRS 38 MIN

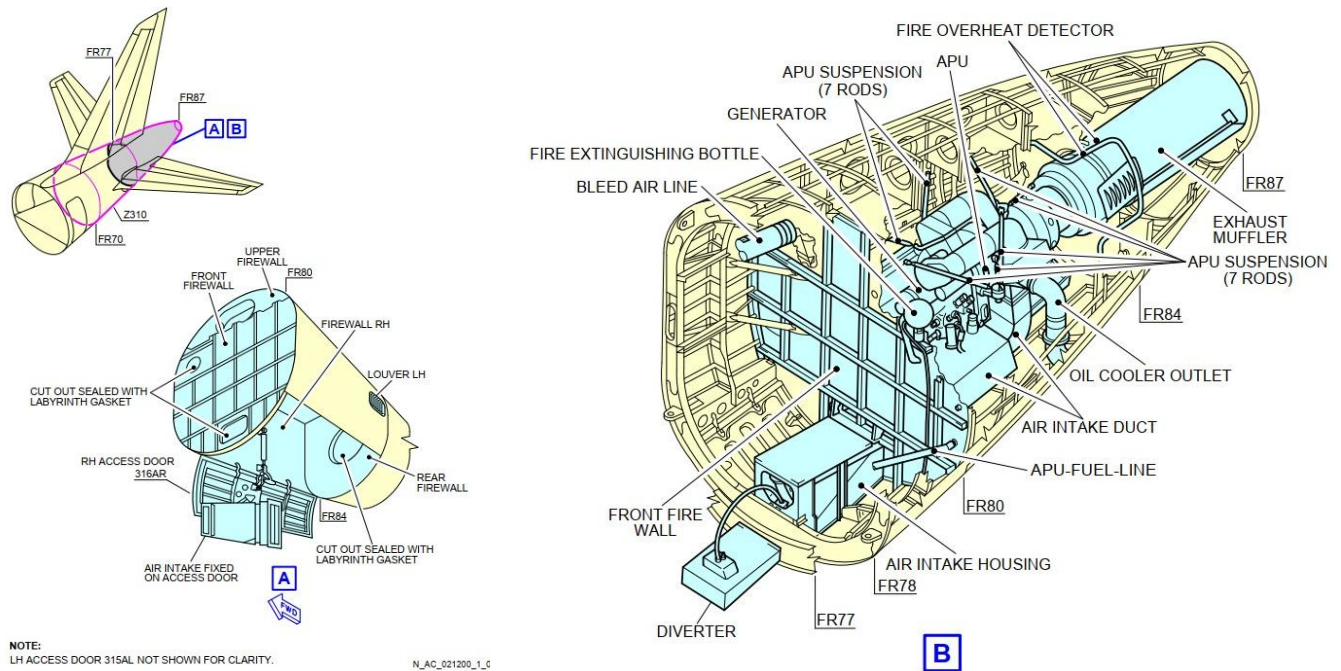


1.6.2 Engine data:

	Engine#1(LH)	Engine#2(RH)
Manufacturer	CFM International	CFM International
Type	CFM56-5B3/3	CFM56-5B3/3
Engine Serial no.	697741	575194
Time Since new(TSN)	41881:29	62603:26
Cycles since new(CSN)	25270	31532
Time since last shop visit(TSV)	445:00	3867:28
Cycle since last shop visit(CSV)	271	2311
Last Major Inspection Carried out	A check done on 15.05.2024	A check done on 15.05.2024
Last inspection Carried out	A check done on 15.05.2024 + weekly check	A check done on 15.05.2024 + weekly check

1.6.3 APU data:

Manufacturer	Honeywell
Type	Model no-131-9A
Serial no.	P4438
Time Since new(TSN) prior to incident flight	29060
Cycles since new(CSN) prior to incident flight	31722
Time since last shop visit(TSV)	8975
Cycle since last shop visit(CSV)	12614
Date of installation on VT-PPT	06.04.2021
Time since installation on VT-PPT	8975
Cycles since installation on VT-PPT	12614
Last major inspection Carried out	During A check done on 15.05.2024
Last inspection Carried out	A check done on 15.05.2024 + weekly check
Average Oil consumption (last 6 months)	<u>No recorded APU oil uplift</u>
Maximum oil consumption rate of a newly overhauled/ New APU	6.5 cc/ hour



APU General layout

APU data after LCV replacement and prior to incident flight:

DATE	Hours	Cycles
13/05/24 (after LCV replacement released to service on 15.05.2024)	29035	31693
17/05/24 (prior to incident)	29060	31722

APU Hrs and cycles since LCV Installation (replacement on 13.05.2024 and released to service on 15.05.2024) were 25 Hrs and 29 Cycles respectively.

The APU last shop visit (at APU TSN: 20085, CSN: 19108) was in August 2018 for Hot section distress after removal from A321 aircraft VT-PPE in July 2018. Air India has submitted that, as per record last oil filter replacement was performed on 08.08.2023 on VT-PPT APU.

1.6.4 Aircraft Maintenance History:

The maintenance of VT-PPT was being conducted by AIESL.

A. MEL history was scrutinised and the following has been observed:

- AIR APU BLEED FAULT, MEL 36-12-02B Cat C was invoked at Kolkata on 12.04.2024. APU Bleed U/S MEL 36-12-01A Cat C was invoked at Delhi on

13.04.2024. Both the MELs were revoked at Delhi on 13.04.2024 by replacing the surge control valve.

- b. APU MAINT. MSG., MEL 49-07-01A Cat C was invoked at Colombo on 02.05.2024 and was revoked on 09.05.2024 at Mumbai by removing the load control valve connector, cleaning and refitting it back.
- c. APU IN MAINT., MEL 49-00-01A Cat C was invoked at Amritsar on 11.05.2024 and was revoked on 13.05.2024 at Mumbai by replacing the Load control valve (ON S/N:4766, OFF S/N: 1264). The aircraft was released to service on 15.05.2024. The subject LCV (S/N: 4766) installed on 13.05.2024 on APU S/N: P4438) [VT-PPT] was cannibalised from APU P-6304 (which was an OFF wing APU). Further, based on engineering data the APU P-6304 did not have any previous history on LCV or other APU BLEED issue prior to cannibalisation of the LCV.

B. On 12.04.2024, during layover inspection, APU oil cooler was replaced due to operational requirement for cleaning. Due to the trending high oil temperature, preventive maintenance to avoid auto shutdown due high oil temperature, oil cooler replaced with serviceable one. Post replacement, oil temperature was found satisfactory.

APU OIL COOLER	PART NO.	S/N
ON	160494-1	2109
OFF	160494-1	3412

C. In co-ordination with M/s Air India, APU Oil uplift data was checked from AMOS /Tech Log pages and LAYOVER / **WEEKLY** checks and observed NIL APU Oil uplift from the last 06 months on the subject APU of VT-PPT.

No records could be produced by M/s Air India regarding the last oil uplift.

D. The approved Aircraft Maintenance Programme of VT-PPT included the ‘General Visual Inspection of APU Compartment Exhaust Muffler Insulation Covers and Bellows’ at 36 MONTHS intervals.

No records were made available by M/s Air India w.r.t. the said inspection.

E. Other defects reported on the APU S/N: P4438

08.02.2024- LOW OIL LEVEL -APU ECB supply and APU CTL CB reset carried out. APU started normally. No LOW OIL LEVEL FAULT message observed. APU service data of oil level ok.

29.02.2024- APU BLEED FAULT during startup- TSM 36-12-00-810-801-A followed. BMC 1&2 test carried out. Pack #2 Operation check carried out & aids parameters of APU bleed observed normal.

17.03.2024-APU BLEED U/S- SCV electrical plug cleaned, wiring check ok. Operational test of APU including EGR ok. ECB BITE test ok.

12.04.2024-APU BLEED FAULT. APU BLEED U/S-TSM task 49-00-81-810-871-A followed, PFR, LLR, PLR reviewed APU surge control valve found faulty same replaced as per AMM task. BITE test of the surge control system carried out test report found satisfactory. Both packs operated on APU bleed operation found satisfactory.

1.6.5 Post-Flight Report (PFR):

A/C ID	DATE	GMT	FLTN	CITY PAIR
VT-PPT	17MAY	1332	AIC807	VIDP VIDP

MAINTENANCE **POST FLIGHT REPORT**

WARNING/MAINT.STATUS MESSAGES

GMT	PH	ATA
1154	02	27-00 F/CTL
1202	06	26-00 APU FIRE
1203	06	49-00 APU EMER SHUT DOWN
1305	06	21-61 AIR PACK 1+2 FAULT

FAILURE MESSAGES

GMT	PH	ATA		SOURCE	IDENT
1154	02	27-94-34	SEC2 OR INPUT OF F/O ROLL CTL SSTU 4CE2	EFCS1	EFCS2

1.6.6 Pilot Defect Report (PDR):

The defect report made by the Pilot at Delhi states the following:

" APU FIRE AFT T/O - ECAM ACTION C/O FIRE WAS OUT OVERWT LND C/O"

1.7 Meteorological information:

Weather reported was 43°C with winds of 04 kts from 330 degrees with no significant change in the trend.

Weather was not a contributory factor.

1.8 Aids of navigation:

All aids to navigation were serviceable. No un-serviceability was reported.

1.9 Communication:

Two way radio communications were available between aircraft and ATC. Neither the crew nor did the ATC unit report any un-serviceability.

1.10 Aerodrome information:

Not applicable.

