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	
7	

Structures Group Chair's Factual Report

(16 Pages)

National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

DCA24MA063

STRUCTURES

Group Chair's Factual Report

May 15, 2024

A ACCIDENT

Location:	Portland, Oregon
Date:	January 5, 2024
Time:	1714 Pacific Standard Time 0114 Coordinated Universal Time (UTC) January 6, 2024
Airplane:	Alaska Airlines flight 1282, Boeing 737-9, N704AL

B STRUCTURES GROUP

Group Chair	Clinton R. Crookshanks National Transportation Safety Board Aurora, Colorado
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Group Member	John Petruzzelli International Association of Machinists Seattle, Washington
Group Member	Ben Hobbs Spirit AeroSystems Wichita, Kansas

C DETAILS OF THE INVESTIGATION

The left mid exit door (MED) plug departed the airplane during the event and the airplane returned safely to Portland International Airport. The group examined the accident airplane from January 6-11, 2024, at the Horizon Airlines facility in Portland, Oregon. The group participated in the laboratory examination of the MED plug at the NTSB Materials Lab from January 23-25, 2024.

The group re-examined the accident airplane from February 13-14, 2024, at the Horizon Airlines facility in Portland, Oregon, to perform some testing and witness the Airworthiness Directive (AD) 2024-02-51 inspection of the right MED plug.

D FACTUAL INFORMATION

1.0 Airplane Information

The Boeing 737-9 airplane is a twin-engine, narrow-body, transport category airplane (Figure 1) originally certified in 2018. The airplane is equipped with a conventional tail and retractable tricycle landing gear. The airplane is 138 feet, 2 inches long, 40 feet, 10 inches tall at the tail, has a fuselage diameter of 12 feet, 4 inches, has a wingspan of 117 feet, 10 inches, and has a horizontal stabilizer span of 47 feet, 1 inch. The airplane primary and secondary wing, fuselage, and tail structure is of all metal construction, primarily aluminum alloys. The accident airplane, SN 67501, was delivered new to Alaska Airlines on October 31, 2023, and received its airworthiness certificate on November 2, 2023.

