AIRCRAFT SERIOUS INCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/3/2/1336		
Aircraft Registration	**ZS-SJF**	**Date of Serious Incident**	25 January 2021	**Time of Serious Incident**	1232Z		
Type of Aircraft	Boeing 737-800			**Type of Operation**	Commercial (Part 121)		
Pilot-in-command Licence Type		Airline Transport Pilot Licence	**Age**	50	**Licence Valid**	Yes	
Pilot-in-command Flying Experience		**Total Flying Hours**	11 261.4		**Hours on Type**	1 841.2	
Last Point of Departure		O.R. Tambo International Airport (FAOR), Gauteng Province					
Next Point of Intended Landing		King Shaka International Airport (FALE), KwaZulu-Natal Province					
Damage to Aircraft		None					
Location of the serious incident site with reference to easily defined geographical points (GPS readings if possible)							
En route from FAOR to FALE abeam Dundee (GPS position: South 28°07'.6" East 030°22'.2")							
Meteorological Information	Wind direction: 220°; Wind speed: 11 knots; Temperature: 21°C; Dew point: 19ºC; Visibility: 10 km; QNH: Unknown						
Number of People On-board	2 + 4 + 119	**Number of People Injured**	0	**Number of People Killed**	0	**Other (On Ground)**	0
Synopsis							

On 25 January 2021, a Boeing 737-800 aircraft with registration ZS-SJF operated by Mango Airlines departed O.R. Tambo International Airport (FAOR) on a scheduled flight to King Shaka International Airport (FALE). On-board the aircraft were six crew (two pilots and four cabin crew) members and 119 passengers. The captain was the pilot monitoring (PM); and the first officer (FO) was the pilot flying (PF). Before take-off, pressurisation and air conditioning system switches were set in accordance with (IAW) pre-take-off checks as outlined in the aircraft's Quick Reference Handbook (QRH). The aircraft climbed and levelled off at flight level (FL) 350. During the descent phase to FALE at 1232Z and after passing FL270 abeam Dundee, the "Cabin Altitude" rapid decompression warning light illuminated, and audio/aural warning sounded. The captain instantly cross-checked the position of the outflow valve before broadcasting a MAYDAY call three times on the very high frequency (VHF) 125.75 megahertz (MHz) to the area controller who had the aircraft on primary surveillance radar. The crew promptly donned their oxygen masks and manually deployed the passengers' oxygen masks. The captain called for Cabin Alt warning checks as stipulated in the aircraft's QRH and actioned those items. The aircraft levelled off at FL090 and a normal approach and landing was carried out on Runway 24 at FALE. No injuries were reported.

Probable Cause/s

The aircraft was unable to maintain cabin pressure for a safe environment of the passengers and the crew members due to the right-side air-conditioning pack bleed air leak; the left-side pack was unable to compensate for a defective right-side pack due to the No.1 engine's 9th stage bleed air valve being locked closed prior to departing FAOR.

Contributing factor/s:

Defective right-side air-conditioning pack components that included the primary heat exchanger, air cycle machine, sense line and the trim air check valve.

SRP Date	11 May 2021	Publication Date	12 May 2021

ABBREVIATION	DESCRIPTION
AIP	Aeronautical Information Publication
ADs	Airworthiness Directives
AFM	Aircraft Flight Manual
AMM	Aircraft Maintenance Manual
APU	Auxiliary Power Unit
ASU	Air Start Unit
AOC	Air Operating Certificate
AMO	Aircraft Maintenance Organisation
ARFF	Aircraft Rescue and Fire-Fighting
ASI	Air Speed Indicator
AMSL	Above Mean Sea Level
ATPL	Airline Transport Pilot Licence
AIMS	Aircraft Information Management System
AD	Advisory Circular
AME	Aircraft Maintenance Engineer
ATO	Aviation Training Organisation
ATC	Air Traffic Controller
CPC	Cabin Pressure Controllers
CAR	Civil Aviation Regulations
CVR	Cockpit Voice Recorder
DCPCS	Digital Cabin Pressurisation Control System
EFIS	Electronic Flight Instrument System
EICAS	Engine Indicating and Crew Alerting System
FAA	Federal Aviation Administration
FALE	King Shaka International Airport
FAOR	O.R. Tambo International Airport
FO	First Officer
FL	Flight Level
FMC	Flight Management Computer
FDR	Flight Data Recorder
IAW	In Accordance With
IFR	Instrument Flight Rules
MOR	Mandatory Occurrence Reporting
MFD	Multi-Function Display
MEL	Minimum Equipment List
MCP	Mode Control Panel
NTSB	National Transportation Safety Board
NM	Nautical Mile
OAMP	Operator’s Aircraft maintenance Program
OFV	Outflow Valve
OEM	Original Equipment Manufacturer
PFD	Primary Flight Display
PF	Pilot Flying
PM	Pilot Monitoring
PSI	Pressure Square Inch