1.11 Flight recorders:

1.11.1 CVR:

The aircraft was installed with a Solid State Cockpit Voice Recorder capable of recording two (02) hours of cockpit communications. The CVR data was retrieved and was utilised in the investigation. Following are the observations made:

1. At relative time 28:05, after pushback from bay no. C31R, weather at destination was discussed. MELs were cross checked and no performance limiting MEL was active as per the crew discussion. Take off from Runway 29R and SID details were discussed.
2. Possible scenarios of overweight landing in case of an air turn back was discussed by the crew.
3. Before-start checklist, after-start checklist and flight controls checks, taxi checklists were carried as per SOP.
4. Crew discussed that the cabin was too hot and a decision to put APU Bleed to ON was made at relative time 36:05.
5. Line up checklist was carried out as per SOP. Crew were cleared for take off by the ATC from Runway 29R with winds 300 degrees and 08 kts.
6. Aircraft took off at relative time 41:26. Autopilot 1 was switched ON immediately after gear up. Aircraft was cleared to FL 070 at relative time 41:58.
7. APU bleed and APU were put to OFF at relative time 43:14. Master caution with continuous repetitive chime is heard at relative time 43:22. Crew announced APU FIRE at relative time 43:27 and continue to do ECAM actions.
8. APU FIRE push button was pushed by the crew and agent was discharged.
9. APU EMERGENCY SHUTDOWN is heard at relative time 43:54.
10. INOP APU status is announced and cleared by the crew. Fire indication was no longer present as per the crew discussion. ATC cleared the aircraft to climb to FL 090 to which the crew request for standby. Crew discussed the ABNORMAL APU FIRE CHECKLIST and carry out the actions as per the checklist. Crew discuss that there is no fire and the intention of not to attempt to start the APU. LAND ASAP in RED is also discussed by the crew.
11. Crew declared PAN PAN with Approach radar at about relative time 45:01 and request to stop climb at FL070 and left heading to diagnose. A heading of 110 degrees is given to the crew by ATC.

12. Crew discuss that they are overweight of about 75.5 tons and burning fuel is a better option to land back. They entered a hold and call a SOD crew into the cockpit to discuss the situation. They then decide to land back at Delhi.
13. Crew review the EMERGENCY AND ABNORMAL PROCEDURE CHECKLIST for APU FIRE and then the OVERWEIGHT LANDING checklist.
14. Crew reviewed the situation and then calculate the required performance calculations to land at Delhi. They communicated their intention of landing back at Delhi to the ATC at relative time 56:31.
15. PIC then called the forward galley cabin crew into the cockpit to brief about the situation & the decision to land back at Delhi.
16. First Officer informed Air India Dispatch about APU FIRE and their decision to land back in Delhi. He also informs that the fire has been put off and they are overweight.
17. PIC then advised the cabin crew to confirm if there are any signs of smoke or fumes in the aft of the aircraft. A cabin crew then confirmed to the cockpit crew that there are no signs of smoke or fire in the aft. During take-off as well the crew did not experience any signs of smoke or fire in the aft.
18. Crew monitor the weather data at 1200 UTC for Delhi. Crew then review the overweight landing checklist and decide that the packs to be put OFF for Landing.
19. PIC returns to the cockpit and reviews the overweight landing checklist again with the FO. They then decide to go ahead with Landing at Delhi, inform the passengers about returning to Delhi due to a technical issue.
20. Crew then confirm that the MCDU was prepared for the approach and carry out short briefing for approach at Delhi with landing weight of 76.7 tons and 835 meters of margin.
21. Crew then request ATC for a long approach to runway 29L with a heading of 090 degrees and a 30 mile localiser interception.
22. Crew then carry out briefing for ILS approach runway 29L and go around & missed approach procedure. Crew inform ATC that after landing they would be vacating from the end of the runway and a fire tender be placed on standby.
23. ATC clearance is received at relative time 1:45:05 to land on runway 29L wind 300 degrees 05 kts. Crew inform tower about their intention of maintaining runway heading should there be a go around.
24. At relative time 1:46:25, a master caution is heard when both the packs were put to OFF as per the overweight landing checklist. Crew then carry out the landing checklist.
25. At relative time 1:48:37, aircraft landed on runway 29L. Aircraft then vacated the runway via Z4-T6. At relative time 1:50:15 both the packs were put to ON.
26. Crew inform the ATC that all operations were normal and then cross T6-RWY 29R-R6-R-A-Link 6 to bay no. C34R. Aircraft was chocks ON at relative time 2:00:21. Crew then carry out parking checklist. Crew then discuss cabin crew informing the PIC about smell in aft 20 minutes prior to landing.

1.11.2 DFDR:

The aircraft was installed with a Solid State Flight Data Recorder. The recording of the unit was retrieved and salient points are as interpreted below:

1. DFDR data recording starts from 11:51:17 UTC, Engine 1 was already operating at IDLE. APU bleed was ON.
2. At 11:51:40 UTC, Engine 2 was started indicated by an increase in EGT and fuel flow and at 11:51:52 UTC aircraft started taxiing. APU bleed was turned OFF at 11:52:22UTC. Engine bleed valves opened at 11:52:25 UTC.
3. During taxi to line-up on runway, at 11:59:07 UTC, APU bleed was selected ON. At 11:59:16 UTC, APU bleed valve status was OPEN. Engine bleed valves closed at 11:59:21 UTC.
4. At 12:00:17 UTC, aircraft started take-off roll. Thrust levers of Engines were advanced to 34.8° (FLX MCT).
5. Aircraft took off at 12:00:58 UTC. Auto Pilot 1 was switched ON at 12:01:12 UTC. Both the thrust levers were brought to CLIMB detent at 12:01:17 UTC. At 12:01:35 UTC, an altitude selection of 7000 ft was made.
6. At 12:02:42 UTC, APU bleed was selected to OFF. The APU bleed valve moved to CLOSE position at 12:02:48 UTC.
7. At 12:02:49 UTC, during climb through 1815.64 ft baro altitude (2009 ft RA), APU FIRE warning was generated. A Master warning was also recorded at 12:02:50 UTC till 12:02:53 UTC. The APU GEN load was disconnected at 12:03:05UTC. The APU FIRE warning remained ON till 12:03:16 UTC. Thereafter the aircraft continued to climb to an altitude of about 5900 ft and levelled out at that altitude.
8. At 12:57:57 UTC, an altitude selection of 2600 ft was made and aircraft started descent. At 12:59:59 UTC, both the auto pilots were engaged.
9. Aircraft landed at 13:08 UTC.

1.12 Wreckage and impact information:

Not applicable.

1.13 Medical and pathological information:

Not applicable.

1.14 Fire:

No evidence of an actual fire has been detected in the APU compartment.

No smoke was reported in the aircraft cockpit or cabin.

1.15 Survival aspects:

The incident was survivable. There was no injury reported to the passengers, crew or any other ground personnel.

1.16 Tests and research:

1.16.1 APU Tear Down inspection (Honeywell)

The involved APU (S/N: P4438) was sent to Honeywell (OEM) for investigation and for identification of the root cause of the APU Fire warning.

Only superficial damages were detected during the APU incoming inspection at the Honeywell facility.

1. Borescope inspection performed with no findings.
2. Magnetic plug and Oil filters were inspected with no findings
3. Before the tear-down, the APU was installed in a test cell to perform the following checks:
 - Dry Crank → No Oil leaks detected during the dry crank
 - Wet Crank → No Fuel leaks detected during the wet crank
 - APU Run → Acceptance Test performed
 - APU Low Bleed Pressure detected on almost every APU Bleed Supply maneuvers
 - APU Hot Air Leaks detected on the T-Duct - Scroll flange and on the LCV.
4. Load Compressor Scroll flange hot air leak:
 - a) It was confirmed that the 4 bolts were only hand tightened. It has been further clarified by M/s Honeywell that, during disassembly of the scroll housing and T-duct, a light break away torque of 4-5 in-lb was measured (torque requirement is 120 in-lb).
 - b) During the APU operation, with the thermal expansion of the parts, a gap was created between the LC scroll and the T-Duct.
 - c) A significant hot air leak occurred due to this gap.
 - d) During the tear down, two different sectors of the flange show evidence of leak
5. Load Control Valve hot air leak
 - a) The valve was removed from the APU and tested separately in the Honeywell lab.
 - b) The external hot air leakage detected was through the LCV shaft seal.
 - c) The leakage rate measured was completely out of the acceptance value.
 - d) An ATP was performed to the valve and failed in several checks.
6. Oil traces on the lower part of the APU Oil Tank and Low Oil Pressure switches:

Before starting the APU, the Oil level was checked and it was significantly over the “FULL” mark. The evidences found confirmed that the oil leak occurred with the APU on wing as a result of an APU over servicing

APU Engine Tear Down inspection results:

- No clear evidence of real fire has been detected on the APU engine itself.
- The external damages correspond with superficial damages as a result of an over temperature exposure, but they are not compatible with flames.
- No oil or fuel leaks were detected during APU operation in the test cell
- Two significant hot air leaks were observed during the APU operation in the test cell and evidence that confirmed both were detected during the tear down of the engine.

APU Fire Detection System is only triggered by:

- Increased overall temperature in the APU Compartment (between 178 and 202°C)
- Increased local temperature (between 452 and 512°C)
- By the time of the event (aircraft climbing at 2900 ft with TAT= 43,2°C), the hot air leaked would have had an estimated temperature of 223°C.
- This hot air flow injection the APU compartment will not explain the APU Fire ECAM alert on its own.

APU Exhaust - Muffler interface damages were reported on MSN 4078.

- Differential pressure between APU Compartment and Muffler allows the introduction of hot gases from the exhaust into the APU compartment when the APU is operated in-flight.
- These hot gases from the exhaust could reach 600°C depending on the operating conditions of the APU.
- APU Bleed OFF significantly increases the APU Exhaust gases air flow, increasing also the hot gases leak into the APU compartment, triggering the APU Fire ECAM alert.

Based on the shop inspection Honeywell concluded that, during climb phase, APU hot air leaks from load control valve & duct in combination with the injection of APU Exhaust gases into the APU compartment would have increased the overall temperature over the triggering limits of the APU Fire ECAM alert, causing the APU Fire indication.

M/s Honeywell has also informed that there are no known industry issues for the scroll housing of T-duct.