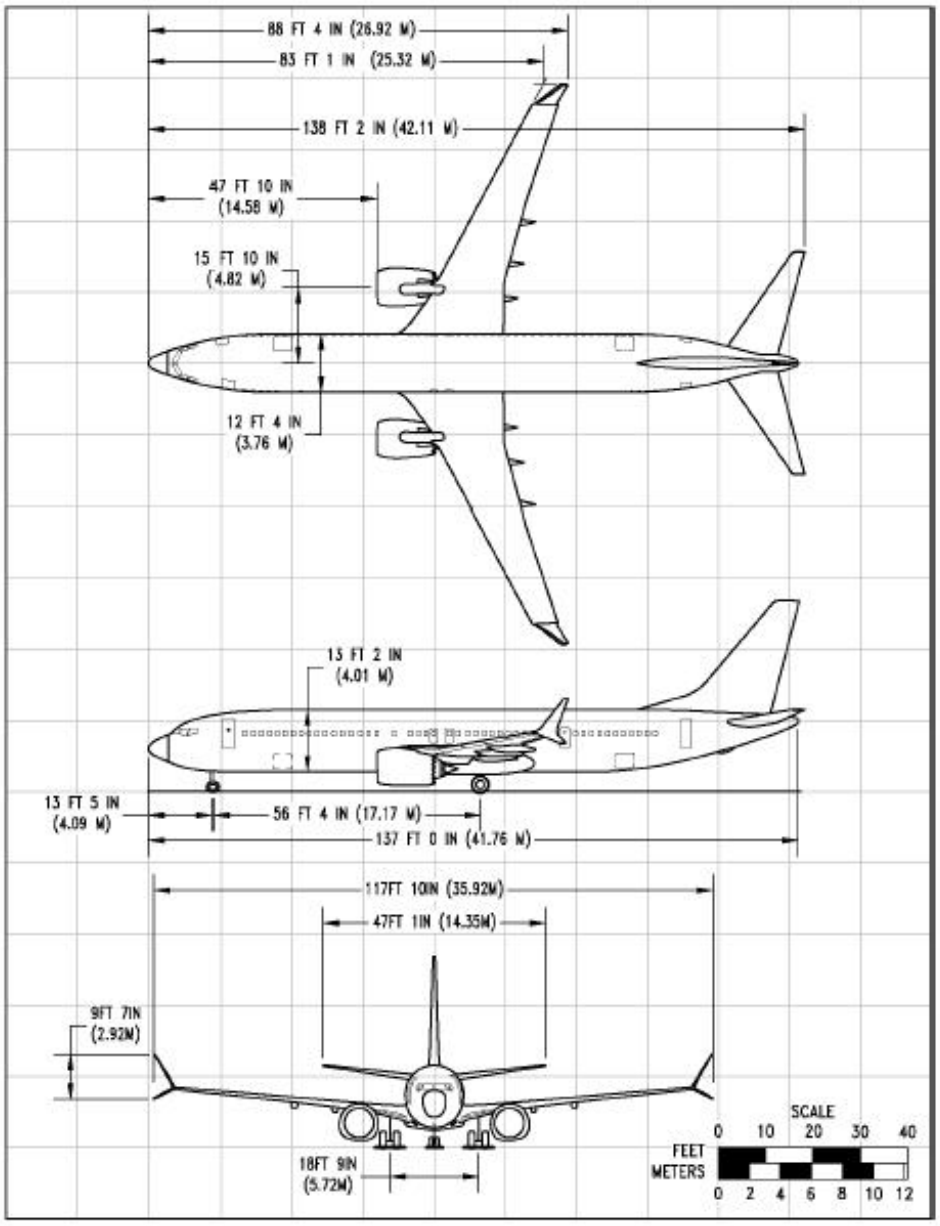

Figure 1. Boeing 737-9 3-view drawing (Source: Boeing. Image Copyright © Boeing. Reproduced with permission.)

1.1 MED Plug Description

The MED plug is about 29 inches wide by 59 inches high (Figure 2). Two identical door plugs are located behind the wing, with the plug centerlines at Station 727I+2, one on each side of the fuselage. The MED plug is located and secured in the fuselage by 12 pressure stops, 2 upper guide fittings, and 2 lower hinge fittings (Figure 3). The pressure loads (radially outward) are carried through 12 stop fittings on the MED plug, 6 on each side, that engage with 6 stop pads on a fuselage frame

forward of the opening and 6 stop pads on a fuselage frame aft of the opening. The 2 upper guide fittings on the upper half of the MED plug, 1 forward and 1 aft, engage with upper guide rollers on the forward and aft fuselage frames. The 2 lower hinge fittings, 1 forward and 1 aft, installed on the lower sill engage with 2 lower hinge guide fittings on the lower end of the MED plug. The plug is secured vertically by two vertical movement arrestor bolts installed through the hinge fittings and hinge guide fittings and two upper guide track bolts installed through the upper guide fittings (Figure 4). After the vertical movement arrestor bolts and upper guide track bolts are removed, the initial MED plug motion for opening is vertically upward at a slight inclination inboard such that the plug stops will clear the fuselage stop pads. Once clear, the MED plug pivots outboard about the lower hinge fitting bolts. The MED plug is only intended to be opened for maintenance and inspection which requires removing the vertical movement arrestor bolts and upper guide track bolts. The strap assemblies below the second stop from the top will restrict the plug from opening to no further than 15° which is sufficient for routine maintenance and inspection purposes.