PSU	Passenger Service Unit
QRH	Quick Reference Handbook
SACAA	South African Civil Aviation Authority
SB's	Service Bulletins
SCCM	Senior Cabin Crew Member
SAAT	South African Airways Technical
TL	Technical Logbook
TUC	Time of Useful Consciousness
TGV	Tango, Golf, Victor
VNAV	Vertical Navigation
VOR	Omni Directional Range

Reference Number	**:** CA18/3/2/1336
Name of Owner/Operator	**:** Mango Airlines SOC (Ltd)
Manufacturer	**:** Boeing Aircraft Company
Model	**:** Boeing 737-800
Nationality	**:** South African
Registration Marks	**:** ZS-SJF
Place	**:** In-flight
Date	**:** 25 January 2021
Time	**:** 1232Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and **not to apportion blame or liability**.

Investigations Process:

The serious incident was notified to the Accident and Incident Investigations Division (AIID) on 25 January 2021 at approximately 1310Z. The serious incident was also reported to AIID via the Mandatory Occurrence Reporting (MOR) system on 26 January 2021 at 0700Z.

The AIID has appointed an investigator-in-charge with an investigation team. Notifications were sent to the State of Manufacturer and Design, namely, the United States of America (USA), which then appointed a non-travelling accredited representative to the investigation. The AIID will lead the investigation and issue the final report.

1. Whenever the following words are mentioned in this report, they shall mean the following:

- *Serious Incident – this investigated serious incident*
- *Aircraft – a Boeing 737-800 involved in this serious incident*
- *Investigation – the investigation into the circumstances of this serious incident*
- *Pilot – the pilot involved in this serious incident*
- *Report – this serious incident report*

2. Photos and figures used in this report were taken from different sources and may be adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report are limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or addition of text boxes, arrows or lines.

Disclaimer:

This report is produced without prejudice to the rights of AIID, which are reserved.

1. FACTUAL INFORMATION

1.1. History of Flight

1.1.1 On 25 January 2021, the crew (pilots) reported for duty at O.R. Tambo International Airport (FAOR) domestic terminal in preparation for flight JE251 on a Boeing 737-800 aircraft, with registration ZS-SJF, operated by Mango Airlines. The aircraft was parked at parking bay A11 and was scheduled to depart for King Shaka International Airport (FALE) situated at La Mercy, KwaZulu-Natal province at 1125Z. The aircraft was operated under Instrument Flight Rules (IFR) and the flight plan was filed with Johannesburg briefing. The crew, before the flight preparation, were joined in their briefing in the aircraft by the operator's technical representative who was a licensed Aircraft Maintenance Engineer (AME). The AME was on standby to assist the crew using his headset during the engine start-up process. The crew, during the technical logbooks (TL) examination, had noticed that the aircraft had two snags that were deferred as per the minimum equipment list (MEL). The deferred snags were the auxiliary power unit (APU) which was inoperative, and the No.1 engine nose cowl anti-ice amber light which remained illuminated; as a result, the No.1 engine 5th stage bleed air valve was locked open so that the nose cowling does not incur icing and the 9th stage bleed air valve was locked closed.

1.1.2 The aircraft was then delayed for about 32 minutes due to time spent updating the aircraft's paperwork. The crew was briefed on the deferred snags and the aircraft was to be dispatched in accordance with (IAW) MEL 30-03-03B. The captain, after examining the aircraft's TL, had decided that he would be the pilot monitoring (PM) and the first officer (FO), the pilot flying (PF). The crew were joined in the cockpit by an off-duty pilot (a Durban-based pilot "FO" returning to his home base) who was seated on the jump seat at the captain's discretion. The four cabin crew members in the meantime prepared the aircraft for the passengers who later boarded the aircraft through the air bridge. The captain, after finishing examining the TL, had walked out of the aircraft using the stairs and performed a walkaround pre-flight inspection and, later, the preparation in the cockpit. The preparation included programming the flight management computer (FMC) and setting up the mode control panel (MCP) for the expected departure routing.