1.16.2 Airbus Comments:

A preliminary on wing APU inspection indicated:

1. APU GEN and Starter paint damaged



2. Traces of oil found on oil tank, oil LOP Switch and APU Drain Port



3. APU Rear Drain Oil Traces



The involved APU (131-9[A] - P-4438) was removed for inspection. Honeywell performed inspection and operational test of the APU and provided the following outcomes:

- Borescope inspection performed with no findings.
- Magnetic plug and Oil filters were inspected with no findings
- No clear evidence of real fire has been detected on the APU engine itself.
- The external damages correspond with superficial damages as a result of an over temperature exposure but they are not compatible with flames.
- No oil or fuel leaks were detected during APU operation in the test cell
- Two significant hot air leaks were observed during the APU operation in the test cell and evidences that confirmed both were detected during the tear down of the engine.
- on the T-Duct - Scroll flange
- on the LCV.

During APU teardown, both hot air leaks where confirmed:

- On the T-Duct as the 4 bolts were only hand tightened.



- On the LCV due to a failure of the shaft seal.



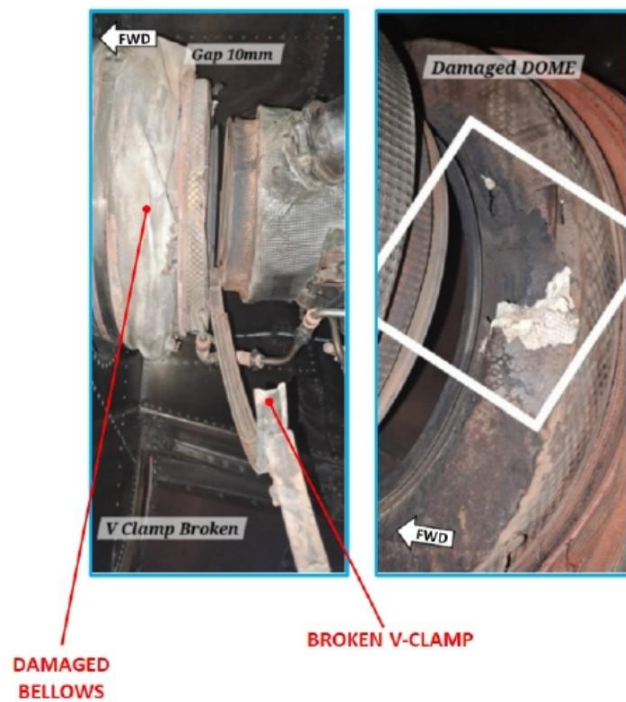
UNIT PART NUMBER	3291432-2	UNIT SERIAL NUMBER	4766	
AMBIENT TEMPERATURE	32.7 DEG F	BAROMETRIC PRESSURE	28.67	IN HG ASS
PERCENT HUMIDITY	68.3 %			
TEST		REQUIREMENT	ACTUAL VALUE	ACCEPT
EXAMINATION OF PRODUCT		ACCEPTABLE WORKMANSHIP APPEARANCE, CLEANLINESS		Fail
DIELECTRIC STRENGTH		2.0 MA MAXIMUM		
INDUCTION RESISTANCE SOLENOID PINS 1, 2, 3, 4 AND 5		100 MEGOHMS MINIMUM		
BONDING RESISTANCE PINS TO TO FLOW BODY FLANGE		15 MILLIVOLTS MAXIMUM		
CONNECTOR CASE TO FLOW BODY FLANGE		15 MILLIVOLTS MAXIMUM		
OPERATING CURRENT		1.5 AMPERES MAXIMUM	0.687	
SWITCH RESISTANCE (VOLTAGE DROP FOR -1)		0.0002 VDC MAX		
SWITCH RESISTANCE (VOLTAGE DROP FOR -2 AND -3)		0.0004 VDC MAX		
SWITCH RESISTANCE (VOLTAGE DROP FOR -1)		0.0002 VDC MAX		
SWITCH RESISTANCE (VOLTAGE DROP FOR -2 AND -3)		0.0004 VDC MAX		
PROOF PRESSURE				
BUTTERFLY CLOSED		NO EVIDENCE OF DAMAGE OR DEFORMATION		
BUTTERFLY OPEN		NO EVIDENCE OF DAMAGE OR DEFORMATION		
MINIMUM VOLTAGE		16 VDC MAXIMUM	0	
PORT LEAKAGE		11 LB/IN (5 KG/IN) MAX		
POSITION INDICATOR SWITCH CONTINUITY OF PINS 2 AND 4		CONTINUITY EXISTS		✓
INCREASING PRESSURE		CONTINUITY IN PINS 2 AND 4 IS BROKEN BY 10 DEGREES MAX FROM FULL CLOSED		DEG
DECREASING PRESSURE		CONTINUITY IN PINS 2 AND 4 IS MADE BY 6 DEGREES MIN FROM FULL CLOSED		DEG
DECREASING PRESSURE		CONTINUITY IN PINS 2 AND 3 IS BROKEN BY 10 DEGREES MAX FROM FULL OPEN		DEG
INCREASING PRESSURE		CONTINUITY IN PINS 2 AND 3 IS MADE BY 6 DEGREES MIN FROM FULL OPEN		DEG
FIVE CYCLE TEST VALVE OPERATION		NO STICKING OR BINDING		Fail
FIVE CYCLE TEST VALVE OPERATION		OPENS AND CLOSSES FULLY PER POSITION SWITCHES		✓
VISUAL POSITION INDICATOR		INDICATES FULL OPEN		
MINIMUM FULL OPENING PRESSURE IN 5 DEGREES OF FULL OPEN POSITION		10 PSIG (69 KPA) MAXIMUM	0.674	Fail
OPENING TIME FROM FULL CLOSE TO WHEN BUTTERFLY IS WITHIN 3 DEGREES FROM OPEN STOP		1.5 SEC MAXIMUM		
CLOSING TIME FROM SOLENOID DE-ENERGIZATION TO WHEN BUTTERFLY STARTS TO MOVE		4.0 SEC MAXIMUM		
CLOSING TIME FROM WHEN BUTTERFLY STARTS TO MOVE TO WHEN BUTTERFLY CLOSSES FULLY		1.5 TO 4.0 SEC MAXIMUM		
CASE LEAKAGE		0.55 LB (0.2 KG) EACH MINUTE MAXIMUM	0.674	Fail
UNIT ACCEPTED DATE _____ (TEST TECHNICIAN)		ACCEPT		

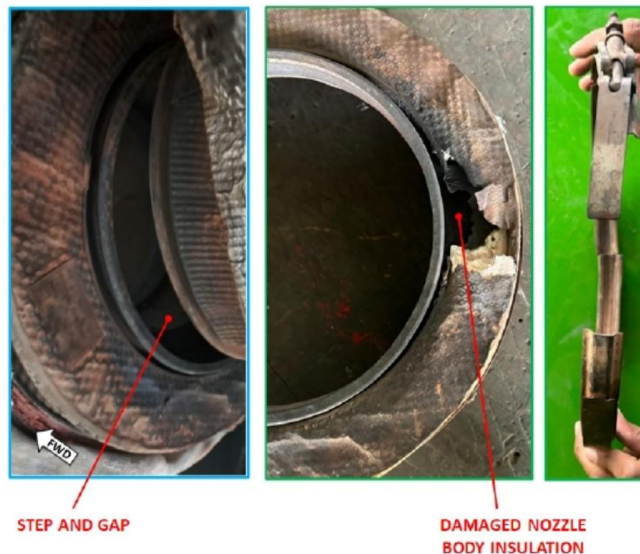
The oil traces on the oil tank, oil LOP Switch and APU Drain Port were confirmed coming from a significant APU oil over-servicing.

It was concluded that there was no evidence of a real fire and no evidence of any APU failure that could have led to an APU fire.

Airbus performed an inspection of the aircraft APU compartment. The APU Compartment firewalls, external surfaces and the APU Integration Components were found globally sooty with significant heat damage observed. But not any signs of fire were detected.

However, During the APU Compartment initial inspection, a gap between the interface thermal blankets and the Nozzle Body thermal blanket was detected. After the removal of the thermal insulation blankets, the APU Exhaust Muffler V-Clamp was found to be broken and displaced. A gap of 10 mm between the APU and the APU Exhaust Muffler was noted. The V-Clamp failure caused not only a gap, but also a step resulting in the misalignment of the APU Engine and APU Muffler centrelines.





Airbus added that, under several operational conditions within the flight envelope, the pressure gradient between the APU Exhaust Muffler inner flow and the APU Compartment could be positive (i.e., the pressure at the APU Exhaust Muffler is larger). Then, a fraction of the APU exhaust gases would be able to discharge into the APU Compartment. These hot gases discharge would have added up together with the APU Engine hot air leaks detected. Also, the triggering of the APU Fire detection System can also take place in an over temperature scenario.

Following the investigation made in cooperation with Honeywell, Airbus confirmed that an increase of the overall temperature in the APU Compartment (between 178 and 202°C) and an increase of the local temperature (between 452 and 512°C) occurred.

By the time of the event (aircraft climbing at 2900 ft with TAT= 43.2°C), the hot air leakage would have had an estimated temperature of 223°C. This hot air flow injection the APU compartment might not explain the APU Fire ECAM alert on its own.

However, When the APU Bleed was switched off during the climb phase, an increase of the mass flow rate through the APU Exhaust would have occurred as a result of the APU Surge Control Valve opening. This increased mass flow rate, together with a favourable gradient of pressure between the APU Exhaust and the APU Compartment, would have led to the discharge of exhaust air flow into the APU Compartment through the gap detected at the APU and APU Exhaust Muffler.

The impact of this discharge flow, combined with the minor leaks coming from the APU Engine, would have increased the APU Compartment temperature over the triggering conditions of the APU Fire Warning System.

As a conclusion:

The most probable scenario is that during MSN 4078 climb phase, the injection of APU Exhaust Gas into the APU Compartment due to failed V-Clamp (increase by the bleed surge condition), in combination with the APU hot gas leaks would have increased the overall

temperature over the triggering limits of the APU Fire detection system, causing the APU Fire ECAM alert.