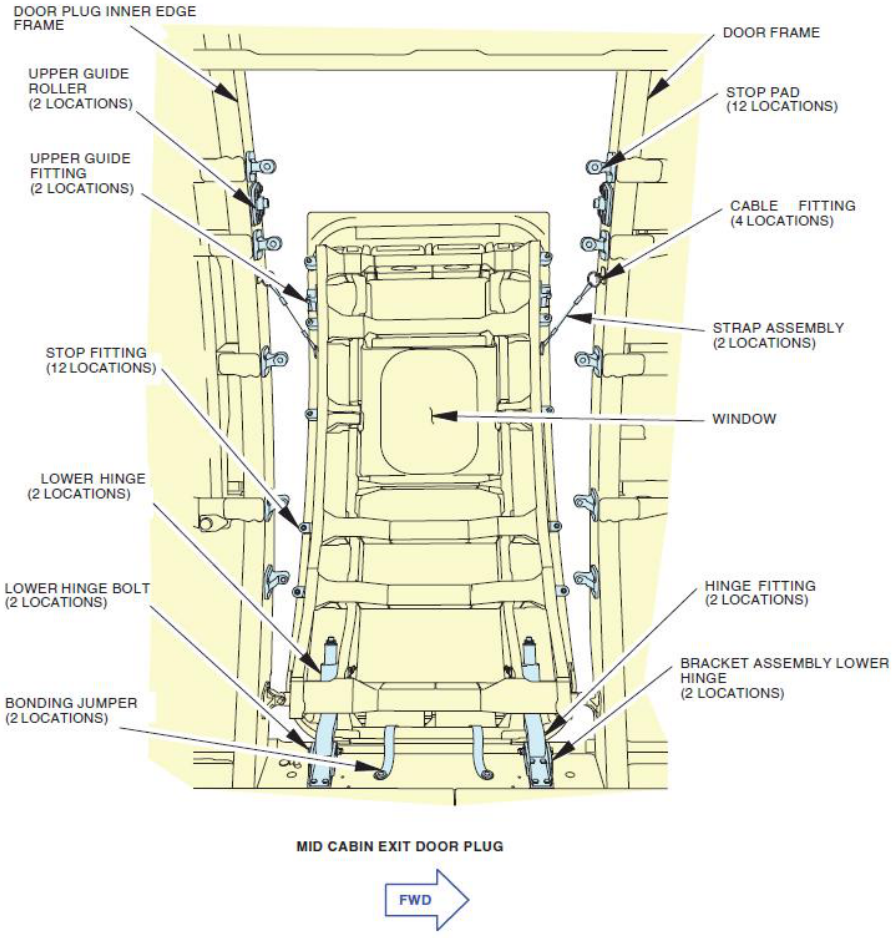

Figure 2. MED Plug drawing, open position (Source: Boeing. Image Copyright © Boeing. Reproduced with permission.)

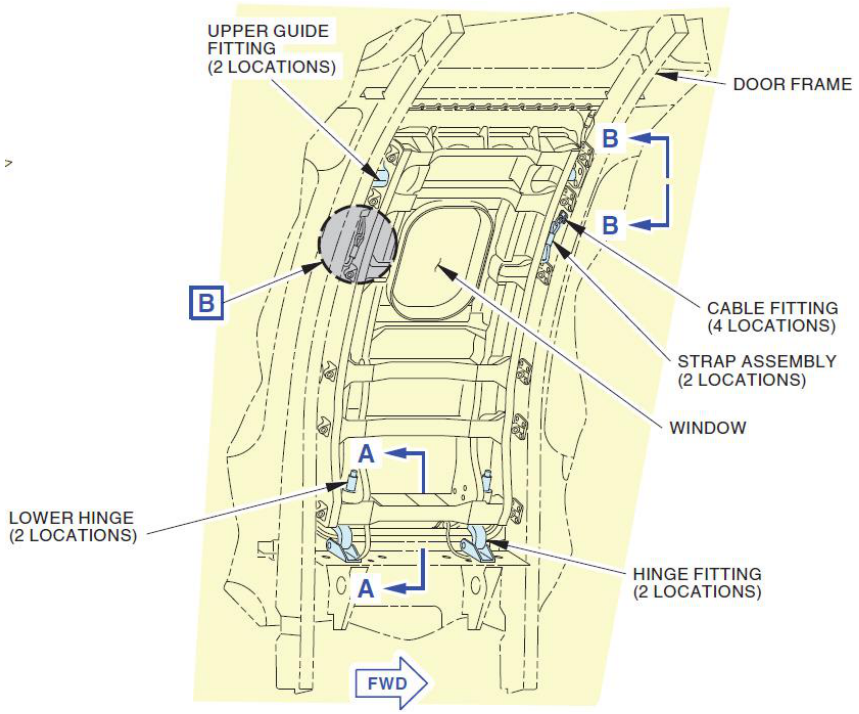

Figure 3. MED Plug drawing, closed position (Source: Boeing. Image Copyright © Boeing. Reproduced with permission.)

