NATIONAL TRANSPORTATION SAFETY BOARD
Investigative Hearing
Alaska Airlines Flight 1282
Boeing 737-9, N704AL
Left Mid Exit Door Plug Separation in Portland, OR
January 5, 2024

Docket No.	SA-543
EXHIBIT	
9A	

Systems Group Chair's Factual Report

(30 Pages)

National Transportation Safety Board

Office of Aviation Safety

Washington, DC 20594

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SYSTEMS

Group Chair's Factual Report

June 28, 2024

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A. ACCIDENT

Location: Portland, OR
Date: January 5, 2024
Time: 1714 pacific standard time (PST)
0114 coordinated universal time (UTC) / (January 6, 2024)
Airplane: 737-9, N704AL

B. SYSTEMS GROUP

Group Chair	Adam Huray NTSB Washington, DC
Group Member	Eric Brown FAA Seattle, WA
Group Member	Bob Wiley Alaska Airlines Portland, OR
Group Member	Lars Gunnarsson Boeing Renton, WA
Group Member	Chris Heck ALPA McLean, VA

C. SUMMARY

On January 5, 2024, at about 1714 pacific standard time, Alaska Airlines flight 1282, a Boeing 737-9, N704AL, returned to Portland International Airport (PDX) after the airplane suffered a rapid decompression when the left mid-cabin door plug departed the airplane, resulting in substantial damage. On board were 2 flight crew, 4 cabin crew and 171 passengers all of whom deplaned at the gate. Several passengers received minor injuries. The flight was a Title 14 CFR part 121 scheduled domestic passenger flight from PDX to Ontario, California (ONT).

D. CABIN PRESSURE CONTROL SYSTEM DESCRIPTION

1.0 Normal Operation

The cabin pressurization system maintains a safe, comfortable cabin pressure altitude at all times. Air conditioning packs continuously force air into the airplane pressure vessel. The cabin pressurization control works by adjusting the position of the outflow valve gates, which changes the rate of air released from the cabin. Under normal operations, the maximum cabin pressure altitude is around 8,000 feet (ft). The pilots can control the cabin pressure in these modes:

- Automatic mode
- Alternate mode
- Manual mode

Controls and indications for the pressurization system are on the P5 forward overhead panel (see Figure 1). There are two cabin pressure controllers (CPCs). Both CPCs are identical, with one CPC identified as the CPC-in-command and the other CPC identified as the alternate. The CPC-in-command alternates each flight leg, with the end of a flight leg occurring at touchdown during landing. Each CPC has its own pressure sensor to sense cabin pressure. The CPCs are installed in the main electronics compartment.

In the automatic pressurization control modes (automatic and alternate), the CPCs automatically schedule cabin pressurization for all phases of the flight. The automatic pressurization schedule is calculated based on the flight altitude and landing altitude which is set by the pilot prior to departure (see section D.2.1 of this report). The CPC-in-command compares the target pressure to the pressure at its internal pressure sensor. If there is a difference, the CPC sends an open or close command to the electronic actuator on the outflow valve assembly. The CPC-in-command modulates the outflow valve to control cabin pressure and rate of pressure change in the cabin. In the event of a negative cabin to ambient differential pressure (lower pressure inside the cabin compared to ambient), the CPC will drive the OFV open.

The P5-6 panel is used to select operational mode (automatic, alternate, or manual) and input the intended flight altitude and landing field elevation. If both CPCs fail, the pilots can control the outflow valve manually by using a switch on the P5-6 panel.[1] Each CPC and the manual control system has its own systems interface and outflow valve actuator motor which gives the pressurization control system a

[1] The Quick Reference Handbook procedure for a Cabin Altitude Warning directs the crew to select manual pressurization and drive the outflow valve fully closed prior to beginning an emergency descent.

triple redundant architecture. The outflow valve is located in the aft, lower right area of the airplane.

Other components related to the cabin pressurization system include positive pressure relief valves, a negative pressure relief valve, and blowout panels (see section D.3.0 of this report for system descriptions of these components). There is also an overboard exhaust valve underneath the forward electronics compartment that discharges equipment cooling exhaust air on the ground. Under normal operation, this valve automatically closes during flight. See Figure 2 for component locations.

Figure 1. Cabin pressure control switches and indications on the P5 panel. The P5-6 selector panel is outlined by the white square.

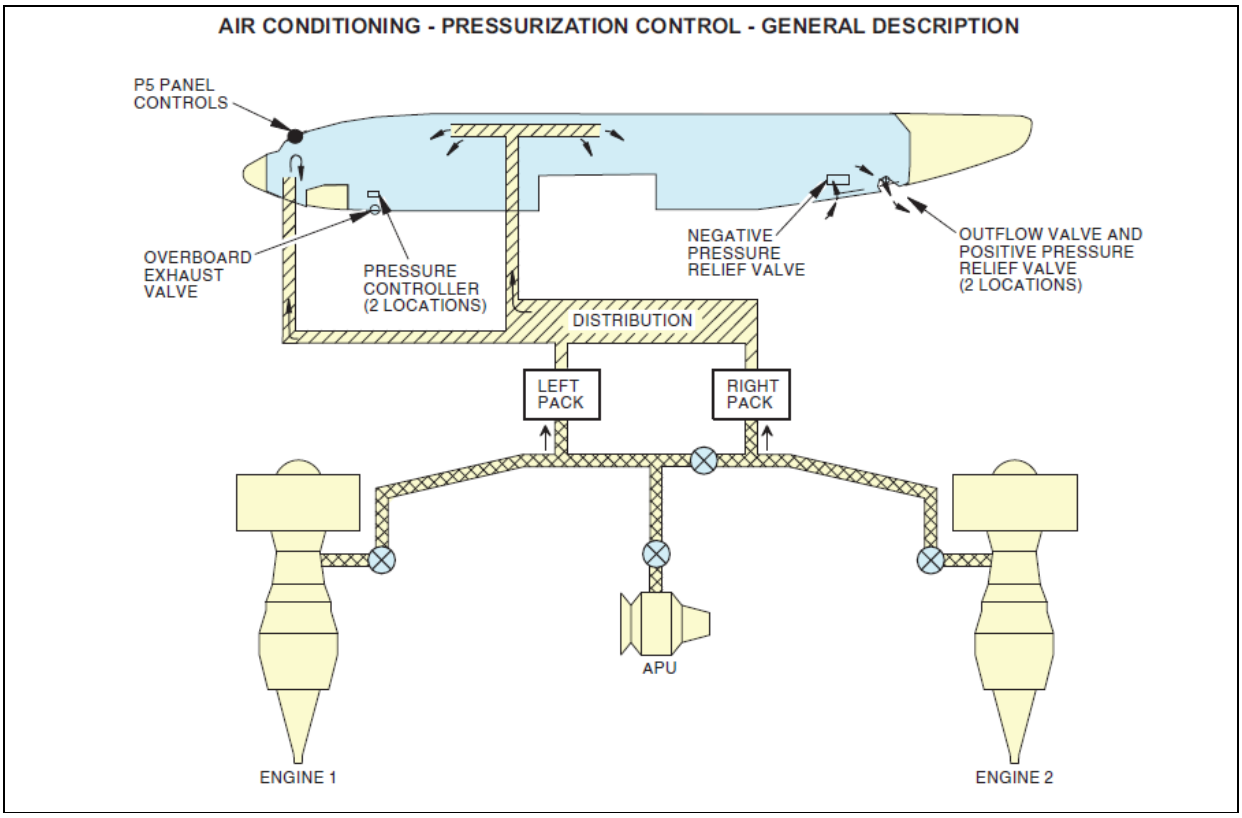

Figure 2. Air conditioning and pressurization component locations. (Note illustration is not side specific and the actual location of the negative pressure relief valve is on the right side of fuselage.) (Image Copyright © Boeing. Reproduced with permission.)

2.0 Automatic Mode Pressurization Schedule

2.1 Normal Flight Phases

A general description of the CPCs control logic for each phase of flight is as follows (also reference Figure 3):

Ground - When the airplane is in the ground phase the airplane is unpressurized and the outflow valve is open.

Takeoff - In the takeoff phase, the system pressurizes the cabin to 0.1 pounds per square inch differential (psid) below field elevation. This prevents an uncomfortable pressure bump (momentary pressure increase) at airplane rotation.