1.1.3 The captain then communicated with air traffic control (ATC) to find out the runway in use and the weather conditions. Using the passenger and baggage figures from the ground handling company and the weather information from the control tower, the captain completed weight and balance, as well as performance calculations before the information was captured in the FMC. The crew then completed taxi and take-off briefing, covering items such as taxi and departure routing, including a discussion on the handling of emergencies during take-off. Final preparations were completed, and doors were closed and armed. Normal communication between the AME and the captain took place, followed by clearance from ATC to start the engines. The aircraft had a total of 6500 kilograms (kg) of Jet A1 fuel. A systematic engine start was done using bleed air from the air start unit (ASU) as the APU was inoperative.

1.1.4 A tow bar was connected to the nose gear and the aircraft was pushed to the taxiway using a tug. Thereafter, a tow bar was disconnected, and the nose gear steering bypass pin was connected. As part of the pre-flight checks, the air-conditioning packs were switched to AUTO position. The cabin pressurisation was configured with the cruise altitude (FL350) and destination airport altitude (304 feet above mean sea level) was set. The pressurisation mode selector was set to AUTO for normal operation. The captain informed the AME via headsets that they were ready to taxi. The AME disconnected his headset and waited on the left-side of the aircraft where he subsequently received a thumbs up. The aircraft was taxied to the holding point for Runway 03L departure. At that time, the cabin crew carried out the safety briefing and demonstration to the passengers in the aircraft. Passengers in the seats next to the over-wing emergency exits were given a short briefing on their role in the event of an emergency and were asked to study the information in the safety briefing card. At 1157Z, the aircraft was cleared by ATC to depart on a standard instrument departure to FL350. The aircraft was configured for a flaps 5 departure and the PF advanced the thrust levers forward. The engines stabilised at 95% N1 and the aircraft rotated at 144 knots and with moderate weather conditions prevailing; the aircraft climbed to FL350. The aircraft began cruise at 459 knots and the cabin pressure remained normal at 87% N1 thrust. During the descent phase to FALE at 1232Z and after passing FL270 abeam Dundee, the “Cabin Altitude” rapid decompression warning light illuminated, and audio/aural warning sounded. The captain instantly cross-checked the position of the outflow valve which indicated closed and the cabin altitude which was above 10 000 feet (ft). The captain took over control of the aircraft. The crew promptly donned their oxygen masks and manually deployed the passengers’ oxygen masks.

Figures 1 & 2: On the left is an illustration of a B737 aircraft animation snap shot showing the “cabin altitude” warning illuminated and the Cabin Altitude which was above 10000 ft; and on the right is a picture of the ZS-SJF aircraft showing the deployed oxygen masks.

1.1.5 The captain made an announcement via an intercom system to confirm with cabin crew whether the masks had dropped. The senior cabin crew member (SCCM) reported that some oxygen masks did not drop, and they had to move some passengers to the seats where the masks had dropped. The crew broadcasted an emergency by broadcasting a MAYDAY call three times on the very high frequency (VHF) 125.75 megahertz (MHz) to the area controller who had the aircraft on primary surveillance radar. The aircraft was cleared for an unrestricted descent with no conflicting traffic, and FALE Aircraft Rescue and Fire-fighting (ARFF) team was put on standby. The captain called for the "Cabin Altitude Warning" emergency descent checklist as stipulated in the Quick Reference Handbook (QRH). Passengers were instructed to remain calm and seated. The crew continued with the descent at a maximum airspeed of 330 knots to FL110 and then to 7000ft. After passing FL100, the crew reduced the airspeed to 250 knots (about 45% N1) before removing the oxygen masks. Once below 10 000ft, the captain reduced the airspeed again and reviewed the situation. The captain made a request to ATC to hold at LE2T1 at 3 000ft. The crew reviewed the cabin altitude warning and emergency descent procedures and checked the pressurisation panel to see if they could manually control the pressurisation, but this was not possible. The captain called the SCCM to the cockpit through an intercom system and, after having established the wellbeing of the passengers and cabin crew members, explained the nature of the problem at hand, his intentions, and that there were no special requirements. The SCCM relayed the information to the rest of the cabin crew. The captain later briefed the passengers about the nature of the problem and requested that they remain calm on their seats. The aircraft made a straight-in-approach and a normal landing was carried out on Runway 24 at FALE. After exiting the active runway, the aircraft was brought to a stop so that the ARFF personnel could inspect the aircraft from the outside. No structural damage was reported by ARFF. The captain, for the second time, briefed the passengers before taxiing the aircraft to parking stand A16.