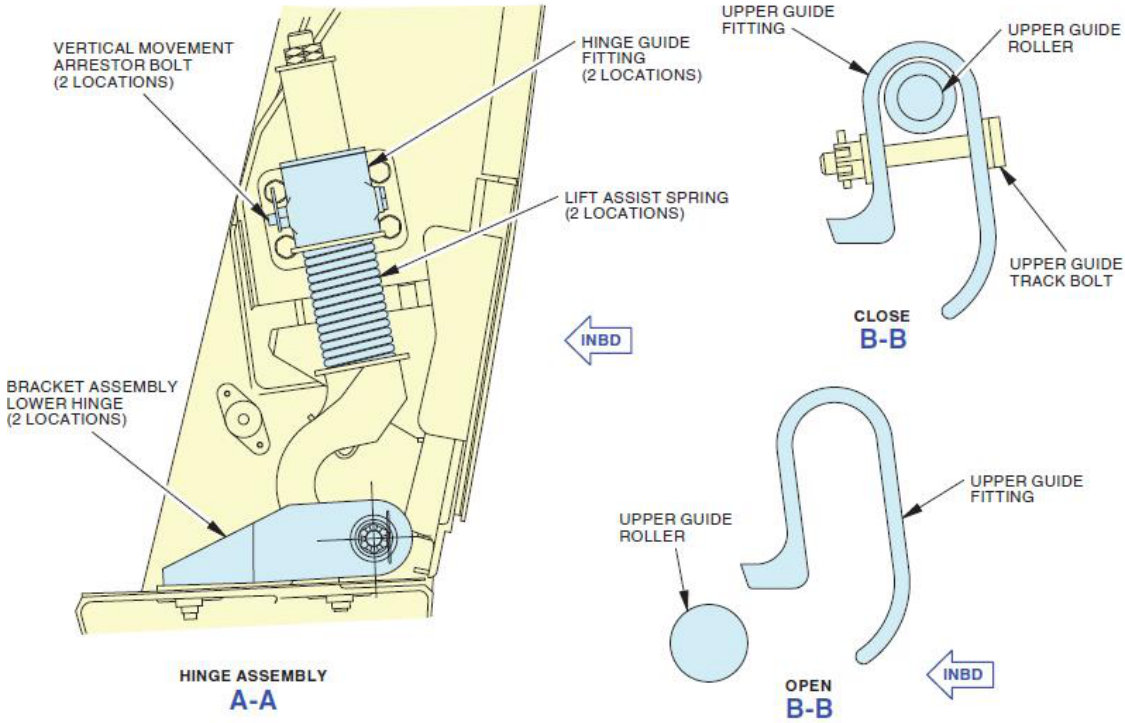

Figure 4. MED Plug lock bolt installation (Source: Boeing. Image Copyright © Boeing. Reproduced with permission.)

2.0 Airplane Examination

The airplane was predominantly intact after the event. There were some areas of scuffing noted to the left horizontal stabilizer leading edge, but there was no evidence of denting or deformation. A general visual examination of the airplane was performed with no obvious evidence of damage to the airframe except as described below. The damage to the MED plug incurred during its departure from the airplane adversely affected the structural strength of the MED plug and the pressurization performance of the airplane requiring replacement of the MED plug which is classified as substantial damage under NTSB regulations.

Interior panel strips were partially pulled out or deformed at the 1AC, 3AC, 3DF, 4DF, 6ABC, 9DEF, 11DEF, 12DEF, and 27DEF passenger seat row locations. The forward edge of the interior panel at the 4AC location was partially pulled away. Seat and other interior damage is documented in the Survival Factors Group Chair's Factual Report in the public docket.

2.1 Left MED Fuselage Opening

The interior sidewall liner, light cover, and return air grille were missing around the left MED plug opening. The 12 fuselage stop pad fittings were mostly intact and remained installed on the forward and aft fuselage frames with varying amounts of damage. The forward and aft upper guide roller fittings were intact and installed on the forward and aft fuselage frames. The roller on each was free to rotate. There was impact damage noted to the fuselage skin at the lower edge of the opening and damage to the seal and seal retainer beneath the lower hinge fittings consistent with hinge over travel. The seal retainers appeared to have cut out areas adjacent to the hinge fittings with more removed material at the aft location. There were several small areas of chipped fuselage paint aft of the opening at the level of the 5A[1] stop. The seal was mostly intact around the perimeter of the opening. There were 3 tears in the upper blade portion of the seal located about 8 inches, 15 inches, and 23 inches aft of the forward frame consistent with the locations of the MED plug upper skin gussets. There was a semi-circular area of damage to the seal above the 1A stop pad about 5 inches below the frame. There was a small portion of the seal edge missing between the 3F and 4F stops. There was waviness and kinks noted in the seal at the upper forward and aft corners indicated by Boeing to be typical and inherent to the design of the seal. There was no deformation noted to the lower sill and the cutout edge frames were undamaged. The bonding jumpers were torn from the attach points on the lower sill with evidence of the jumper terminals inside the sealant at the jumper fasteners on the sill. The sill drains were intact and not plugged.

[1] The stop pad and fitting locations were numbered from 1 to 6 starting at the top and appended with an F for the forward locations and an A for the aft locations. See the Materials Laboroatory Factual Report 24-007 for an annotated photo of the stop pad locations.

The forward lower hinge fitting was mostly intact and installed in the forward lower hinge bracket assembly on the sill as designed. Two jam nuts remain installed at the upper end of the hinge fitting but there was no washer present. There was about 5/16 inch of the threaded end of the forward hinge fitting protruding above the jam nut. The lift assist spring and forward lower hinge guide fitting were separated from the hinge fitting and MED plug and not recovered. The forward hinge bracket assembly on the sill was intact and installed with no noted damage.