The cabin pressurization rate of change limit during the takeoff phase is 350 sea level feet per minute (slfpm).[2]

Climb - When the air/ground system indicates that the left and right landing gear are in the air, the climb phase starts.

During the climb phase the maximum cabin pressurization rate of climb is a customer selectable option. The option selected for the event aircraft was 600 slfpm.

Cruise - In the cruise phase, the system maintains a constant cabin altitude. The cabin altitude will be the landing field elevation for flights with a flight altitude of 18,500 feet or less. For flights with a flight altitude above 18,500 feet, the cabin altitude will increase to a pressure differential from ambient that keeps the airplane within a safe limit.

These are the differential pressure schedules for various altitudes during cruise:

FLIGHT ALTITUDE	SCHEDULE
SEA LEVEL TO 18,500	LANDING FIELD ELEVATION
18,500 TO 28,000	7.45 psid
28,000 TO 37,000	7.80 psid
37,000 AND ABOVE	8.35 psid

NOTE: Deviations from flight altitude may cause the differential pressure to go as high as 8.45 psid to maintain a constant cabin altitude.

Descent - When the airplane external pressure increases to 0.25 pounds per square inch (psi) more than the FLT ALT (flight altitude) selection, the descent phase starts.

The maximum cabin pressurization rate of descent is a customer-selectable option. The option selected for the event aircraft was 350 slfpm.

The system will pressurize the cabin to 0.15 psid below the LAND ALT selection (landing field elevation). The 0.15 psid pressurization prevents pressure bumps from occurring during landing.

[2] By design, it is allowable for the cabin rate of change to exceed the target limits for short durations during climb and descent.

Landing - When the airplane lands and the requirements for the ground phase are met, the system depressurizes the cabin at a maximum rate of 500 slfpm. When the cabin pressure is the same as the local ambient pressure, the outflow valve goes completely open.

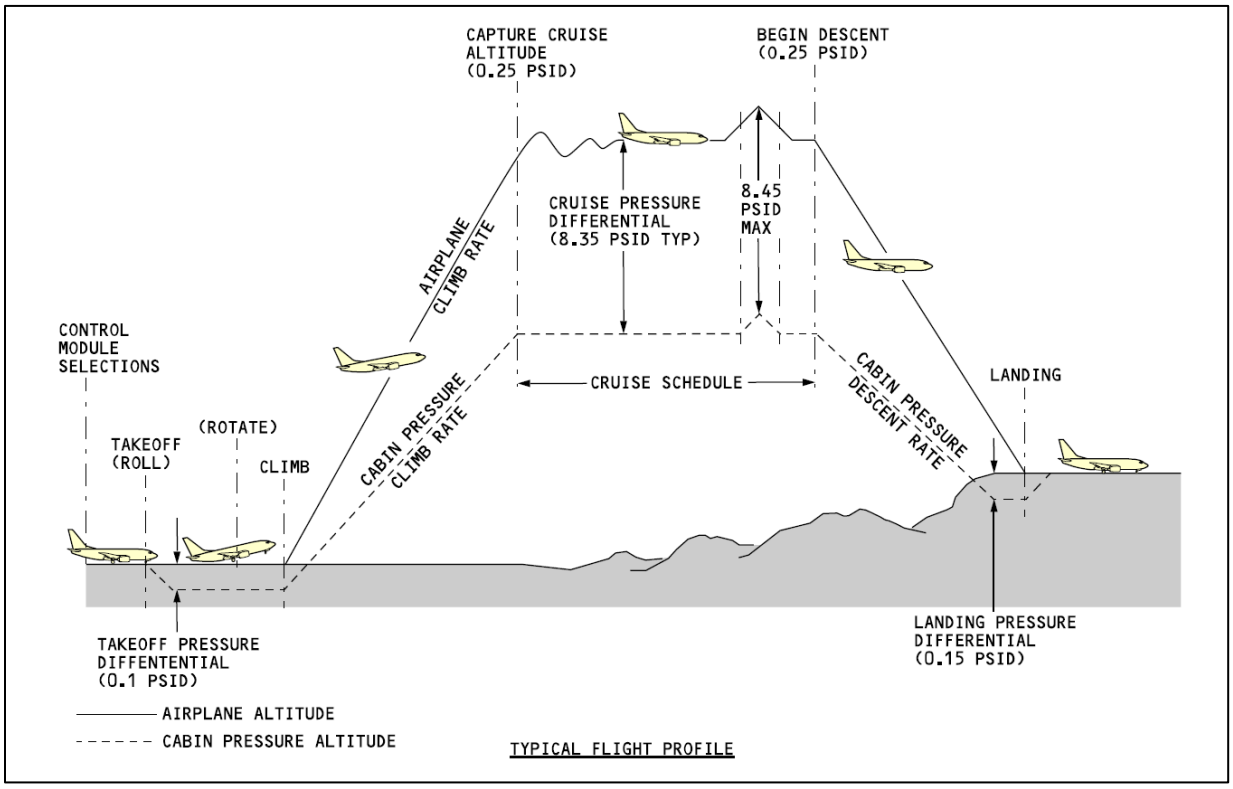

Figure 3. CPC controlled cabin pressure profile. (Image Copyright © Boeing. Reproduced with permission.)

2.2 Off-Schedule Descent

An off-schedule descent occurs when the airplane starts to descend off schedule (airplane descends before getting to cruise altitude). The off-schedule descent (OFF SCHED DESCENT) indication on the P5 forward overhead panel will illuminate (see Figure 1). The light informs the crew that the system will control cabin pressure for a return to the take-off field per the normal descent schedule. If the flight crew diverts to a field other than the take-off field, the flight crew must reset the flight altitude to the current altitude and reset the landing altitude to the new landing field elevation. The off-schedule descent feature only operates when the cabin pressurization system is in the AUTO (automatic) or ALTN (alternate) modes and does not apply when the system is in the MANUAL mode.

3.0 Fail Safe Devices

If the pressurization system fails, the airplane structure is protected from excessive pressure differentials via two positive pressure relief valves and a negative pressure relief valve. The equalization of pressure prevents damage to the airplane structure. The positive pressure relief valves are mechanical devices and operate independently. They do not interface with other airplane pressurization components and no crew action is necessary. The positive pressure relief valves are pneumatically operated by cabin-to-ambient pressure differential. They control pressure to a nominal 8.95 +/- 0.15 psi more than ambient. When the differential pressure is too high, the valve opens. The open valve lets air out of the airplane thereby relieving the cabin pressure. When the cabin-to-ambient differential pressure returns to nominal 8.95 +/- 0.15 psi, the valve closes. The negative pressure valve is a flapper type valve. It is pneumatically operated by cabin-to-ambient pressure differential and will prevent the pressure outside of the airplane from exceeding 0.75 psi more than the pressure inside of the airplane.

Cargo compartment blowout panels prevent damage to the airplane structure during a sudden decompression. There are three cargo compartment ceiling blowout panels, two in the aft cargo compartment and one in the forward cargo compartment. There are eight bulkhead blowout panels, three in the forward cargo forward bulkhead, three in the forward cargo aft bulkhead, and two in the aft cargo compartment waste tank enclosure. See Figures 4 and 5. In addition, the flight deck door is designed to open to relieve pressure in the flight deck during significant sudden cabin decompression events.