Airbus confirmed that an increase of the overall temperature in the APU Compartment (between 178 and 202°C) and an increase of the local temperature (between 452 and 512°C) occurred. By the time of the event (aircraft climbing at 2900 ft with TAT= 43.2°C), the hot air leakage would have had an estimated temperature of 223°C. This hot air flow injection the APU compartment might not explain the APU Fire ECAM alert on its own.

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Airbus concluded that during the climb phase, the injection of APU Exhaust Gas into the APU Compartment due to failed V-Clamp (increase by the bleed surge condition), in combination with the APU hot gas leaks would have increased the overall temperature over the triggering limits of the APU Fire detection system, causing the APU Fire ECAM alert.

1.17 Organizational & Management Information:

M/s Air India Ltd. is holding a valid Air Operator Certificate no. S-9 issued by DGCA valid upto 30.06.2028. It operates a fleet of Airbus A-319, A-320ceo and neo, A-321ceo and neo, A350 and Boeing B777-200 and B777-300, B787-800 aircraft serving domestic and international destinations.

M/s Air India Ltd. has an approved CAMO under DGCA approval Q-3/AIR INDIA/CAMO/2744 AOC/S-9. The maintenance of VT-PPT was being performed by M/s Air India Engineering Services Ltd. (AIESL).

It has also been submitted by Air India that as per record last oil filter replacement performed on VT-PPT APU was on 8th Aug 2023. No other record of APU oil uplift found.

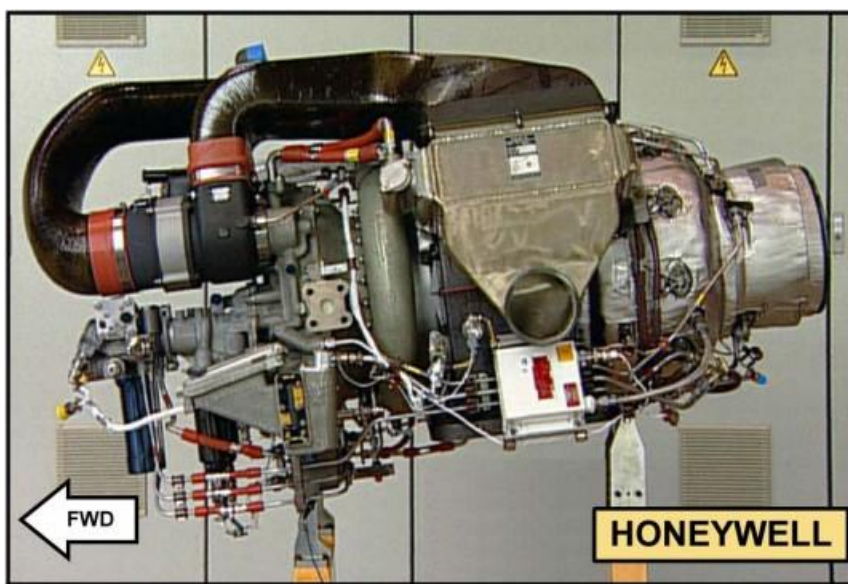
1.18. Additional information:

1.18.1 DFDR review (flights after LCV replacement on 15.05.2024)

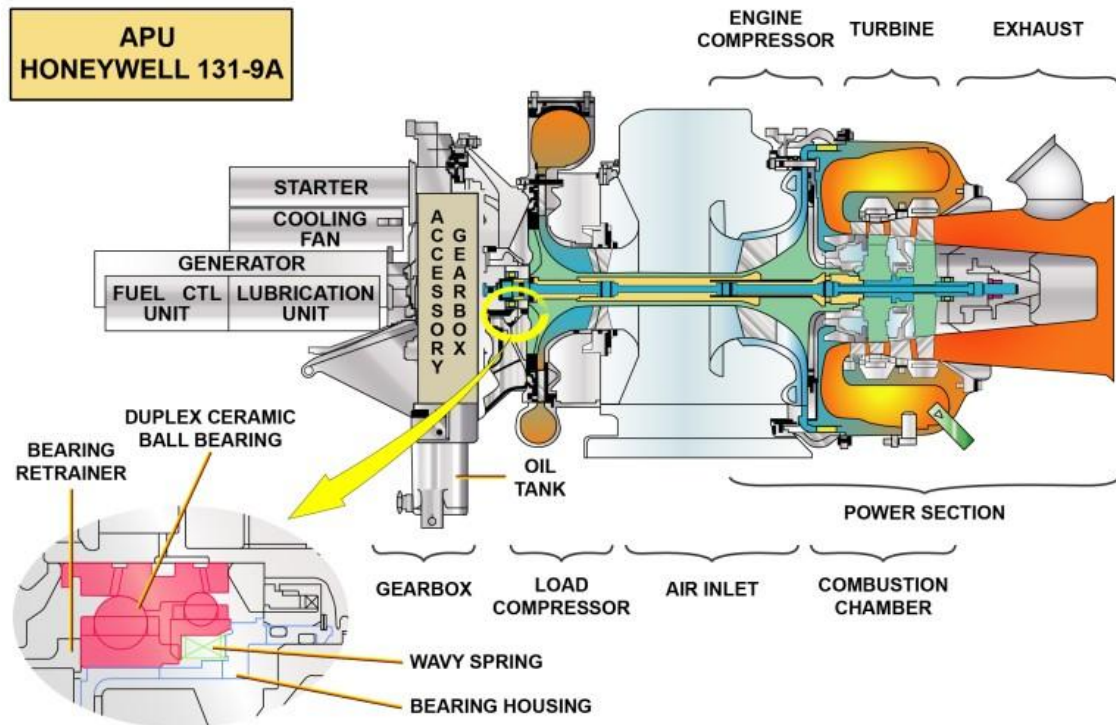
As per the DFDR data review, the data on APU bleed ON/OFF during take-off (since LCV replacement on 13.05.2024, CRS on 15.05.2024) is as detailed below:

Origin	Dest.	Dep. Date	Flight No.	Remarks
VIDP	VIDP	Fri May 17 2024 11:50:29 IST	AI 807	APU BLD ON takeoff
VAUD	VIDP	Fri May 17 2024 09:27:21 IST	AI 470	APU BLD off takeoff
VIDP	VAUD	Fri May 17 2024 07:27:45 IST	AI 469	APU BLD off takeoff
VCBI	VIDP	Fri May 17 2024 02:35:17 IST	AI 282	APU BLD off takeoff
VOMM	VCBI	Fri May 17 2024 00:18:49 IST	AI 273	APU BLD off takeoff
VCBI	VOMM	Thu May 16 2024 12:04:54 IST	AI 274	APU BLD off takeoff
VIDP	VCBI	Thu May 16 2024 07:36:06 IST	AI 281	APU BLD ON takeoff
VABB	VIDP	Thu May 16 2024 04:05:38 IST	AI 866	APU BLD off takeoff
VABO	VABB	Thu May 16 2024 01:47:58 IST	AI 670	APU BLD off takeoff
VABB	VABO	Wed May 15 2024 23:46:14 IST	AI 669	APU BLD off takeoff

1.18.2 APU: Honeywell HW 131-9A



Honeywell HW 131-9A APU



APU Air system:

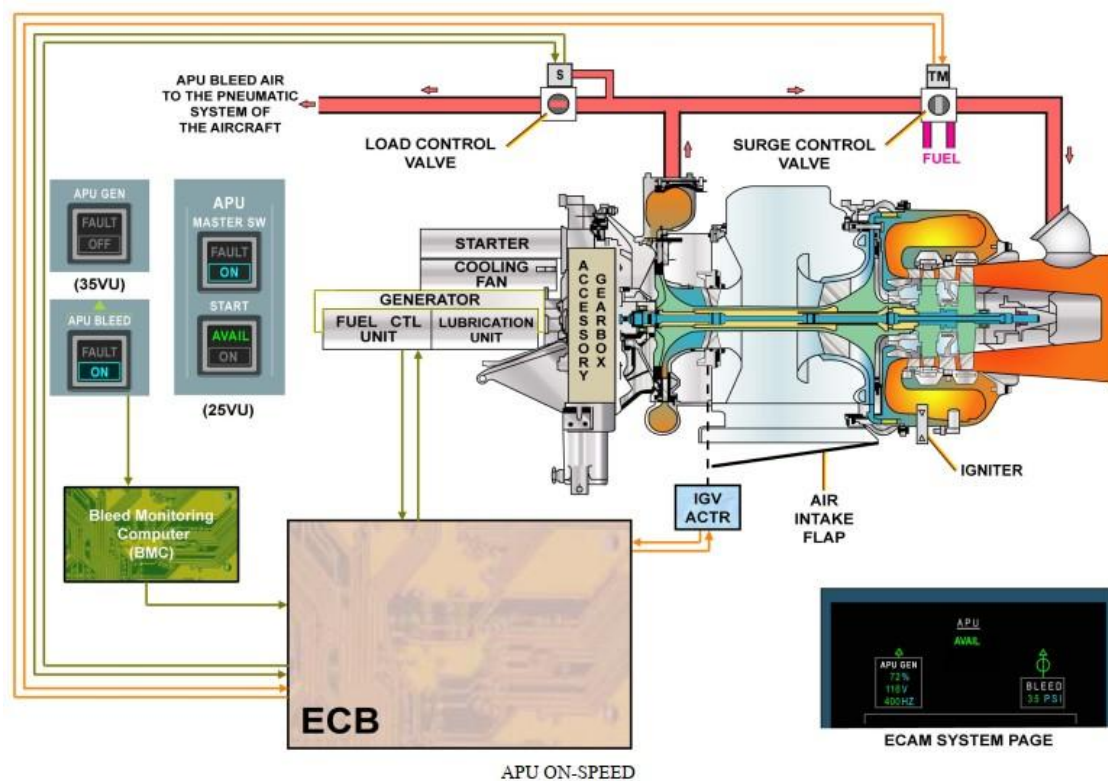
The Auxiliary Power Unit (APU) load compressor supplies the APU bleed air. The quantity changes with the different bleed air demands of the pneumatic system.