The aft lower hinge fitting was mostly intact and installed in the aft lower hinge bracket assembly on the sill as designed. Two jam nuts and a washer remained installed at the upper end of the hinge fitting. There was about 5/16 inch of the threaded end of the aft hinge fitting protruding above the jam nut. The washer was bent and deformed upward. The aft lower hinge guide fitting remained installed on the shaft of the hinge fitting with the lift assist spring and upper and lower washers installed. Initially, there was a sock jammed between the upper spring coils that separated during manipulation of the hinge for the investigation. The aft hinge bracket assembly on the sill was intact and installed with no noted damage.

The 12 fuselage stop pad fittings, forward and aft upper guide roller fittings and serrated plates, and forward and aft lower hinge bracket assemblies with lower hinge fittings attached were removed from the airplane and shipped to the NTSB Materials Laboratory for further examination. See the Materials Laboratory Factual Report 24-007 in the public docket for the details of the examination.

2.2 Left MED Plug

The left MED plug departed the airplane during the event and was recovered in the back yard of a house located at [redacted] Additional items from the airplane were recovered in the vicinity to include a seat back tray table, the plastic window reveal from the interior sidewall panel, a seat head rest, and two cell phones. The plug was mostly intact with some damage. The plug window assembly remained intact and installed in the plug.

The following information was on the affixed data plate and/or written on the chord flange:

AIRCRAFT MOD: 737
MFR Y0279
PN 146A6202-9101
SN Y0279-000153 (written had -0000153)
Line Unit 8799 (only written)
Made in Malaysia (only written)
Cont. Insp. Stamp SAA 101QU (only on data plate)

The 12 stop fittings on the left MED plug were all intact with the stop pins installed with varying amounts of damage. The stop pin heads were missing at the 3F,

4F, 5F, 6F, 5A, and 6A locations. The forward upper guide fitting remained installed and was mostly intact except for a fracture along the inboard track surface. The aft upper guide fitting remained installed and was mostly intact except for a fracture along the inboard track surface.

The passenger window remained installed in the plug and the forward center spring clip was disengaged; all other spring clips were installed and engaged with the window assembly. There was an area of discoloration and streaking on the exterior surface of the MED plug skin from the forward edge at the upper forward corner. There were discrete, vertically spaced dirt witness marks at the upper edge of the MED plug on the inboard surface where it mates with the upper seal.

The recovered left MED plug was shipped to the NTSB Materials Laboratory for further examination.

2.3 Right MED Plug

The right MED plug was intact and remained installed in the fuselage. An initial visual examination of the right MED plug was performed but nothing was removed or disturbed during the initial examination. Boeing developed a multi-operator message (MOM) giving instructions for inspections of the 737-9 MED plug (MOM-MOM-24-0010-01B(R4)). The inspections were mandated through AD 2024-02-51. The group witnessed the performance of the AD inspection on the right MED plug during the follow-up examination. The group developed an examination plan prior to the visit that followed the steps of the MOM with some additional steps added to the plug opening procedures.

There was no record of the right MED plug being opened after delivery from Spirit AeroSystems and no physical evidence that it had been opened. The MOM steps 1.a through 1.i.ii were completed first. The forward and aft upper guide track bolts were installed in the guide tracks with one washer under the head of the bolt and one washer under the nut. The castellated nuts were installed, and the cotter pins were intact. Both upper guide track bolts rotated freely by hand. The forward and aft vertical movement arrestor bolts were installed in the lower hinge guide fittings with one washer under the head of the bolt and one washer under the nut. The castellated nuts were installed, and the cotter pins were intact. Both vertical movement arrestor bolts were tight and could not be rotated by hand. The forward and aft lower hinge bolts were installed in the lower hinge brackets with one thick washer and one thin washer under the head of the bolt and two thick washers and one thin washer under the nut. The castellated nuts were installed, and the cotter pins were intact. Both lower hinge bolts rotated freely by hand. The compressed length of the lower hinge springs was measured to be 2-15/32” on both. There were wrench witness marks on the bolt heads for both upper guide roller fittings on the door frame.

The stop pins were aligned with the stop pads at all 12 locations. There was no gap between the stop pin head and stop pad at the 1F, 1A, 2A, 4F, 5F, and 6F locations. The gap between the stop pin head and stop pad was measured to be 0.004″ at the 3F location, 0.005″ at the 3A location, 0.006″ at the 2F and 4A locations, 0.008″ at the 5A location, and 0.009″ at the 6A location. The gap between the fuselage skin and the right MED plug skin was measured to be from 0.036″ to 0.302″ on the sides and bottom and 1.55″ on the top. The right MED plug skin surface was inboard of the fuselage skin surface around the periphery and measured 0.035″ to 0.098″.