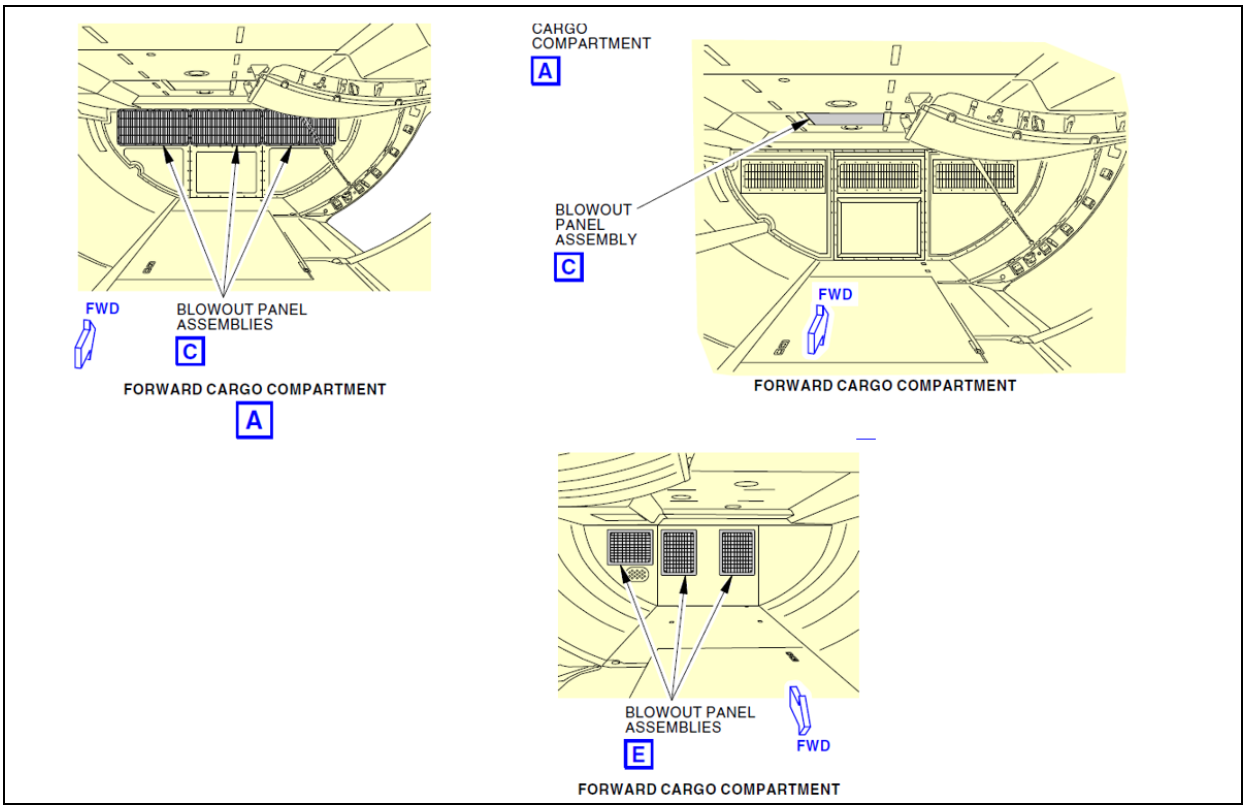

Figure 4. Forward cargo compartment pressure relief panels. (Image Copyright © Boeing. Reproduced with permission.)

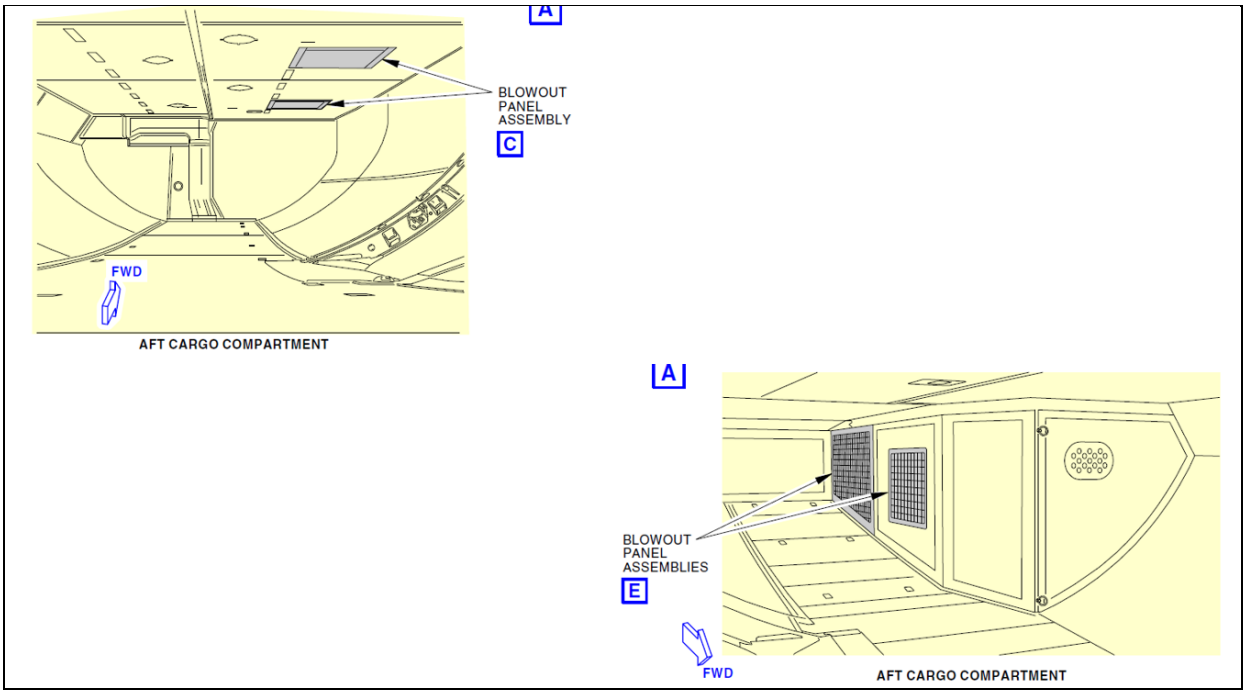

Figure 5. Aft cargo compartment pressure relief panels. (Image Copyright © Boeing. Reproduced with permission.)

A cabin altitude warning system tells the crew when the cabin pressure altitude goes over 10,000 ft. This warning is activated by either of the two redundant pressure switches on the ceiling in the forward electronic equipment compartment. It operates an aural warning horn on the control stand and indicator lights on the P1-3 and P3-1 panels in the flight deck. See Figure 6 for location of the indicator lights. The horn cutout button is on the P5 forward overhead panel. Per design it is acceptable for the switches to activate anywhere between 9,000 – 11,000 ft. See Figure 1 in section D.1.0 for a picture of the horn cutout button, and other cabin pressurization controls discussed in this report.

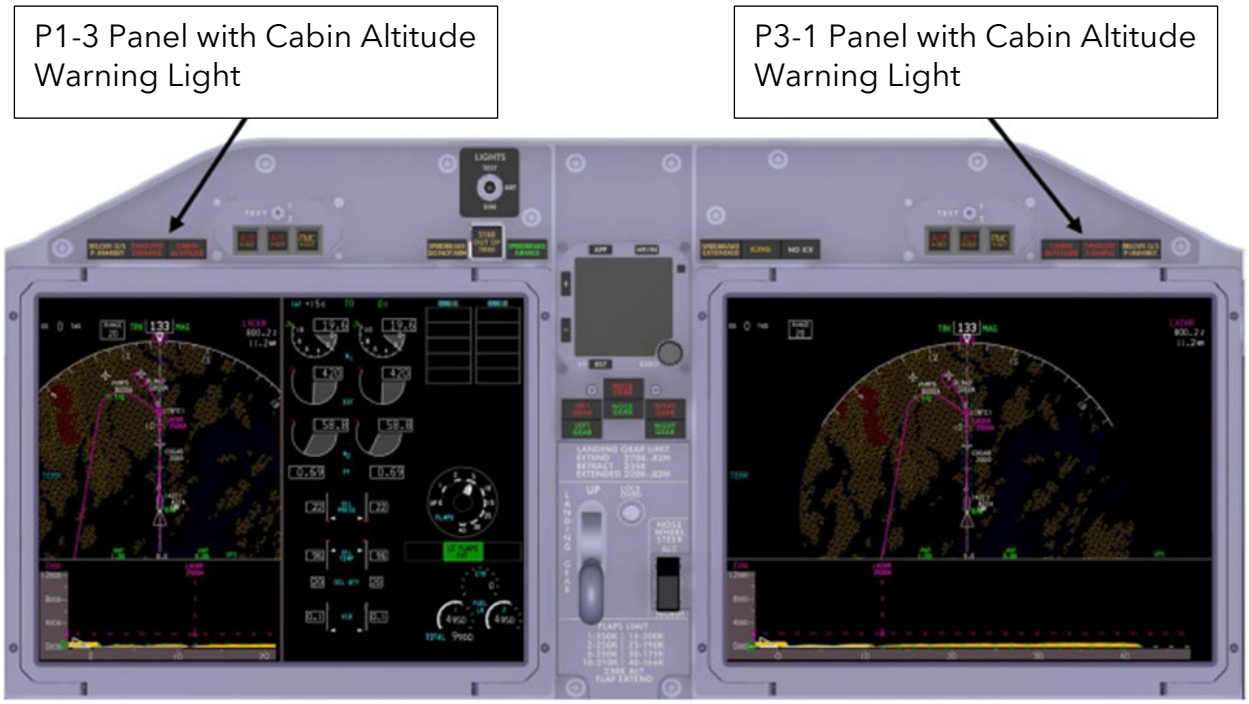

Figure 6. Cabin altitude warning indicator lights. (Image Copyright © Boeing. Reproduced with permission.)