1.1.6 According to the captain's written statement, the flight lasted approximately 1.13 hours and the aircraft had 4000kg of Jet A1 fuel remaining. After parking and shutting down the engines, the SCCM made an announcement to the passengers and asked them if they needed medical assistance. An adult female passenger reported that her child could not hear properly, and the matter was handed over to the ramp agent. Most of the passengers were happy that they were able to use the oxygen masks without difficulty as they had watched the pre-take-off video explaining how to use them. The SCCM stated that apologies were made to the passengers, and that most of them were happy that they were safe and had expressed their gratitude to the crew. All passengers disembarked using the forward door. The aircraft was grounded for investigation and Mango Airline safety management team was informed. During a post-flight visual inspection by the South African Airways Technical (SAAT) engineers, no structural damage was noticed on the aircraft. Most of the oxygen masks in the cabin had dropped and all their chemical generators had activated. The flight was conducted under the provisions of Part 121 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.1.7 The serious incident occurred during the descent to FALE abeam Dundee, about 70 nautical miles (nm) north of Tango, Golf, Victor (TGV) - very high frequency omni-directional range (VOR) beacon at Global Positioning System (GPS) determined to be South 28°07'.6" East 030°22'.2".

Figure 3: The approximate position of the aircraft when the serious incident occurred. (Source: Google Earth)

1.2. Injuries to Persons

Injuries	Pilot	Cabin crew	Pass.	Total On-board	Other
Fatal	-	-	-	-	-
Serious	-	-	-	-	-
Minor	-	-	-	-	-
None	2	4	119	125	-
Total	2	4	119	125	-

1.3. Damage to Aircraft

1.3.1 The aircraft sustained no damage.

1.4. Other Damage

1.4.1 None.

1.5. Personnel Information

Captain (Pilot-in-command):

Nationality	South African	Gender	Male	Age	50
Licence Number	0272448499	Licence Type	Airline Transport Pilot Licence		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instrument and Grade II Flight Instructor				
Medical Issue Date	5 October 2020				
Medical Expiry Date	31 October 2021				
Restrictions	Nil				
Previous Accidents	None				

Flying Experience of the Captain:

Total Hours	11 261.4
Total Past 90 Days	103.2
Total on Type Past 90 Days	103.2
Total on Type	1 841.2

*NOTE: The hours shown above were obtained from the pilot questionnaire. Scrutiny into the captain's records kept at the South African Civil Aviation Authority (SACAA) showed that he had a Boeing 737-800 aircraft endorsed on his licence. His last proficiency check on B737-800 aircraft was provided by Mango Airlines Aviation Training Organisation (ATO) No. CAA/0307 on 26 and 27 October 2020, and the candidate was assessed as competent in all aspects. The Boeing 737-800 pilot proficiency check was conducted on 26 and 27 October 2020 with an expiry date of 30 April 2021. His previous experience included a Boeing 737-100/200/300/900 series, Boeing 777-200, Beechcraft Baron 55/58, Cessna Caravan C206/C208, Pilatus PC-12 Eagle/Spectre, Piper single/multi-engine series aircraft and varied operations, including charter and instructional flights.

First Officer (FO):

Nationality	South African	Gender	Male	Age	26
Licence Number	0271012940	Licence Type	Airline Transport Pilot Licence		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Instruments and Grade II Flight Instructor				
Medical Issue Date	7 October 2020				
Medical Expiry Date	31 October 2021				
Restrictions	Nil				
Previous Accidents	None				

Flying Experience of the FO:

Total Hours	3 362.5
Total Past 90 Days	77.2
Total on Type Past 90 Days	64.9
Total on Type	724.1

*NOTE: The hours shown above were obtained from the pilot questionnaire. Scrutiny into the FO's records kept at the South African Civil Aviation Authority (SACAA) showed that he had a Boeing 737-800 aircraft endorsed on his licence. His last proficiency check on B737-800 aircraft was provided by Mango Airlines, ATO No. CAA/0307 on 15 July 2020 and the candidate was assessed as competent in all aspects. The Boeing 737-800 pilot proficiency check was conducted on 15 July 2020 with an expiry date of 31 January 2021. His previous experience included a Boeing 737 300-900 series, Beechcraft Super King Air B200/300, Cessna Caravan C206/C208, Cessna single reciprocating-engine aircraft and varied operations, including instructional flights.