The lower hinge bracket assemblies on the sill were seated on the fixed serrated plates and the distance from the inboard edge of the serrated plate to the inboard edge of the bracket assembly measured 0.078″ on the forward and aft bracket assemblies. The upper guide roller fittings were seated on the fixed serrated plates and the distance from the upper edge of the serrated plates to the upper edge of the guide roller fitting measured 0.078″ on the forward and aft. The distance from the inboard edge of the serrated plate to the inboard edge of the guide roller fitting measured 0.020″ on the forward and 0.039″ on the aft. The lower hinge guide fittings on the right MED plug were seated on the fixed serrated plates and the distance from the upper edge of the serrated plate to the upper edge of the guide fitting measured 0.033″ on the forward and 0″ on the aft. The gap between the upper guide fitting and upper guide roller measured 0.090″ on the forward side and 0.003″ on the aft side. The gap between the upper guide track bolt and upper guide roller exceeded 0.025″ on the forward and aft.

Following the completion of MOM step 1.i.ii the group paused to open the plug. The distance from the lower sill to the lower edge of stop beam 6 measured 4.28″ at the forward hinge location and 4.25″ at the aft hinge location with the vertical movement arrestor bolts still installed. The two upper guide track bolts and two vertical movement arrestor bolts were removed and retained for further examination along with all the hardware. The right MED plug did not move when the bolts were removed. A strap was attached to stop beam 6 to facilitate lifting and a force gage was connected to the strap. An upward force of 120 pounds was applied (to the limits of the gage) with no movement of the plug. Additional force by two people, estimated to exceed 150 pounds total, was applied and the plug moved up disengaging the stops. Repro-rubber was applied inside the upper guide track fittings in order to measure the gaps between the guide tracks and rollers and the plug was closed. After reopening the right MED plug and removing the repro-rubber, the inboard gap between the fitting and roller was measured to be 0.025″ on the forward and 0.023″ on the aft. The upper gap between the fitting and roller was measured to be 0.010″ on the forward and 0.025″ on the aft. The plug was opened and closed several times, and the gaps were remeasured using repro-rubber. The inboard gap between the fitting and roller measured 0.037″ on the forward and

0.031″ on the aft. The upper gap between the fitting and roller measured 0.039″ on the forward and 0.036″ on the aft.

The four bolts attaching each lower hinge guide fitting to the right MED plug were examined. All bolt heads were seated and there were 2-3 threads evident beyond the nutplates. Each of the bolts was loosened to check the running torque on the nutplates before being re-torqued to 34-36 in-lb. All nutplates had a minimum 2 in-lb of run-on torque as required. The four bolts attaching each lower hinge bracket assembly to the lower sill were removed to check the grip length with no discrepancies noted. The bolts were reinstalled and all nutplates had a minimum 3.5 in-lb of run-on torque, as required. The bolts were re-torqued to 78-82 in-lb. The four bolts attaching each upper guide roller fitting to the door frame were examined. All bolt heads were seated and there were 2-3 threads evident beyond the nutplates. Each of the bolts was loosened to check the running torque on the nutplates before being re-torqued to 97-103 in-lb. All nutplates had a minimum 3.5 in-lb of run-on torque, as required.

The exterior gap between the lower edge of the right MED plug and the fuselage opening was examined at 3 different plug vertical positions. With the right MED plug in the fully down position, the distance between the lower sill and the lower edge of stop beam 6 was measured to be 4-5/16″ at the forward and aft hinge locations. The lower gap on the exterior measured 0.079″ (Position A (left), Figure 5). With the plug in the middle position, the distance between the lower sill and the lower edge of stop beam 6 was measured to be 4-17/32″ at the forward hinge and 4-9/16″ at the aft hinge. The lower gap on the exterior measured 0.315″ (Position B (center), Figure 5). With the plug in the upper position (stop pin to pad instability point), the distance between the lower sill and stop beam 6 was measured to be 4-7/8″ at the forward and aft hinge locations. The lower gap on the exterior measured 0.630″ (Position C (right), Figure 5).

Figure 5. Right MED plug exterior at position A (left), position B (center), and position C (right) [NTSB photos].

There was a dirt witness mark along the upper edge of the plug on the inboard surface where it mated with the upper seal that appeared to align with the bulb feature of the seal. A sample of the material was retained for further analysis as detailed in the Materials Laboratory Factual Report 24-007. The forward and aft upper guide track fittings had disturbed paint on the inboard and outboard surfaces consistent with a washer being installed (Figure 6). The hole bores and outer hole corners had disturbed and missing paint. The forward and aft lower hinge guide fittings had disturbed paint on the inboard surfaces consistent with a washer being installed (Figure 7). The hole bores and outer corners of the holes had disturbed and missing paint.