Bleed supply: The bleed air supply to the aircraft pneumatic system is controlled by a Load Control Valve (LCV). The pneumatically-actuated CLOSE/OPEN butterfly valve, which allows or stops the bleed airflow from the APU to the aircraft users is controlled by the Electronic Control Box (ECB) and opens when the APU BLEED P/B SW is ON, The APU BLEED PB sends 'ON' signal to the ECB via the Bleed Monitoring Computer (BMC).

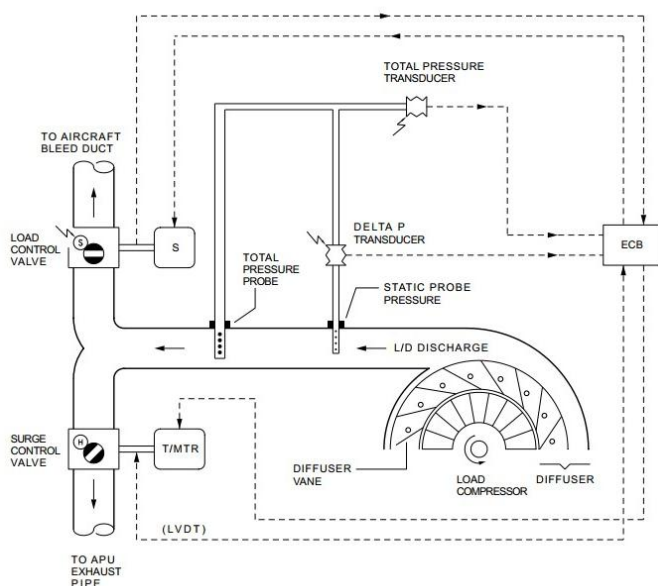
Surge Protection: Load compressor surge protection is ensured by a surge control valve, which discharges the excess of air in the exhaust and prevents compressor surge. The main unit is the Surge Control Valve (SCV). The SCV is installed on the tee-duct in the aft direction to direct excessive bleed air overboard through the APU exhaust. The SCV is a hydraulically actuated butterfly valve, which is normally spring loaded open. A hydraulically operated actuator, controlled by an electrohydraulic servo valve, opens or closes the valve. The hydraulic power is supplied by the high pressure side of the FCU. The ECB controls the servo valve, via a torque motor, to open or close the butterfly valve of the SCV.

Bleed control: The quantity of air necessary to the aircraft bleed users is controlled by the opening angle of the load compressor Inlet Guide Vanes (IGVs). The IGVs are moved by a fuel-powered actuator (IGC-Actuator). Pressurised fuel is supplied by the internal pressure regulator part of the APU Fuel Control Unit.

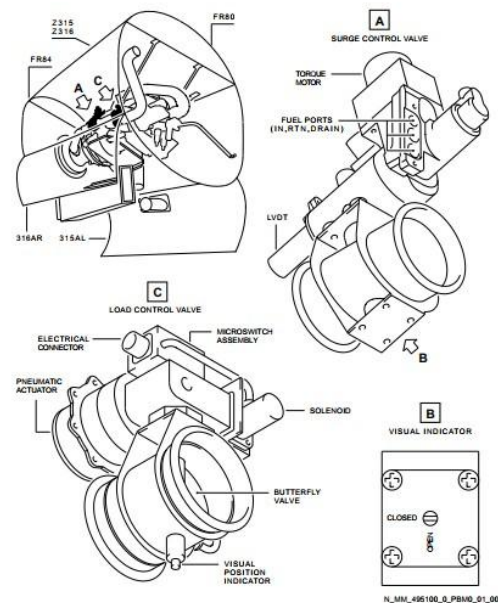
The APU bleed air is supplied to the aircraft pneumatic system from the APU load compressor via the tee-duct and the load valve. The Load Control Valve (LCV) is installed at the forward end of the tee-duct and forms the interface to the aircraft pneumatic system. It is a simple CLOSED/OPEN butterfly valve and therefore not able to regulate the quantity of bleed air flow. It permits or stops the bleed air flow from the APU to the aircraft users. The LCV is normally spring-loaded closed and uses load-compressor bleed-air, controlled by a valve-mounted solenoid, to provide the force for valve opening. The ECB controls and monitors the LCV position. When the ECB receives an APU bleed demand signal it commands the solenoid of the LCV to open the valve. Two switches (full open/full closed) within the LCV transmit position feedback signals to the ECB. A position indicator on the valve shaft gives additional visual information of the LCV position. The different quantity of APU bleed air flow is depending of the aircraft pneumatic system demands like:- MES- ECS, To control the bleed air flow, delivered by the load compressor, and to prevent APU overtemperature it is necessary to regulate the air flow guided to the load compressor inlet. This is achieved by the Inlet Guide Vanes (IGV). The IGVs are moved by the Inlet Guide Vane Actuator (IGVA), which uses fuel hydraulic power to position the IGVs. The IGV position is computed by the ECB, primarily based on- aircraft bleed demand (i.e. MES, ECS),- ambient temperature (T2), and the inlet pressure (P2).



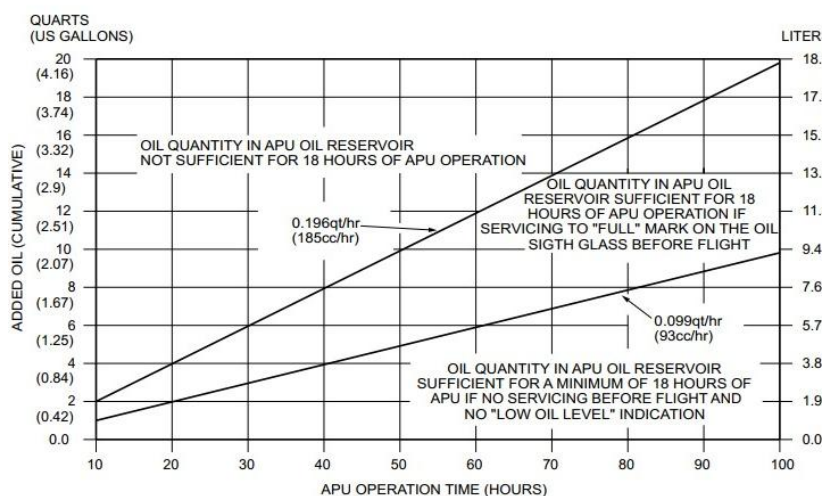
APU running at ON-SPEED



AMM reference: APU- Bleed and Surge block diagram



AMM reference: APU Bleed and Surge Component location



NOTE:
MAXIMUM OIL CONSUMPTION FOR NEW OR NEWLY OVERHAULED
APU IS 0.007qt(6.5cc) AN HOUR

CAUTION:

OIL CONSUMPTION IS THE INTERNAL LOSS OF OIL FROM BEARING SEALS AND AIR/OIL SEPARATOR DURING THE APU OPERATION. EXTERNAL LEAKS ARE NOT PERMITTED. CORRECT EXTERNAL LEAKS AND CLEAN THE APU, APU COMPARTMENT AND APU AIR INTAKE IMMEDIATELY, IF CONTAMINATED. IF THE OIL CONSUMPTION IS MORE THAN 93 cc/hr, OR THERE IS A SUDDEN INCREASE IN OIL CONSUMPTION, DO THE OIL CONSUMPTION MONITORING VERY CAREFULLY TO PREVENT BAD APU DAMAGE.

NOTE:

THE ADDED OIL (CUMULATIVE) (VERTICAL SCALE) IS THE TOTAL QUANTITY OF OIL ADDED IN TO THE APU OIL RESERVOIR TO COMPENSATE FOR THE APU OIL CONSUMPTION DURING AN APU OPERATION TIME PERIOD (HORIZONTAL SCALE).

AMM reference: APU oil consumption

APU Exhaust System:

The APU exhaust system ducts the engine exhaust gas overboard. Its secondary function is to decrease the exhaust noise level. To keep aerodynamic losses during APU operation to a minimum, the duct has a sufficiently large diameter. The APU exhaust system discharge is positioned at the very aft end of the aircraft, there, a low pressure area is generated during flight. This design makes sure that exhaust gases do not re-enter the APU air intake system.

Muffler Assembly.

The forward end of the muffler assembly is attached to the APU turbine flange. The rear extends through the access fairing 317AL into the airstream. The APU compartment aft fire wall (FR 84) has a cutout for the muffler assembly. The muffler assembly is held by rails which are part of the tailcone muffler compartment.

A flexible connection allows for relative movement between the APU and the muffler assembly and allows for any vibrations and inertia loads during operation. Drainage provisions are incorporated into the muffler assembly. One ventilation louver each at the top and the bottom of the muffler compartment limits the structure temperature to 110 deg. C max. The muffler assembly surface temperature does not exceed 232 deg. C.

(1) Major Components of Exhaust Muffler Body:

(a) Muffler Substructure

This is a riveted corrosion resistant steel (CRES) structure, made of frames, an outer tube and provisions for external seals and insulation segments. It has the function of:

- the load carrying structure of the complete muffler assembly,
- the muffler resonator,
- attaching the muffler assembly to the rails in the tailcone muffler compartment.

(b) FR84 Fire Wall Seal

A circumferential fireproof seal is installed on a bracket on the muffler substructure. It seals the gap between the fire wall cutout in FR84 and the exhaust muffler assembly.

(2) Hot Nozzle Assembly

This component is directly attached to the APU turbine flange with a V-clamp. It is in contact with the tail pipe assembly through the piston ring and the muffler body through the externally installed bellows. APU movement is not transmitted to the muffler assembly. A drain port is installed at the lowest point.

(3) Bellows

It is the flexible connection between the hot nozzle and the muffler body. It is also a back-up seal to prevent exhaust gas leakage into the APU compartment. It is attached to both items with band clamps. It allows movement between the APU and the muffler body. Bellows are made of Glass Silicone web material.