The outflow valve has a fail-safe aneroid switch (referred to as an outflow valve cabin pressure switch) on each electronic actuator. The switch causes the valve to go fully closed if the cabin pressure altitude gets to 14,776 +/- 216 ft. The switch will deactivate when the cabin pressure altitude goes below 14,776 +/- 216 ft. This function overrides normal automatic control only. It does not override manual mode of the valve.

4.0 Cabin Pressure AUTO FAIL Light and Operation

The amber AUTO FAIL light gives the flight crew indication that one or both CPC automatic systems are inoperative. As discussed earlier in this report, one CPC is the CPC-in-command and maintains automatic cabin pressurization control. The other CPC is the alternate, or backup, should the CPC-in-command fail. If the CPC-in-

command fails, the system automatically changes pressurization control to the alternate CPC.

The two CPCs automatically do start-up and continuous built-in test equipment (BITE) tests. If the active CPC BITE detects a fault or failure, it transfers active control to the backup CPC.

The AUTO FAIL light will illuminate due to the following:

- Power loss
- Cabin altitude rate of change is too high (>2,000 slfpm) and outflow valve not in correct position
- Cabin altitude is too high (>15,800 ft) and outflow valve not in correct position
- Wiring failures
- Outflow valve component failures
- CPC failures
- Selector panel (P5-6) failures
- Cabin differential pressure is too high (>8.75 psi)

If the system is in the AUTO mode when an AUTO FAIL event occurs, these lights come on:

- Amber AUTO FAIL light
- Green ALTN light (if the backup system is operational and active)
- MASTER CAUTION and AIR COND (air conditioning) annunciator lights

The AUTO FAIL light turns off when the crew selects the ALTN position on the mode selector. In the event of a dual CPC failure, the AUTO FAIL light will be on and the ALTN light will be off. The FLT ALT and LAND ALT (landing altitude) displays will go to dashes. In this case, there is no automatic alternate to switch to, and the crew would be required to control the outflow valve position manually by switching the mode selector to MAN (manual).

E. ON-SCENE ACTIVITES

1.0 Flight Deck Observations

The flight deck was examined for switch positions and circuit breaker conditions. The aircraft was taxied to the gate and shut down normally following the landing. In addition, the aircraft was towed to a different location at the airport prior to the arrival of investigators. Therefore, the as-documented positions may not be representative of the positions at the time of the event.

The following observations were made:

- Cabin pressure control mode selector was observed in the MAN position (note that the Alaska Airlines Quick Reference Checklist procedure for "CABIN ALTITUDE WARNING or Rapid Depressurization" requires the mode selector to be placed in the MAN position)
- The outflow valve position indicator was noted near CLOSED
- The manual outflow valve position switch is spring loaded to neutral. It was in neutral between OPEN and CLOSE
- The AUTO FAIL, OFF SCHED DESCENT, ALTN, and MANUAL system status lights on the cabin pressurization panel were all operational
- The FLT ALT selector was displaying 33000 ft[3]
- The LAND ALT selector was displaying 950 ft[4]
- The DIFF PRESS (differential pressure) indicator was near 0 psi
- The CABIN ALT (cabin altitude) indicator was near 0 ft
- The CABIN CLIMB indicator was near 0 ft/min
- The PASS OXYGEN (passenger oxygen) guarded switch was in the closed (NORMAL) position and the safety wire had not been broken
- The crew oxygen indicator indicated 1200psi
- The captain's side oxygen mask was observed out of storage with the oxygen level set to NORM (normal)
- The first officer's side oxygen mask was observed out of storage with the oxygen level set to 100%
- EMER EXIT LIGHTS (emergency exit lights) switch was OFF with guard open

The following circuit breakers were observed to be open and were either tagged by maintenance to facilitate work performed after the accident flight or were collared. There were no open circuit breakers that were not tagged or collared.

[3] Value is stored in non-volatile memory, and therefore the selector display showed the last selected value.

[4] Value is stored in non-volatile memory, and therefore the selector display showed the last selected value.

Captain's side circuit breaker panel:

Panel	Location	CB Name	Condition
P18-2	C7	VOICE RCDR RELAY	Tagged by Maintenance
P18-2	C9	FLIGHT RECORDER AC	Tagged by Maintenance
P18-2	C10	FLIGHT RECORDER DC	Tagged by Maintenance
P18-2	D6	VOICE RCDR/RIPS	Tagged by Maintenance
P18-2	D7	INOP	Collared

First officer's side circuit breaker panel:

Panel	Location	CB Name	Condition
P6-1	A17	INOP	Collared
P6-3	A1	INOP	Collared
P6-3	B2	INOP	Collared
P6-3	B15	INOP	Collared
P6-3	B18	INOP	Collared
P6-3	C1	INOP	Collared
P6-5	B12	INOP	Collared
P6-5	C8	INOP	Collared
P6-5	C9	INOP	Collared
P6-5	D2	INOP	Collared
P6-5	D5	INOP	Collared

Boeing records indicate that all INOP circuit breakers were INOP upon aircraft delivery. The B18 circuit breaker on the P6-3 panel is for the left mid exit door proximity switch and the C8 circuit breaker on the P6-5 panel is for the left mid exit door flight lock. Boeing stated that these two circuit breakers are not used if a door plug is installed in the left mid exit door location. In addition, the PC Power 1 circuit breaker (P6-5 panel, location A5) and the PC Power 2 circuit breaker (P6-5 panel, location A8) were opened and tagged during the on-scene investigation by maintenance to facilitate removal of the passenger seats.

2.0 Condition of Pressurization Fail Safe Devices

In the forward cargo bay, the forward three pressure relief panels, and the center aft panel were displaced. The ceiling pressure relief panel was not displaced. In the aft cargo bay only the forward waste tank enclosure panel was displaced. Both ceiling pressure relief panels were not displaced. Refer to Figures 4 and 5 for relief panel locations. In addition, the cockpit door was observed to be open and the main latch no longer retained the door, consistent with a door latch that operated per design during a significant rapid depressurization event.

The cabin pressure outflow valve was observed to be approximately in the closed position with no obstructions or anomalies noted. The two cabin overpressure relief valves were observed in the normal position with no anomalies noted. The negative pressure relief door was observed in the closed position. Light hand pressure could open the negative pressure door which was spring set to the closed position.

3.0 Aircraft Level Testing

3.1 Cabin Pressure Controller – BITE Procedure

TASK 21-31-00-740-801 (CPC BITE Procedure) from the 737-8/9 Aircraft Maintenance Manual (AMM), Rev 20, dated 15 Sep 2023, was performed on CPC 1 and CPC 2. This task initiates the BITE functions of the CPCs. Both units passed all BITE tests with no faults identified.

3.2 Cabin Pressure Control - System Status Test:

A production level system status test was performed on both CPC 1 and CPC 2. There is no AMM tasks for these tests so the tests were performed with Boeing engineering guidance based on Blocks 700 (CPC 1) and 800 (CPC 2) of Boeing test document YM21317317:0001, REV F. The tests were designed to verify that the inputs to the CPC's were valid and that the CPC's were configured properly. Both units passed their respective tests with no anomalies or unexpected values identified. A summary of the test procedure that was performed is provided below.

Test set-up included:

- Cycled the circuit breaker for CPC 2 to put CPC 1 in control
- Ensured the air conditioning packs and recirculation fans were off
- Set the cabin pressure control mode selector to AUTO
- Set the FLT ALT to 33000 on the P5-6 selector panel
- Set the LAND ALT to 500 on the P5-6 selector panel

Test steps included:

The following information was obtained from the SYSTEM STATUS --> PRESENT STATUS menu on the CPC 1 front panel BITE screen.