The force required to translate the plug upward from its closed position was examined after it had been manipulated several times and still exceeded the limits of the force gage (120 lb). The MOM inspections and data gathering were completed. Closure of the right MED plug required no adjustments to achieve the AMM specified parameters.

Figure 6. Right MED plug forward (left) and aft (right) upper guide track fitting outboard holes after removal of the upper guide track bolts (NTSB Photos).

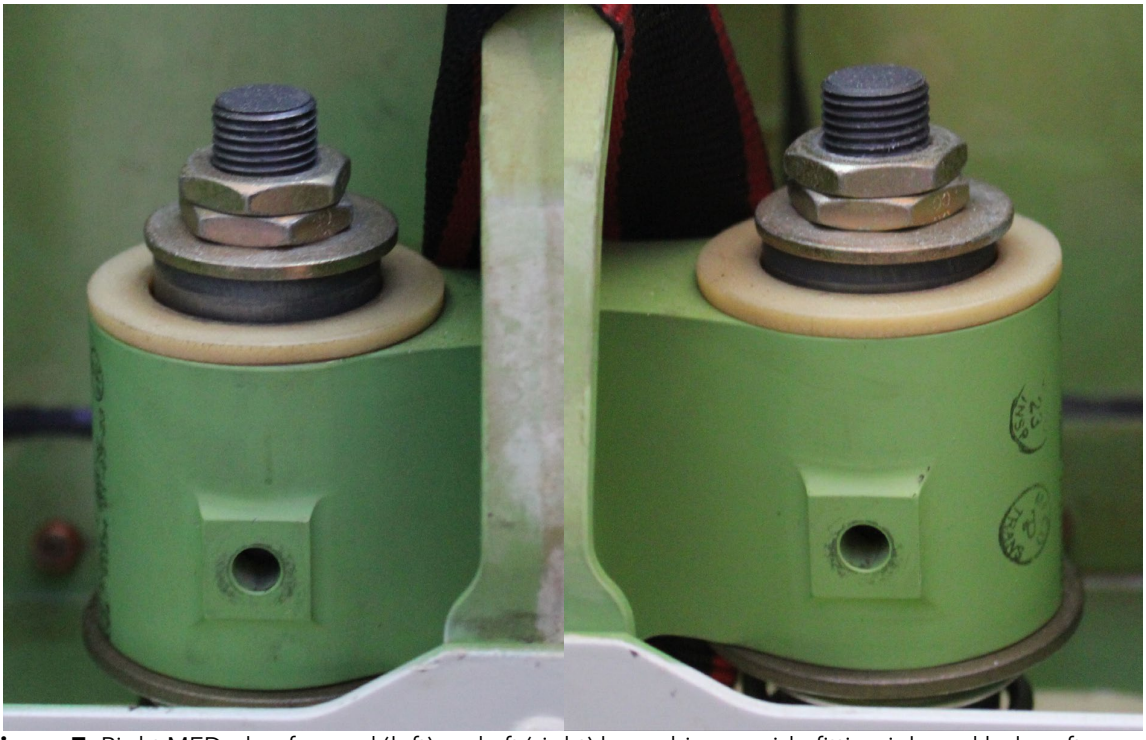

Figure 7. Right MED plug forward (left) and aft (right) lower hinge guide fitting inboard holes after removal of the vertical movement arrestor bolts (NTSB Photos).

E TESTS AND RESEARCH

1.0 Boeing Information

1.1 MED Plug Loads Analysis

The airplane had accrued 154 flight cycles at the time of the accident and the last 9 flights were recorded on the Quick Access Recorder (QAR). The Boeing Dynamic Loads group examined the data for the last 9 flights in an attempt to approximate the inertial loads on the MED plug. The loads were grouped into 3 different categories. Ground operations were defined as taxi-out, takeoff, landing, rollout, and taxi-in with no pressurization loads. Climb was defined as the time the airplane was ascending when the internal cabin pressure was increasing until it was stabilized at the maximum for the given flight. Descent was defined as the time the airplane was descending when the internal cabin pressure was decreasing from maximum for the given flight to zero. The airplane vertical acceleration (Nz) recorded on the QAR was translated to the MED plug location using the structural elastic fuselage model to generate the Nz at the MED plug. A histogram was prepared that grouped the Nz values into 0.05 g buckets from 0.2 g to 1.8 g. The group focused on the Nz values less than 1.0 g when the inertial loads on the MED plug were minimum and reduced the effective weight of the plug. The results estimated the smallest Nz was 0.40-0.45 g that occurred only once in the 106,008 Nz values counted. Estimated Nz values of 0.45-0.50 g occurred twice. The 0.40-0.45 g level represented an effective plug weight of 25 lb, acting downward, reduced from the nominal 63 lb weight of the plug at 1.0 g. There were a total of 29 Nz values counted less than 0.75 g representing less than 0.03% of the total, with six of these 29 occurring during descent, and the remainder occurring during airplane ground operations. The vast majority of the exceedances counted (97.3%) fell into the 0.95 to 1.0 g range. Boeing Dynamic Loads estimated an error of about +/- 0.15 g in the Nz values, as a result of uncertainties related to airplane weight and load distribution, the location of the plug away from the elastic axis (centerline) of the fuselage, and the effect of the accelerometer data filter.