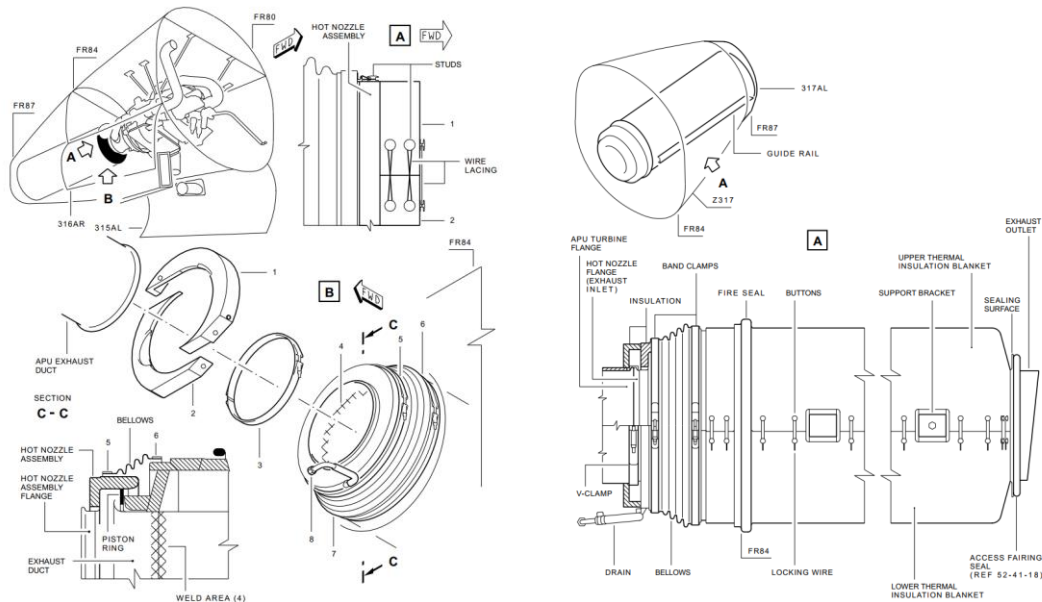
(4) V-Clamp Insulation Segments

To make sure that the surface temperature does not exceed 232 Deg. C, the connection between the APU turbine flange and the hot nozzle assembly is insulated. Two half-circle insulation segments cover the interface, held in position with lockwire fastened to the buttons on these items

Muffler Assembly Installation:

Support rails align the assembly with the APU. Longitudinal positioning is provided at the rear attachment brackets only. Lateral positioning is made by fixing the assembly to the left rail. The distance between the rails is 6mm larger than the distance between the muffler assembly attachment brackets. Thus the muffler assembly is positioned 3mm to the left of the APU longitudinal axis. The attachment at the right rail allows for thermal expansion differences.

The 3mm displacement is taken up at the muffler assembly/APU turbine flange interface by the bellows and the sealing ring.



APU exhaust (AMM reference)

1.18.3 FCOM Reference:

PACKS: Normal Procedures: Standard Operating Procedures-Before Takeoff

If the take-off has to be achieved without air bleed fed from the engines for performance reasons, but air conditioning desired, the APU bleed may be used with packs ON, thus maintaining engine performance level and passenger comfort. In case of APU auto shut down during take-off, the engine thrust is frozen till the thrust is manually reduced. The packs revert to engine bleed which causes an increase of EGT to keep N1/EPR.

If the take-off is performed with one pack unserviceable, the procedure states to set the failed pack to OFF. The take-off may be performed with the other pack ON (if performances permit) with TOGA or FLEX thrust, the pack being supplied by the onside bleed. In this asymmetric bleed configuration, the N1 take-off value is limited to the value corresponding to the bleed ON configuration and take-off performance must be computed accordingly.

FIRE DETECTION

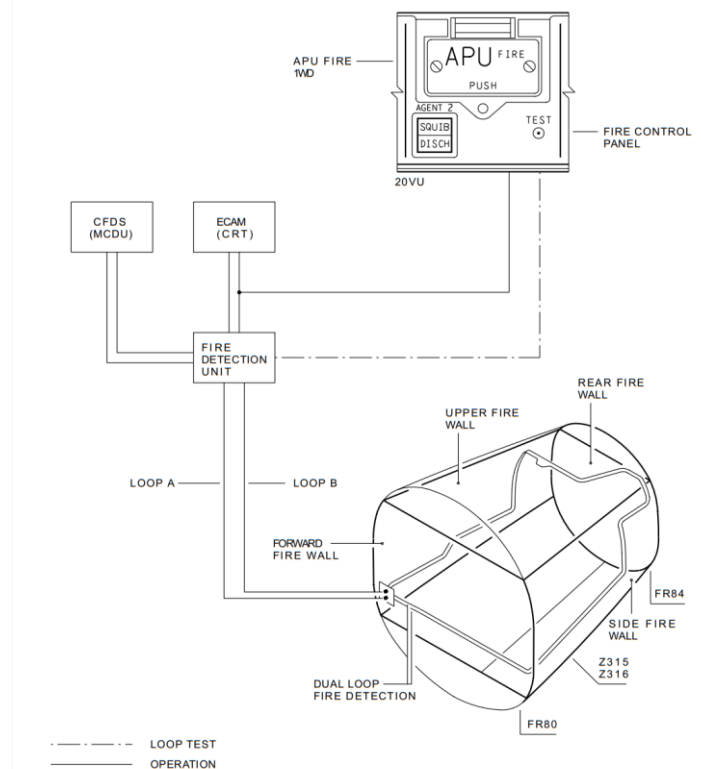
The engines and the APU each have a fire and overheat detection system consisting of: -
Two identical detection loops (A and B) mounted in parallel

- A Fire Detection Unit (FDU). The fire detection loops consist of:
- One fire sensing element in the APU compartment.

When a sensing element is subjected to heat, it sends a signal to the FDU. As soon as loops A and B detect temperature above a preset level, the fire warning system is triggered.

A fault in one loop (break or loss of electrical supply) does not affect the warning system and the unaffected loop still protects the aircraft.

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



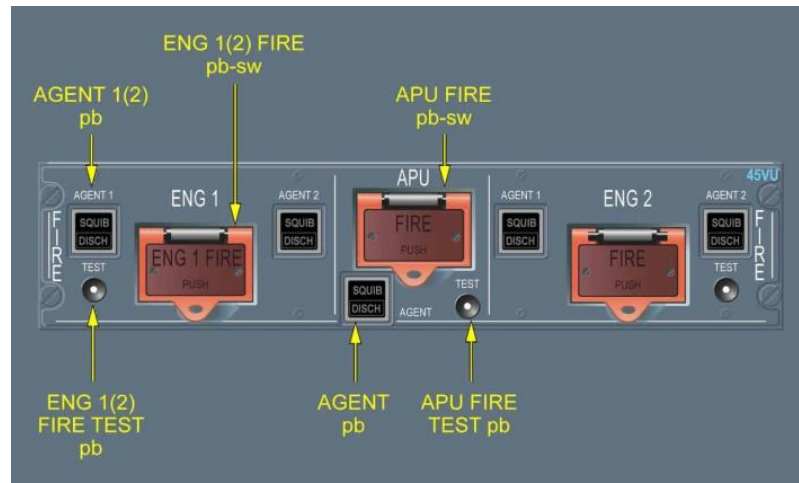
APU Fire and Overheat detection (AMM reference)

APU FIRE PB-SW

The PB-SW normal position is in, and guarded. When the flight crew pushes it, the PB-SW is released and sends an electrical signal that performs the following for the APU:

- Shuts down the APU
- Silences the aural warning
- Arms the squib on the APU fire extinguisher - Closes the low-pressure fuel valve
- Shuts off the APU fuel pump
- Closes the APU bleed valve and X bleed valve and deactivates the APU generator.

The red lights come on, regardless of the PB-SW position, whenever an APU fire warning is activated.



Fire Panel

AGENT PB

The APU AGENT PB becomes active when the flight crew releases the APU FIRE PB-SW. A brief push on the pushbutton discharges the corresponding fire agent.

- “SQUIB” comes on white when the pilot releases the APU FIRE pb-sw.
- “DISCH” comes on amber when the fire extinguisher bottle has lost pressure.

Note: A red disk, which is outside at the rear of the fuselage, signals that the agent is not discharged overboard due to bottle overpressure.

1.18.4 FCOM reference: ABNORMAL AND EMERGENCY PROCEDURES: APU Fire

APU FIRE

Applicable to: ALL

Ident.: PRO-ABN-APUF-C-00017402.0001001 / 21 MAR 16

ANNUNCIATIONS

Triggering Conditions:

L2

This alert triggers when:

- Fire is detected by both loops, or

- Fire is detected by one loop when the other loop is faulty, or

- A rupture occurs in both loops within 5 s.

Flight Phase Inhibition:

Phase	Event	Inhibition
1	ELEC PWR	No
2	1ST ENG STARTED	No
3	1ST ENG TO PWR	No
4	80 kt	No
5	LIFTOFF	Yes
6	1500 ft	Yes
7	800 ft	Yes
8	TOUCHDOWN	Yes
9	80 kt	No
10	2ND ENG SHUTDN	No

Ident.: PRO-ABN-APUF-C-00017925.0001001 / 21 MAR 16

LAND ASAP

APU FIRE P/B.....PUSH

L2

APU LP valve closes.

Aural warning stops.

APU FIRE pb-sw remains on, as long as a fire is detected.

L1

AGENT AFTER 10 S.....DISCH

L2

The 10 s delay allows the airflow to decrease, which increases the effect of the agent.

Automatic countdown on the ECAM.

L1

MASTER SW.....OFF

L2

Do not attempt to restart the APU.