- Ensured FLT ALT = 33000 was displayed
- Ensured LAND ALT = 500 was displayed
- Ensured AUTO IN CTRL (auto in control) was displayed
- Ensured display for OFV (outflow valve) position showed a value between +100 DEG OPEN (degrees open) and +122 DEG OPEN. Actual value was +111 DEG OPEN.
- Ensured NO AUTO FAIL was displayed
- Ensured display for CAB PRESS (cabin pressure) showed a value between 13.70 PSI and 15.70 PSI. Actual value was 14.76 PSI.
- Ensured CARGO HT VALVE CL (cargo heat valve closed) was displayed.
- Ensured LFT PACK FLOW OFF (left air conditioning pack flow off) was displayed
- Ensured RT PACK FLOW OFF (right air conditioning pack flow off) was displayed

The following information was obtained from the SYSTEM STATUS --> SYSTEM CONFIG (system configuration) menu on the CPC 1 front panel BITE screen.

- CPC 1 was identified as the master controller
- Ensured ROC SEL (rate of climb select) HIGH was displayed [HIGH = 600 ft/min]
- Ensured ROD SEL 2 (rate of descent select 2) HIGH was displayed [HIGH = -350 ft/min]
- Ensured ROD SEL1 LOW was displayed [LOW = -350 ft/min]
- Ensured QFE SEL (barometric correction based on landing field elevation select) HIGH was displayed [HIGH = QFE not selected, QNH (barometric correction based on sea level) selected]
- Ensured OFV CONN (outflow valve connected) LOW was displayed [LOW = OFV connected]
- Ensured IBIT IN (initiated built-in-test signal from other controller) HIGH was displayed [HIGH = other controller not in test]
- Ensured CARGO HT VLV LOW was displayed [LOW = closed]
- Ensured MANUAL IN HIGH was displayed [HIGH = manual not selected]
- Ensured LEFT A/G (air/ground) LOW was displayed [LOW = ground mode]
- Ensured RT A/G LOW was displayed [LOW = ground mode]
- Ensured SHOP MODE HIGH was displayed [HIGH = not shop mode]
- Ensured L PACK VLV LOW was displayed [LOW = air conditioning pack off]

- Ensured R PACK VLV LOW was displayed [LOW = air conditioning pack off]
- Ensured 41K SEL (41,000 ft select) LOW was displayed [LOW = 41k altitude option selected]
- Ensured AUTO CTL IN LOW was displayed [LOW = other controller not in control]
- Ensured PNL OK (panel okay) HIGH was displayed [HIGH = selector panel not failed]
- Ensured BBJ (Boeing Business Jet) SEL HIGH was displayed [HIGH = BBJ option not active]
- Ensured HIGH LFE (high landing field elevation) HIGH was displayed [HIGH = HIGH LFE mode not active]

The test was repeated for CPC 2 with the following differences:

- P5-6 panel was set to ALTN to put CPC 2 in control
- Ensured display for OFV (outflow valve) position showed a value between +100 DEG OPEN (degrees open) and +122 DEG OPEN. Actual value was +111 DEG OPEN.
- Ensured display for CAB PRESS (cabin pressure) showed a value between 13.70 PSI and 15.70 PSI. The actual value was verified to be within range but was not recorded.
- CPC 2 was identified as "not master controller"[5]

3.3 Cabin Pressure Control – Pressurization System Ground Test

AMM TASK 21-31-00-700-802 (Pressurization System Ground Test) was performed on CPC 1 and CPC 2. This maintenance test verifies that the pressurization system is functioning properly in automatic mode and that the outflow valve is responding correctly to commands. Both units passed with no faults identified. In addition, the outflow valve was visually observed to be operational during these tests.

3.4 Digital Flight Control Systems (Autopilot):

AMM TASK 22-11-00-740-804 (Digital Flight Control System BITE Library Test) was performed. The BITE library test does a check of the interfaces between the Digital Flight Control System (commonly referred to as "Autopilot") and its line replaceable units. The BITE library test contained three types of tests: automatic tests, interactive tests, and surface tests with hydraulics on. The automatic tests contained individual tests for the Air Data Inertial Reference Unit, autothrottle, distance measuring equipment, low-range radio altimeter, mode control panel (MCP) interface, Flight Management Computer, analog sensors, Stall Management Yaw Damper Computer, very high frequency omni-directional range receiver, multi-mode

[5] The CPC identification does not indicate which controller is in control

receiver/instrument landing system, common display system, MCP display and self-test, and discrete inputs. The interactive tests contain individual tests for the Air Data Inertial Reference Unit, very high frequency omni-directional range receiver, multi-mode receiver/instrument landing system, MCP pushbuttons, MCP flight director switches, MCP indicated airspeed/Mach changeover, MCP bank angle limit, MCP speed select, MCP altitude select knob, MCP vertical speed knob, MCP displays/self-test, MCP command engage switch/control wheel steering engage switch interlock, MCP course/heading select, altitude alert, and disengage warning. The surface tests contain individual tests for the elevator, ailerons, speed/stabilizer trim, Mach trim, flaps, and dual stabilizer. All tests passed for channels A and B.

4.0 Data Sources and Downloads

4.1 Aircraft Communication Addressing and Reporting System (ACARS)

Alaska Airlines airplanes are configured to send pilot-initiated maintenance messages and engine related data automatically during flight. All other maintenance messages generated during a flight are stored in memory and are automatically sent to the server during each landing roll out. All ACARS automatically generated messages for the environmental control system since the time of aircraft delivery were reviewed. Two flights contained environmental control system automatically generated messages. On Nov 23, 2023, during flight 814, at time 01:27:58, the following message was reported: "ENV CTRL SYS MSG - LOW INFLOW / HIGH LEAKAGE (FC 30) IN CLIMB".[6] This fault occurs when a CPC detects that the outflow valve gate is less than 3 degrees (approximately fully closed) for more than 5 seconds, and indicates that there is low air flow into the cabin or there is high air leakage from the cabin. This fault does not result in an AUTO FAIL indication or an automatic CPC-in-command transfer. Review of the ACARS message showed that at the time of the fault, the aircraft configuration was consistent with a "no engine bleed takeoff" procedure.[7] A no engine bleed takeoff is an FAA approved procedure that increases the performance of the airplane but may result in a brief time of low air inflow into the cabin. There were no other environmental control system messages reported through ACARS for this flight.

The second flight with ACARS reported environmental control system messages was the accident flight, for which the following messages were reported after the door plug released from the airplane:

[6] All times reported for ACARS messages in this section are PST

[7] The ACARS message revealed that the fault was recorded at an altitude of 2274 ft. Just prior to the occurrence of the fault, the environmental control system (ECS) isolation valve was closed, both engine bleed air switches were off, the left ECS pack was on, the right ECS pack was off, the APU bleed valve was open, the left bleed air duct was pressurized to 42 psi, and the right bleed air duct was pressurized to 3 psi. Then the engine 2 bleed air switch turned on, the right ECS pack turned on and the APU bleed valve turned off, and immediately following the fault the engine 1 bleed air switch turned on.

17:13:21	CABIN ALTITUDE EXCEEDS 9000 FEET
17:13:42	CABIN ALTITUDE EXCEEDS 10000 FEET
17:14:05	CABIN ALTITUDE EXCEEDS 13500 FEET
17:14:27	CABIN RATE EXCEEDS +/- 1500 SLFPM
17:15:26	LOW INFLOW / HIGH LEAKAGE IN CLIMB
17:15:54	OFV PRESSURE SWITCH ACTIVE AT 14500 FEET
17:17:15	AIRCRAFT RATE HIGH FAIL

In addition, all ACARS messages posted for the following flights were reviewed:[8]

Flight 405	12/08/2023
Flight 807	12/08/2023
Flight 880	12/09/2023
Flight 675	01/03/2024
Flight 1059	01/03/2024
Flight 1284	01/03/2024
Flight 1318	01/03/2024
Flight 36	01/04/2024
Flight 356	01/04/2024
Flight 389	01/04/2024
Flight 19	01/05/2024

Review of these messages revealed only 1 message that was related to the environmental control system. The message was in the form of a maintenance report, which is a maintenance message the crew initiates through ACARS to inform flight operations of a maintenance issue during flight. On January 3, 2024, during flight 1284, at time 13:29:47, a maintenance report was sent that stated "AUTOFAIL LIGHT ILLUMINATED ON PRESSURIZATION PANEL. RAN CHECKLIST. OPS NORMAL IN ALT MODE IN BOOK". See section F of this report for the corresponding maintenance record regarding this flight.