1.2 MED Plug Design Capability with Variable Bolt Installation

Boeing conducted an engineering review of the 737-9 MED plug design capability with variable bolt installations. As designed, two upper guide track bolts and two vertical movement arrestor bolts are installed to prevent upward movement of the MED plug. The review showed the MED plug design ensures that one vertical movement arrestor bolt installed in a hinge assembly is capable of preventing upward movement of the plug. Alternatively, with no vertical movement arrestor bolts installed in either hinge assembly, the two upper guide track bolts are capable of preventing sufficient upward movement to disengage the stop pins from the stop pads. Therefore, if only one vertical movement arrestor bolt is installed in a hinge

assembly, then the other vertical movement arrestor bolt and both upper guide track bolts are not needed to ensure the plug remains in place. If no vertical movement arrestor bolts are installed in the hinge assemblies, then both of the upper guide track bolts are required to ensure the plug remains in place.

1.3 Depressurization Certification

The 737-9 airplane structure is certified to withstand a sudden depressurization at any altitude in accordance with *Title 14 Code of Federal Regulations* 25.365(e) at amendment level 87. The regulation defines the calculation for the maximum hole size that is based on the maximum cross-sectional area of the fuselage. The calculated hole size is 820 in^2 for the 737-9 airplane. The Boeing certification analysis utilized a differential pressure of 8.35 psi between the interior and exterior of the airplane which represents the maximum differential pressure provided by the pressurization system during normal operation. The analysis also used a worst-case scenario with the cabin altitude at sea-level and the maximum differential pressure to represent the maximum mass of air that must escape through the depressurization hole which is a scenario that cannot occur in normal flight but adds conservatism to the analysis. See the Systems Group Chair's Factual Report for an explanation of the pressurization control system operation and the examination of the components after the accident. The fuselage hole created by the departure of the plug was about 1,682 in^2 and the recorded pressure differential at the time of the event was 5.73 psi.

2.0 FAA Information

The FAA issued Emergency AD 2024-02-51on January 6, 2024, based on the preliminary findings from the investigation. The AD prohibited further flight of all 737-9 airplanes until the right and left MED plugs had been inspected and any discrepancies were corrected using a method approved by the FAA. Boeing worked with the FAA to develop multi-operator message MOM-MOM-24-0010-01B(R4) that provided approved instructions for inspection of the 737-9 plugs. By January 31, 2024, all but 4 airplanes had been inspected and, in all cases, the 2 upper guide track bolts and the 2 vertical movement arrestor bolts were installed, and the plugs were engaged with the fuselage stop fittings. The 4 uninspected airplanes included the accident airplane, 2 airplanes undergoing heavy maintenance, and 1 airplane outfitted for executive transport. There were some discrepancies reported as part of the AD inspection to include loose upper guide track bolts (no torque requirement existed before the MOM), the incorrect number of washers installed at various locations, clearances/gaps that were out of limits, loose fasteners at various locations, incorrect fastener grip lengths, missing cotter pins, and minor damage to components. The 2 airplanes in heavy maintenance were inspected by February 14, 2024, and found to have the upper guide track bolts and the vertical movement arrestor bolts installed. Discrepancies noted on these airplanes were similar to the others. The accident airplane right MED plug has been inspected as outlined in

section D.2.3, but the inspection of the left MED plug cannot be completed until a new left MED plug is installed. The remaining executive transport airplane is subject to United States and European Union sanctions preventing communication with the operator.

The FAA issued Safety Alert for Operators (SAFO) 24001 on January 21, 2024, providing information on the 737-900ER MED plug. The 737-900ER MED plugs have an identical design to the 737-9 MED plugs and the FAA encouraged operators to conduct a visual inspection to ensure that the upper guide track bolts and the vertical movement arrestor bolts were installed. The available fleet data indicated that all the 737-900ER airplanes in service had surpassed the MED plug inspection threshold in the maintenance program and should have been opened and inspected at least once prior to the issuance of the SAFO.

Submitted by:

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Aerospace Engineer (Structures)