Continued on the following page

AIC A318/A319/A320/A321 FLEET

FCOM

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PRO-ABN-APUF P 1/2

22 MAR 17

APU FIRE (Cont'd)

Ident.: PRO-ABN-APUF-C-00012211.0001001 / 16 NOV 11

STATUS

INOP SYS

APU

Investigation report: VT-PPT AI-807 17.05.2024

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1.18.5 AMM reference (fire detection): The fire detection system consists of two identical (electrically independent) loops (A and B). They are installed in the APU compartment adjacent to critical components, such as:

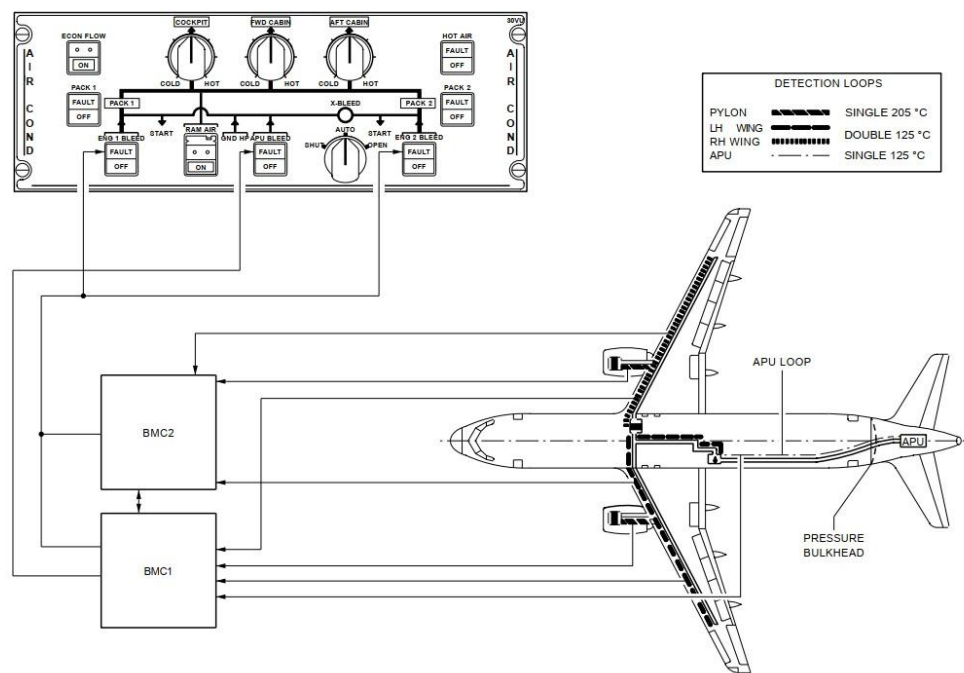
- fuel lines,
- starter generator,
- FCU,
- ignition box,
- turbine plenum.

1.18.6 AMM reference (Bleed detection): Leak detection loops are installed along with the hot air supply ducts of the pneumatic system and are connected to the BMCs. The leak detection system is organized into three loops. The loops and the protected areas:

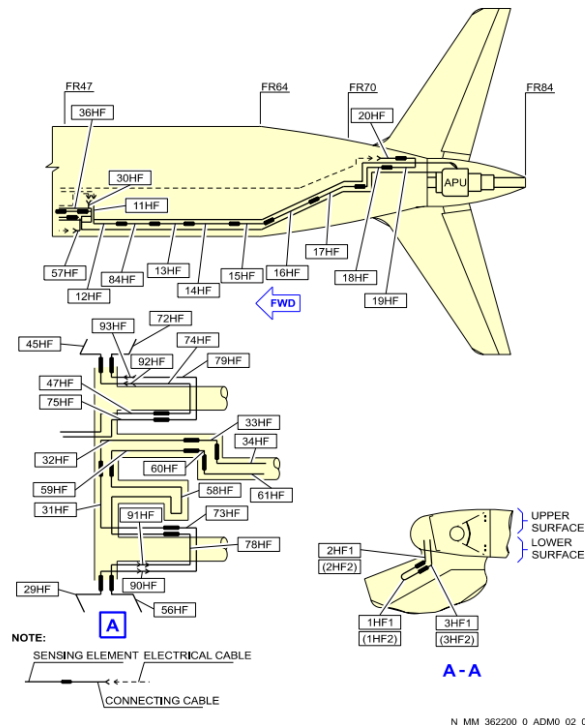
Pylon: the pre-cooler outlet area,

Wing: wing leading edge and belly fairing

APU: APU aft supply duct (left hand side of the fuselage) from APU firewall to wheel well area.



Bleed Leak Detection Loops



APU Bleed detection loop

1.19 Useful or effective investigation techniques:

Nil.

2. Analysis:

2.1 Operational handling of the aircraft:

PIC was the PF operating the sector. Both the flight crew were holding valid licenses for operating the type of aircraft and had sufficient flying experience for the duties assigned to them. As per Airbus philosophy w.r.t. handling of ECAM warning or cautions, if an ECAM warning disappears while a procedure is being applied, the warning can be considered no longer applicable. Application of the procedure can be stopped. In the subject case, the warning disappeared after application of the ECAM procedure by the flight crew. The crew actions were satisfactory.

2.2 Serviceability of the aircraft:

The aircraft VT-PPT was entered in the register of India w.e.f. 30.10.2009 by DGCA-INDIA and its last ARC was issued on 15.02.2024 which was valid till 17.02.2025. The last major inspection was A check performed on 15.05.2024.

The aircraft was installed with Honeywell APU 131-9A, S/N: P4438 on 06.04.2021. The APU had completed a total of 29060 Hrs (TSN) and 31722 Cycles. M/s Air India Ltd. has an approved CAMO under DGCA approval Q-3/AIR INDIA/CAMO/2744 AOC/S-9. The maintenance of VT-PPT was being performed by M/s Air India Engineering Services Ltd. (AIESL).

Leak detection loops are installed along with the hot air supply ducts of the pneumatic system and are connected to the BMCs. The APU leak detection loop is installed on the APU aft supply duct (left hand side of the fuselage) from APU firewall to wheel well area. No bleed leak detection loop is installed on the duct in the APU compartment.

MEL history on the APU revealed that two APU bleed related MELs (AIR APU BLEED FAULT, MEL 36-12-02B Cat C & MEL 36-12-01A Cat C) were invoked in Kolkata and Delhi on 12.04.2024 and 13.04.2024 respectively. They were revoked on 13.04.2024 during the layover inspection at Delhi by replacing the Surge control valve. APU oil cooler was replaced due to operational requirement for cleaning. Due to the trending high oil temperature, preventive maintenance to avoid auto shutdown due high oil temperature, oil cooler replaced with serviceable one. Post replacement, oil temperature was found satisfactory. Further, on 02.05.2024, APU MAINT. MSG., MEL 49-07-01A Cat C was invoked at Colombo and was revoked on 09.05.2024 at Mumbai by removing the load control valve connector, cleaning and refitting it back. On 11.05.2024, APU IN MAINT., MEL 49-00-01A Cat C was invoked at Amritsar and was revoked on 15.05.2024 at Mumbai by replacing the Load control valve. All the MELs were revoked within the specified time limits for category C MEL.

No records could be produced by M/s Air India regarding the last oil uplift on APU. Nil APU Oil uplift from the last 06 months was noted on the subject APU as verified from AMOS /Tech Log pages and LAYOVER / WEEKLY checks whereas the nominal oil consumption as per AMM is 6.5 cc/hr for a new APU/newly overhauled APU.

During shop visit, OEM Honeywell commented that before starting the APU, the Oil level was checked and it was significantly over the "FULL" mark. The evidences found confirmed that the oil leak occurred with the APU on wing as a result of an APU over servicing. This indicates that M/s Air India CAMO was not monitoring the oil consumption and the condition of the subject APU.

Honeywell added that only superficial damages were detected during the APU incoming inspection at the Honeywell facility. During dry Crank, no oil leaks detected. During Wet crank, no Fuel leaks were detected.

Following significant observations were reported by the OEM in shop report:

APU Low Bleed Pressure detected on almost every APU Bleed Supply maneuvers

APU Hot Air Leaks detected on the T-Duct - Scroll flange and on the LCV:

Load Compressor Scroll flange hot air leak was confirmed because 4 bolts were found to be improperly torqued. During the APU operation, with the thermal expansion of the parts, a gap was created between the LC scroll and the T-Duct resulting in a significant hot air leak.

On separate testing of the Load Control Valve in Honeywell lab, external hot air leakage detected was through the LCV shaft seal, the leakage rate of which was completely out of the acceptable value.

During the investigation the various maintenance activities performed on the days leading to the incident were evaluated, though maintenance were performed on the SCV replacement on 13.04.2024, LCV including electrical connection cleaning and reinstallation on 09.05.2024 and LCV replacement on 15.05.2024, no evidence could be traced which could lead to a finding w.r.t. any activity which would require removal of the Load Compressor Scroll flange, that was found to be improperly torqued during the shop inspection after the incident. The replacement of the valves only requires the disconnection of clamps and no torquing of bolts are involved. The evaluation of the AMP and AMM indicated that there are no tasks w.r.t. the APU Load compressor in Line maintenance.

The APU (P/No.4438) was sent to shop for investigation in August 2018 for hot section distress after removing from another A321 aircraft VT-PPE in July 2018. The APU had accumulated a total of 8975 hours after the last shop visit and since installation of VT-PPT in 2021. Although work was carried out on the bleed related components in the shop, leak from the Load Compressor Scroll flange due to improper torquing of bolts could not be attributed to the said shop visit in 2018 considering no similar defect history from installation of APU in 2021 till the subject incident.

No records/instances of any line maintenance activity performed in the said area on the APU could be identified and hence the reason for hand tightening of all the four bolts on the load compressor scroll flange could not be identified. For the same reason, it appears to be a case of unauthorised work beyond scope of approval.

M/s Honeywell has reported that there are no known industry issues for the scroll housing of T-duct.

Exhaust Muffler interface damages were reported on the APU. During the APU Compartment initial inspection, a gap between the interface thermal blankets and the Nozzle Body thermal blanket was detected. After the removal of the thermal insulation blankets, the APU Exhaust Muffler V-Clamp was found to be broken and displaced. A gap of 10 mm between the APU and the APU Exhaust Muffler was noted. The V-Clamp failure caused a gap and a misalignment of the APU Engine and APU Muffler centrelines.