4.2 Network File Server Onboard Maintenance Function:

The onboard maintenance function from the network file server was viewed on the inboard display unit.[9] The available maintenance messages related to maintenance chapters 21 (air conditioning) and 36 (pneumatic) were photographed

[8] All ACARS messages for these flights were requested because an initial maintenance records review identified an Auto Fail light illumination near these dates. At a later date, the full ACARS records were also requested for flights on 11/23/2023 and 12/07/2023; however, in accordance with Alaska Airlines enroute communications retention procedures the data had already been deleted at the time of the request. As stated in this section of the report, all ACARS messages related to the environmental control system for these dates had previously been requested and reviewed.

[9] The network file server is part of the Onboard Network System which is a computer-based information system that supports flight, maintenance, and cabin operations.

(see Attachment 1).[10] The data dated back to Dec 29, 2023. The following is a summary of recorded messages that were related to the cabin pressurization system:

Time: 0114 - 06JAN2024[11]
Flight Phase: Descent
Maintenance Message: 21-30310
CABIN ALT RATE IS HIGH (cabin altitude rate is high)

Time: 0112 – 06JAN2024
Flight Phase: Climb
Maintenance Message: 21-30900/21-39001
OFV CABIN PRESSURE SWITCH COMMANDED OFV CLOSED (outflow cabin pressure switch commanded outflow valve closed)

Time: 0112 – 06JAN2024
Flight Phase: Climb
Maintenance Message: 21-30300
LOW AIR SUPPLY OR HIGH FUSELAGE LEAKAGE

Time: 0112 – 06JAN2024
Flight Phase: Climb
Maintenance Message: 21-30180/21-30181
CABIN ALTITUDE EXCEEDED 13,500 FEET

Time: 0112 – 06JAN2024
Flight Phase: Climb
Maintenance Message: 21-30170/21-30171
CABIN ALTITUDE EXCEEDED 10,000 FEET

Time: 2145 – 04JAN2024
Flight Phase: Taxi In
Maintenance Message: 21-30151
OFV SIGNAL IS OUT OF RANGE (corresponds to "074 OFV_RS422_CTR_TO_ OFV_ACTIV_FAIL" fault, see section G.1.0)

Time: 2145 – 04JAN2024
Flight Phase: Taxi In
Maintenance Message: 21-30331
CPC-2 HAS AN INTERNAL FAULT (corresponds to "039 RS422_XMIT_FAIL" fault, see section G.1.0)

[10] Messages related to other maintenance chapters were also captured in the photographs. Note that some of the photographed maintenance messages were caused by the configuration of the airplane at the time of documentation.

[11] The onboard maintenance function recorded times are in coordinated universal time (UTC).

Time: 2124 – 03JAN2024
Flight Phase: Cruise
Maintenance Message: 21-30151
OFV SIGNAL IS OUT OF RANGE (corresponds to "074 OFV_RS422_CTR_TO_OFV_ACTIV_FAIL" fault, see section G.1.0)

Time: 2124 – 03JAN2024
Flight Phase: Cruise
Maintenance Message: 21-30331
CPC-2 HAS AN INTERNAL FAULT (corresponds to "039 RS422_XMIT_FAIL" fault, see section G.1.0)

Time: 2124 – 03JAN2024
Flight Phase: Cruise
Maintenance Message: 21-55220/21-55221
IASC-L/R (AIR COND) HAS NO INPUT FROM CPC-2 ON ARINC 429 and CPCS STATUS 2 BUS OR CPC-2 DATA IS INVALID (Integrated Air Supply Controller is not receiving valid CPCS (cabin pressure controller system) data)

The onboard maintenance function showed that the pack flow schedule was set to "11". This is the configuration setting that corresponds to the 186-occupant option for the 737-9 airplane.

4.3 CPC On-Airplane Fault History Download

The cabin pressure controllers were part number 21933-01AD (Boeing part number 10-62231-52), serial numbers 23210434 (CPC-1) and 23210426 (CPC-2). Limited fault history is viewable directly on the LED display on the CPC. The following faults were present in the viewable history:[12,13]

CPC 1

Flight Leg: 00[14]
Faults: MANUAL SWITCH, ACFT RATE HI (aircraft cabin pressure rate high); CAB PRES SW ACTIV (cabin pressure switch active), LO INFL/HI LEAKG (low inflow/high leakage); CAB ALT 13500 FT (cabin altitude greater than 13,500 ft)

Flight Leg: 32

[12] It is possible for the faults for each flight leg to vary between CPC 1 and CPC 2 because some faults are only recorded by the CPC-in-command.

[13] The faults in the viewable history correlate to faults recorded in Attachments 2 and 3. Definitions for each fault can also be found in Attachments 2 and 3.

[14] For the purpose of this section, fault leg 00 is the accident flight, and the other fault leg numbers represent how many flights prior to the accident flight they occurred.

Faults: DADC #2 INVALID (digital air data controller #2 invalid); DADC #1 INVALID (digital air data controller #1 invalid)

Flight Leg: 41
Faults: DADC #1 INVALID (digital air data controller #1 invalid); DADC #2 INVALID (digital air data controller #2 invalid)

Flight Leg: 94
Faults: DADC #2 INVALID (digital air data controller #2 invalid); DADC #1 INVALID (digital air data controller #1 invalid)

CPC 2

Flight Leg: 00
Faults: MANUAL SWITCH, CAB PRES SW ACTIV (cabin pressure switch active), CAB ALT 13500 FT (cabin altitude greater than 13,500 ft), CAB ALT 10000 FT (cabin altitude greater than 10,000 ft)

Flight Leg: 04
Faults: OFV OR WIRING (outflow valve or wiring); CONTRL LRU FAIL (CPC failure)

Flight Leg: 07
Faults: OFV OR WIRING (outflow valve or wiring); CONTRL LRU FAIL (CPC failure)

Flight Leg: 32
Faults: DADC #2 INVALID (digital air data controller #2 invalid); DADC #1 INVALID (digital air data controller #1 invalid)

Flight Leg: 41
Faults: DADC #1 INVALID (digital air data controller #1 invalid); DADC #2 INVALID (digital air data controller #2 invalid)

Flight Leg: 93
Faults: OFV OR WIRING (outflow valve or wiring); CONTRL LRU FAIL (CPC failure)

Flight Leg: 94
Faults: DADC #2 INVALID (digital air data controller #2 invalid); DADC #1 INVALID (digital air data controller #1 invalid)

In addition, Boeing sent a specialist to download the non-volatile memory within the CPCs per AMM task 21-31-00-970-801. The procedure had to be varied

slightly due to an issue with the download equipment connecting to the CPCs, but the download was successful. The raw data file was converted by Boeing, and the fault history was summarized and provided to the group. The data contained fault data since the time the aircraft was delivered. All faults recorded during this activity were also identified during the fault history download at the CPC manufacturer. See section G.1.0 of this report for information related to the CPC download at the manufacturer.

4.4 Avionics Data Recording: All

Avionics Data Recording (ADR-ALL) includes all avionics data provided to the Onboard Network System. This includes data collected by the Digital Flight Data Acquisition Unit (including data that is also recorded on the flight data recorder and quick access recorder (QAR)). The storage capacity of the onboard network file server allowed for data back to 12/20/2023 to be recorded. Although this data was captured in raw format, it was not used by the investigation team because the QAR data (see section E.4.5) also contained the required information at the times of interest within the ADR-ALL available data date range.

4.5 Quick Access Recorder

The QAR memory card was removed from the aircraft on January 7, 2024. It was downloaded by the investigation team on Jan 9, 2024. Alaska Airlines typically removes and downloads the QAR data card every 3 days during their scheduled lower-level maintenance check. The card was installed on January 3, 2024, and contained the event flight plus the 8 prior flights (9 flights total).

Data from all 9 available flights were reviewed by the investigation team. The data showed that for these flights, up to the time immediately following the door plug departure, the maximum cabin to ambient differential pressure recorded was 7.7969 psi and the minimum cabin to ambient differential pressure recorded was -0.0469 psi. During descent following the door plug departure the minimum cabin to ambient differential pressure recorded was -0.0938 psi. The data also showed that the cruise altitudes for the 8 flights prior to the accident flight were between 28,000 ft and 37,000 ft. The only recorded occurrence in the data of the pressurization system operating in manual mode occurred after the door plug departure on the accident flight. The relevant data from the accident flight, flight 356 on January 4, 2024, and flight 1284 on January 3, 2024, can be found in the "Flight Data Recorder Specialist's Report" located in the public docket for this investigation.[15]

[15] The data for flight 356 and flight 1284 were of initial interest because a maintenance records search revealed that the cabin pressure system AUTO FAIL light illuminated on these flights.