Muffler insulation covers and bellows inspection is covered under the Aircraft Maintenance Programme at an interval of 36 months. It is inferred that M/s Air India had no records of the said inspection, as reply was not submitted even after several reminders. The replacement of the exhaust muffler/bellows is not a hard time task and its general visual inspection covers examination of the bellows for tears and cracks, examination of the two bellows band clamps

for signs of damage, examination of the thermal insulation of the exhaust muffler for tears, cracks or discoloration.

Further the matter was discussed in detail with M/s Air India and it was reported that no such observations were reported on any other similar aircraft when a one-time fleet wide check on the exhaust muffler was performed following the incident.

Review of the maintenance and flight data indicates that the last maintenance on the APU, wherein the APU compartment was opened was on 13.05.2024 and aircraft was released to service on 15.05.2024. The APU had accumulated 25 Hrs and 29 cycles since LCV Installation (replacement on 13.05.2024 and released to service on 15.05.2024). No observation of black soot was made by the AME during LCV replacement on 13.05.2024, any such evidence would have been unlikely to remain unnoticed. Also, it has been identified that, after the LCV replacement on 13.05.2024 and subsequent release to service on 15.05.2024, only one APU BLEEDS ON takeoff was performed out of the ten flights. Hence, it appears that the muffler damage might have occurred after the release to service on 15.05.2024.

CAMO of M/s Air India failed to effectively monitor and ensure that the actual cause of the defect was identified through the maintenance performed. There were significant gaps in the oversight on part of the of the airline CAMO over the maintenance of its aircraft by the contracted Aircraft Maintenance Organisation, AIESL wherein the oil uplift, oil consumption of the on-wing APU were neither known to the airline CAMO nor was it identified prior to the incident. It is inferred that M/s Air India CAMO had no records of the exhaust muffler and bellows related inspection, as reply was not submitted even after several reminders.

2.3 Circumstances leading to the incident:

Prior to take off from Delhi, the APU was kept ON: and both packs were utilised with cross bleed valve kept OPEN, APU GEN was ON.

This was a typical operation for hot days in order to remove the non-propulsive loads from the Main Engines, while at the same time bleed is made available for air conditioning of the cabin, considering the high ambient temperature.

104 seconds after lift-off while the aircraft was in climb crossing 2009ft, APU BLEED was switched OFF. Nine seconds after APU BLEED was removed, APU FIRE warning was recorded at 12:03:06 UTC. 16 seconds after APU FIRE alert was triggered, APU GEN load was removed and the FIRE warning was active for 28 seconds.

During shop inspection, no clear evidence of real fire has been detected on the APU engine itself. The external damages (paint damage to the APU components) correspond with superficial damages as a result of an over temperature exposure, but they are not compatible with flames.

Considering the time of the event (aircraft climbing at 2900 ft with TAT= 43.2°C), the hot air leaked was estimated to have a temperature of 223°C. However as per OEM definition, this hot air flow introduction into the APU compartment alone would not result in an APU Fire ECAM alert. However, inspection revealed damaged to the APU Exhaust - Muffler interface. The differential pressure between APU Compartment and Muffler allows for the introduction of hot gases from the exhaust into the APU compartment when the APU is operated in-flight, which could reach 600°C depending on the operating conditions of the APU. The APU Bleed OFF significantly increase the APU Exhaust gas air flow, increasing also the hot gases leak into the APU compartment, this combination of hot bleed air leak and exhaust gases would have increased the overall temperature over the triggering limits of the APU Fire ECAM alert, and was the reason identified for triggering the APU Fire ECAM.

3. Conclusion:

3.1 Findings:

1. The aircraft was having a valid Certificate of Registration and Airworthiness Review Certificate at the time of incident. The applicable Airworthiness Directive, Service Bulletins were complied with on the aircraft. There were no defects reported prior to the occurrence sector or any items related to APU or performance limiting MEL.
2. Weather was not a contributory factor to the incident.
3. The PIC was the Pilot Flying and the First Officer was the Pilot Monitoring, for the incident sector. Flight Duty Time of both the crew members was within the specified limits. Both the crew members were having valid licences and ratings for operating the aircraft.
4. Both the operating crew members were subjected to pre-flight medical test at the starting of the flight duty cycle at Delhi and after a 'negative' result for alcohol breath analyser test, they were cleared for flight operations.
5. No bleed leak detection loop is installed on the duct in the APU compartment.
6. APU bleed was put to ON for take off for air conditioning as this is a typical operation for hot days.
7. During climb phase APU bleed was turned OFF and APU FIRE ECAM warning triggered which was active for about 28 seconds.
8. Crew shutdown the APU and the agent was discharged. 'PAN PAN' call was made by the crew and the aircraft landed back at Delhi.
9. Black soot was observed in the upper portion of the APU compartment. Paint discoloration/ heat damage signs were observed on rear portion of the RH APU cowl door.
10. No smoke was reported in the aircraft cockpit or cabin. No injury was reported to the crew or passengers.
11. Crew actions after being alerted by the ECAM message were satisfactory and in compliance of the checklists.
12. The APU last shop visit (at APU TSN: 20085, CSN: 19108) was in August 2018 for Hot section distress after removal from A321 aircraft VT-PPE in July 2018.

13. The subject APU (S/No. P4438) was installed on 06.04.2021 on the aircraft VT-PPT. The APU has accumulated 8975 hrs after installation on the aircraft VT-PPT.
14. The LCV (S/No.: 4766) installed on 13.05.2024 on APU (S/N: P4438) [VT-PPT] was cannibalised from APU P-6304 (which was an OFF wing APU).
15. APU P-6304 did not have any previous history on LCV or other APU BLEED issue prior to cannibalisation of the LCV (S/N: 4766).
16. The findings made during shop analysis of the APU (S/No: P4438) revealed the following:
 - a. Oil level was checked during induction in the shop and it was reported to be significantly over the “FULL” mark.
 - b. The external damages correspond with superficial damages as a result of an over temperature exposure but they are not compatible with flames.
 - c. No oil or fuel leaks were detected during APU operation in the test cell.
 - d. Two significant hot air leaks, one on the T-Duct - Scroll flange and other on the LCV were observed during the APU operation in the test cell and evidences that confirmed both were detected during the tear down of the engine.
 - e. Both hot air leaks were confirmed on the T-Duct as the 4 bolts were only hand tightened & on the LCV due to a failure of the shaft seal.
 - f. The oil traces on the oil tank, oil LOP Switch and APU Drain Port were confirmed coming from a significant APU oil over servicing.
 - g. Exhaust Muffler interface damages were reported on the APU. A gap between the interface thermal blankets and the Nozzle Body thermal blanket was detected. APU Exhaust Muffler V-Clamp was found to be broken and displaced. The V-Clamp failure caused a gap and a misalignment of the APU Engine and APU Muffler centrelines.
 - h. Honeywell concluded that there was no evidence of a real fire and no evidence of any APU failure that could have led to an APU fire.
17. APU hot air leaks from load control valve & T-Duct - Scroll flange in combination with the ingestion of APU exhaust gases into the APU compartment due to APU Exhaust Muffler V-Clamp failure, would have increased the overall temperature over the triggering limits of the APU Fire ECAM alert, causing the APU Fire indication.
18. During two instances on 12.04.2024 & 13.04.2024 APU bleed related MELs were invoked and the same were revoked on 13.04.2024 layover inspection by replacing the Surge control valve.

APU MAINT. MSG., MEL was invoked at Colombo on 02.05.2024 and was revoked on 09.05.2024 at Mumbai by removing the load control valve connector, cleaning and refitting it back.

APU IN MAINT., MEL was invoked at Amritsar on 11.05.2024 and was revoked on 13.05.2024 at Mumbai by replacing the Load control valve. Subsequently the aircraft was released on 15.05.2024.
19. It seems that the muffler damage might have occurred after the aircraft’s release to service on 15.05.2024.

20. No APU oil uplift records were available for the past 06 months prior to the incident, whereas the nominal oil consumption as per AMM is 6.5 cc/hr for a new APU/newly overhauled APU.
21. No evidence could be traced to any activity which would require removal of the Load Compressor Scroll flange, that was found to be improperly torqued during the shop inspection after the incident. The evaluation of the AMP and AMM indicated that there are no tasks w.r.t. the APU Load compressor in Line maintenance.
22. The replacement of the valves (SCV & LCV) only requires the disconnection of clamps and no torqueing of bolts are involved. Since all the 04 bolts on the load compressor scroll flange were found hand tightened and the finding was limited to only VT-PPT, the instance could not be identified/traced.
23. Muffler insulation covers and bellows inspection is covered under the Aircraft Maintenance Programme at an interval of 36 months. However, M/s Air India had no records of the said inspection.
24. M/s Air India CAMO failed to monitor the APU oil uplift & consumption and thereby the condition of the said APU. Also, exhaust muffler and bellows related inspection details were not tracked timely by M/s Air India CAMO.
25. A one-time fleet wide check on the exhaust muffler was performed by M/s Air India following the incident and no observations were reported.

3.2 Probable cause:

The most probable cause of the incident was APU hot air leaks from load control valve & T-Duct - Scroll flange in combination with the ingestion of APU exhaust gases into the APU compartment, which would have increased the overall temperature over the triggering limits of the APU Fire ECAM alert, causing the APU Fire indication.

Lack of effective control of M/s Air India CAMO on the maintenance activities being performed on the APU contributed to the incident.

4. Safety Recommendations:

1. DGCA HQ may take appropriate action on M/s Air India for not ensuring the satisfactory completion of scheduled tasks and for not monitoring the oil uplift/ oil consumption data of the APU.
2. M/s Air India to monitor APU Oil consumption, uplift and condition of the APU on all its A320 family fleet and ensure oil over servicing is avoided.
3. Based on Finding 16 (g), DGCA may advise all A320 family aircraft operators to carry out one-time fleet wide inspection of the APU exhaust components.

(KONAKANCHI SUPRADEEP)
Air Safety Officer
Member

(LINJU VALAYIL PHILIP)
Deputy Director of Air Safety
Investigator-In-Charge

Date: 02.09.2025

Place: New Delhi