F. MAINTENANCE RECORDS

Aircraft Registration: N704AL
Flight hours at time of accident: 510:18 hrs
Flight cycles at time of accident: 154

The maintenance log book discrepancies and non-routine maintenance tasks since the delivery of the airplane to Alaska Airlines were reviewed. The following discrepancies for the cabin pressurization system were identified:

Dec 7, 2023 – Defect description: "AUTO FAIL LIGHT ILLUMINATED ON PRESSURIZATION PANEL." Maintenance resolution: "CYCLED TO MANUAL & BACK TO AUTO - AUTO FAIL RESET. NO HISTORY."

Jan 3, 2024 – Defect description: "IN CRUISE. FL330. AUTO FAIL LIGHT ILLUMINATED ON PRESSURIZATION PANEL. RAN CHECKLIST/ OPS NORMAL IN ALT MODE". Maintenance resolution: " PERFORMED IFIM TASK 21-31-00-810-850. FAULT HAS BEEN CLEARED AND NO FAULT AT THIS TIME. A/C OK FOR SERVICE."[16]

Jan 4, 2024 – Defect description: "AUTO FAIL LIGHT ON PRESSURIZATION PANEL ILLUMINATED ON TAXI IN, FOLLOWED BY THE ALTN GREEN LIGHT". Maintenance resolution: "RESET CPC 1&2 PERFORMED CPC BITE PROCD IAW AMM 21-31-00-740-801.TEST PASSED.AUTO FAIL LIGHT EXT."

Jan 4, 2024 – Defect description: "PER SEAMC [ALASKA AIRLINES SEATTLE MAINTENANCE CONTROL]… A/C RESTRICTED FROM ETOPS OPERATION DUE CABIN PRESSURE AUTO FAIL LIGHT".[17] Maintenance resolution: unresolved at time of accident.

Jan 4, 2024 – Defect description: "TECH SERVICE REQUESTED A FOLLOW-UP FOR CABIN PRESS CONTROL SYSTEM PRESSURIZATION AUTO FAIL LIGHT

[16] IFIM (Interactive Fault Isolation Manual) Task 21-31-00-810-850 is titled "Cabin Pressure Control Module AUTO FAIL and ALTN Light On, AUTO FAIL Light Goes Off When Mode Selector Switch Is At ALTN – Fault Isolation".

[17] ETOPS stands for Extended Range Twin Operations. This approval allows the aircraft to operate over a route that contains a diversion point further than one hour flying time at the approved one-engine inoperative cruise speed. Alaska Airlines stated that they voluntarily temporarily restricted the airplane from ETOPS flights so that the airplane would remain near convenient maintenance bases should another Auto Fail light occur. Note that the airplane was already restricted from ETOPS due to an open Minimum Equipment List deferral (see deferrals paragraph in this section of the report, to include footnote 17).

CAME ON IN FLIGHT CODE 21-30151,21-30150,21-30330,21-30331".[18]
Maintenance resolution: unresolved at time of accident.

The maintenance logbook discrepancies and non-routine maintenance tasks since aircraft delivery were also reviewed for ATA Chapter 22 "Auto Flight" defect reports. The following defects were identified:

Nov 2, 2023 – Defect description: "PER TASK CARD MAX-22EO-21269-1 ACCOMPLISH TASK CARDS TO ESTABLISH THE CAT IIIA CAPABILITY OF THE AIRCRAFT." Maintenance resolution: "ACCOMPLISHED REQUIRED TASK CARDS PER TASK CARD MAX-22EO-21269-1 TO ESTABLISH THE CAT 111A (LLM) CAPABILITY OF THE AIRCRAFT."

Nov 24, 2023 – Defect description: "INFO ONLY TOUCHDOWN 10 FT LEFT OF CENTERLINE" Maintenance resolution: "INFO NOTED THANKS"

Nov 27, 2023 – Defect description: "PER T/C: M9-44EO-23210-1-2, AIRCRAFT REQUIRES APPLICATION OF MEL 22-99D [CAT III AUTOLAND NOT AUTHORIZED DUE TO MAJOR MAINTENANCE] AND MEL 34-99D [CAT III HEAD UP GUIDANCE SYSTEM OPERATIONS NOT AUTHORIZED DUE TO MAJOR MAINTENANCE] ..." Maintenance resolution: "ACCOMPLISHED FLIGHT MANAGMENT SYSTEM AND NAVIGATION- FUNCTIONAL CHECK REF T/C 22-ASA-01. ALL TEST PASS. ACCOMPLISHED FUNCTIONAL CHECK-HEAD- UP GUIDANCE SYSTEM HGS-6000 REF T/C 34-ASA-03. ALL TEST PASS".

The following deferrals per the aircraft's FAA approved Minimum Equipment List were active on the aircraft at the time of the accident:

28-22-01A – Aft fuel boost pump inop[19]
25-70-01C – Foreign documents
25-28-01D – Forward galley foldable table bottom latch

There were no deferrals per the aircraft's FAA approved Configuration Deviation List active at the time of the accident.

[18] In this instance, a "follow up" refers to additional maintenance troubleshooting to investigate a repetitive defect. Alaska Airlines maintenance policy requires that if a defect is reported two times in ten days, then Technical Services is required to evaluate the discrepancy.

[19] This deferral was applied during maintenance prior to the flight with the occurrence of the AUTO FAIL light on January 3, 2024. This MEL required that the airplane be restricted from ETOPS operations until the deferral was resolved.

G. COMPONENT EXAMINATIONS:

The NTSB, German Federal Bureau of Aircraft Accident Investigation (BFU), Federal Aviation Administration (FAA), and Boeing met at the Nord-Micro facility in Frankfurt, Germany, on April 17-18, 2024, for the examination of the two CPCs and the cabin pressure outflow valve removed from the event airplane. Nord-Micro is the manufacturer for these components. All units were stored in secure storage, and shipping boxes remained unopened, until the team arrived for the examination.

1.0 CPC Examinations

The following information was on the CPCs' labels:

LRU: Pressure Controller
P/N: 21933-01AD
Boeing P/N: 10-62231-52
Revision: A
S/N: 23210434
F/T: 07-23
*This CPC was in position 1 at the time of the accident

LRU: Pressure Controller
P/N: 21933-01AD
Boeing P/N: 10-62231-52
Revision: A
S/N: 23210426
F/T: 06-23
*This CPC was in position 2 at the time of the accident

Both units were visually inspected with no concerning external damage identified. All tamper seals were intact. The pressure port screens on each unit were clean with no blockages present. The non-volatile memory from each unit was downloaded and the acceptance test procedure PVA-21933-01 was performed on both units. Both units passed all portions of the test. The units were then opened and a microscopic examination of the universal asynchronous receiver-transmitter (UART) microchip was performed by a qualified technician. No anomalies were noted with the microchip or its attachment to the circuit board.

The faults, and relevant associated data for each fault, retrieved from the non-volatile memory of both CPCs can be found in Attachments 2 and 3.[20] The elapsed time parameter showed that for the accident flight, there were no faults recorded until after the CABIN 10000 FT MESSAGE occurred. The CABIN 10000 FT MESSAGE occurs when the cabin altitude exceeds 10,000 ft, and would be expected to occur

[20] The term "faults" in the non-volatile memory refers to both faults and status messages.

shortly after a rapid decompression at a cabin altitude above 10,000 ft. The data also shows that, excluding pre-delivery flights, there were four AUTO FAIL events.[21] These events occurred in CPC 1 on flight leg 10, and CPC 2 on flight legs 62, 148, and 151 (for reference the accident flight leg was 155). For each AUTO FAIL event, a "039 RS422_XMIT_FAIL" fault occurred followed 2.3 seconds later by a "074 OFV_RS422_CTR_TO_OFV_ACTIV_FAIL" fault. A "039 RS422_XMIT_FAIL" fault occurs when the CPC microcontroller determines there is a data transmission error from the UART lasting at least 1 sec. A "074 OFV_RS422_CTR_TO_OFV_ACTIV_FAIL" fault is set in the CPC when the outflow valve does not detect data communication from the CPC for 3 seconds.[22] According to the manufacturer, this fault signature is unique and consistent with an intermittent failure of the UART microchip internal to the CPCs. A manufacturer's review of repaired CPCs between January 2021 and December 2023 found that 10 out of 585 repaired units showed this particular fault code sequence, and each of the 10 units had UART chips from the same chip lot as the CPCs from the event airplane. By design, either of these faults will result in the affected CPC automatically transferring cabin pressure control to the alternate CPC. In addition, a master caution will alert and the AUTO FAIL annunciation light will illuminate in the flight deck. Review of the QAR data (see section E.4.5), which captured the two most recent AUTO FAIL occurrences, showed that when the fault occurred, the alternate CPC automatically took command and there was no disruption or obvious effect to cabin pressure control. The cabin pressure remained at the expected values based on the designed pressurization schedule before, during, and after these AUTO FAIL events.

Review of the CPC non-volatile memory also showed that, excluding pre-delivery flights, there were two occurrences of "030 INFLOW LEAKAGE FAIL" faults recorded.[23] These events occurred on flight leg 46 (flight 814 on Nov 23, 2023) and on the accident flight. As detailed in section E.4.1, examination of the ACARS message related to flight 814 revealed that the occurrence of this fault was consistent with a "no bleed takeoff" procedure. In addition to the information provided in the ACARS message, the CPC NVM showed that for flight 814, the cabin pressure was within an expected value range based on the pressurization schedule and aircraft altitude at the time the fault occurred. During the accident flight, the "030 INFLOW LEAKAGE FAIL" fault was posted after the CABIN 10000 FT MESSAGE fault was posted. The CABIN 10000 FT MESSAGE occurred shortly after the rapid decompression event.

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[21] Boeing records indicate that the first 8 flights (flight legs 1-8 in Attachments 2 and 3) were pre-delivery flights. These flights often include unique operations designed to test various aircraft systems.

[22] The outflow valve electronic units will identify and record this fault. The CPC will then also record this fault once it receives the status information from the outflow valve electronic units.

[23] There were three pre-delivery flights with 030 INFLOW LEAKAGE FAIL faults recorded. The NVM data showed that for each fault one or both air conditioning pack valves were closed, which could contribute to low inflow into the cabin.

2.0 Outflow Valve Examination

The following information was on the outflow valve label:

Outflow Valve
P/N: 21230-10BA
MOD: None Selected
S/N: 23210137
DMF: 042023 (April 2023)

The outflow valve was visually examined. Protective shipping caps were present over all connectors and the tamper seals on both electronic boxes remained intact. The manual motor connector (J5) shell was damaged. Part of the connector shell was broken and missing, and the connector pins were bent. The J3 connector (with attached mating connector and wire) on electronic box 1 was also bent and the mounting plate for the connector was slightly deformed. Damage to both connectors occurred during shipping and was verified by comparing the damage to pictures taken prior to shipping. All other connectors were undamaged with pins that were straight and clean. The bonding strap was disconnected at the forward gate and the bonding strap remained connected but the connection bolt was loose at the aft gate. These bolts were unscrewed by maintenance to facilitate the removal of the outflow valve from the aircraft. The Teflon seals were intact and appeared to be undamaged. All linkages were securely connected. No other damage or anomalies were identified on the outflow valve (see Figure 7).

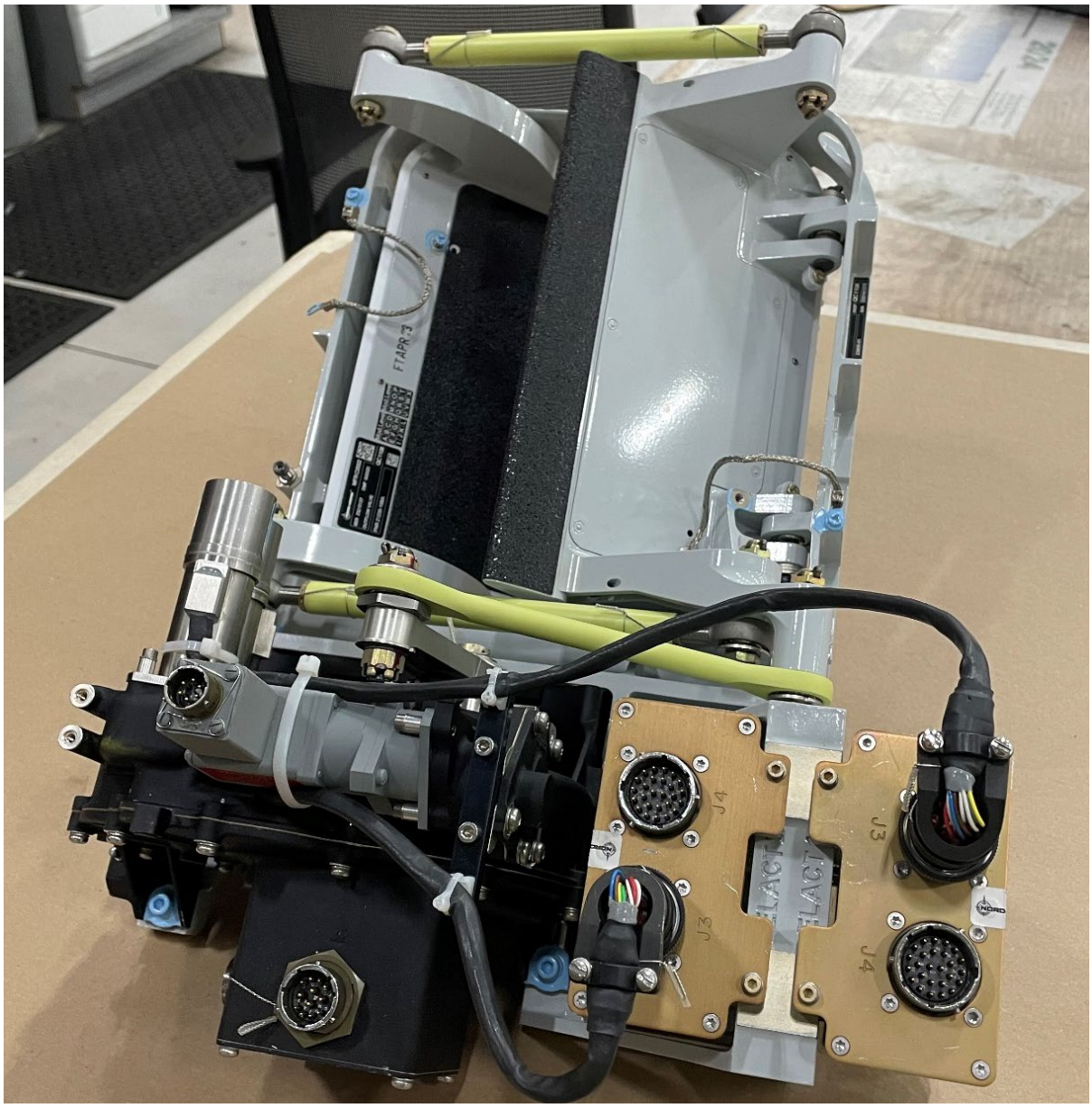

Figure 7. Condition of outflow valve following removal from the accident airplane. (Note picture was taken prior to shipping to the manufacturer.)

The shell for the manual motor connector had to be partially removed to facilitate rebending of the connector pins so that the unit could be connected to the test bench. The non-volatile memory was downloaded from both electronic boxes. With the exception of pre-delivery flights, there were six combined faults recorded in the memory of both units. Four of the faults were labeled "RS422_CTR_OFV_ACTIVITY_FAIL" and corresponded to the "074 OFV_RS422_CTR_TO_OFV_ACTIV_FAIL" faults that were recorded in the CPC memory. The other two faults were labeled "CAB_PRESS_SWITCH_ACTIVATED", and corresponded to the "090 OFV_CAB_PRESS_SWITCH_STATUS" faults that were recorded in the CPC memory that occurred shortly after the accident flight

decompression. These faults were recorded when the outflow valve cabin pressure switch activated during the accident sequence.

The test stand for the memory download also performed a basic incoming functional test which the outflow valve passed. The unit was then subjected to the ATP test per document PVA-21230-10. The unit passed all portions of the test except step 5.6. In this test, the unit leakage was 2.5 kg/min at a differential pressure of 550.1 mbar (allowable 2.4 kg/min at differential pressure greater 548.5 mbar). According to the manufacturer this condition may allow for a slight increase in leakage when the valve is commanded fully closed at high differential pressures, and would have little, if any, effect on the performance of the valve in flight.

Both electronic boxes were then removed and functionally tested per acceptance test procedure document PVA-23546-01. Both electronic boxes passed all portions of the test.

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