Cabin Crew Members:

1. SCCM:

   The SCCM was a 49-year-old female. Her medical certificate was issued on 16 January 2020 with an expiry date of 31 January 2022. Her last proficiency check on B737-800 aircraft was conducted on 4 July 2020 with an expiry date of 4 July 2021.

2. Second cabin crew member:

   The second cabin crew member was a 31-year-old female. Her medical certificate was issued on 13 April 2018 with an expiry date of 30 April 2023. Her last proficiency check on B737-800 aircraft was conducted on 26 February 2020 with an expiry date of 26 February 2022.

3. Third cabin crew member:

   The third cabin crew member was a 40-year-old female. Her medical certificate was issued on 25 April 2019 with an expiry date of 30 April 2024. Her last proficiency check on B737-800 aircraft was conducted on 11 October 2019 with an expiry date of 11 April 2021.

4. Fourth cabin crew member:

   The fourth cabin crew member was a 36-year-old male. His medical certificate was issued on 12 December 2019 with an expiry date of 31 December 2024. His last proficiency check on B737-800 aircraft was conducted on 23 December 2019 with an expiry date of 23 December 2021.

1.6 Aircraft Information

1.6.1 Aircraft description:

The Boeing 737-800 is a low-wing, narrow body, single-aisle jet transport aircraft manufactured by Boeing Commercial Aircraft Company situated in Seattle, United States of America (USA). The aircraft incorporates an advanced technology wing design that helps increase fuel capacity and efficiency, both of which increase range. The advanced wing airfoil design provides an economical cruise speed of 0.785 Mach. The aircraft has an electronic flight instrument system (EFIS) installed on the flight deck, which displays data electronically. The EFIS consist of the primary flight display (PFD) that features all information which is critical to the flight, such as: airspeed, altitude, heading, and vertical speed, to name a few. The aircraft also has a multi-function display (MFD) that shows pilots navigational and weather information. The information is typically presented as a chart or map with different information overlays. In addition, the aircraft has the engine-indicating and crew-alerting system (EICAS) which displays information pertaining to the aircraft's system. This includes the fuel, propulsion and electrical systems. If any mechanical problem arises with the aircraft, the EICAS alerts the crew.

Figure 4: ZS-SJF aircraft. (Source: https://www.jetphotos.com)

The Boeing 737-800 aircraft is designed to operate short and medium range flights and has a seating capacity of 189 passengers in the cabin for all economy configurations. The ZS-SJF aircraft is powered by two high bypass ratio, dual rotor turbo fan engines, each developing 26 400 pounds of thrust at sea level. It was also configured with 186 economy class seats at the time of the serious incident flight to FALE. According to the aircraft flight manual (AFM), the minimum flight crew necessary to operate the aircraft are two pilots and four cabin crew members.

Airframe:

Type	Boeing 737-800	
Serial number	30006	
Manufacturer	Boeing Aircraft Company	
Year of manufacture	2000	
Total airframe hours at the time of incident	49930.41	
Last weekly check inspection before the incident flight (Hours & Date)	49912.20	21 January 2021
Hours since last A-check	18,21	
Last scheduled A-check inspection	49584.47	3 December 2020
Hours since last A-check inspection	345.94	
C of A (Issue Date)	25 October 2004	
C of A (Expiry Date)	31 October 2021	
C of R (Issue Date) (Present owner)	9 October 2018	
Maximum take-off weight	79 015kg	
Airworthiness directive status	Complied With	
Type of fuel recommended	Jet A1	
Fuel used	Jet A1	
Operating categories	Standard Part 121	

Engine No.1:

Type	CFM 56-7B26
Serial number	876396
Hours since new	48 226
Last scheduled inspection	A-check

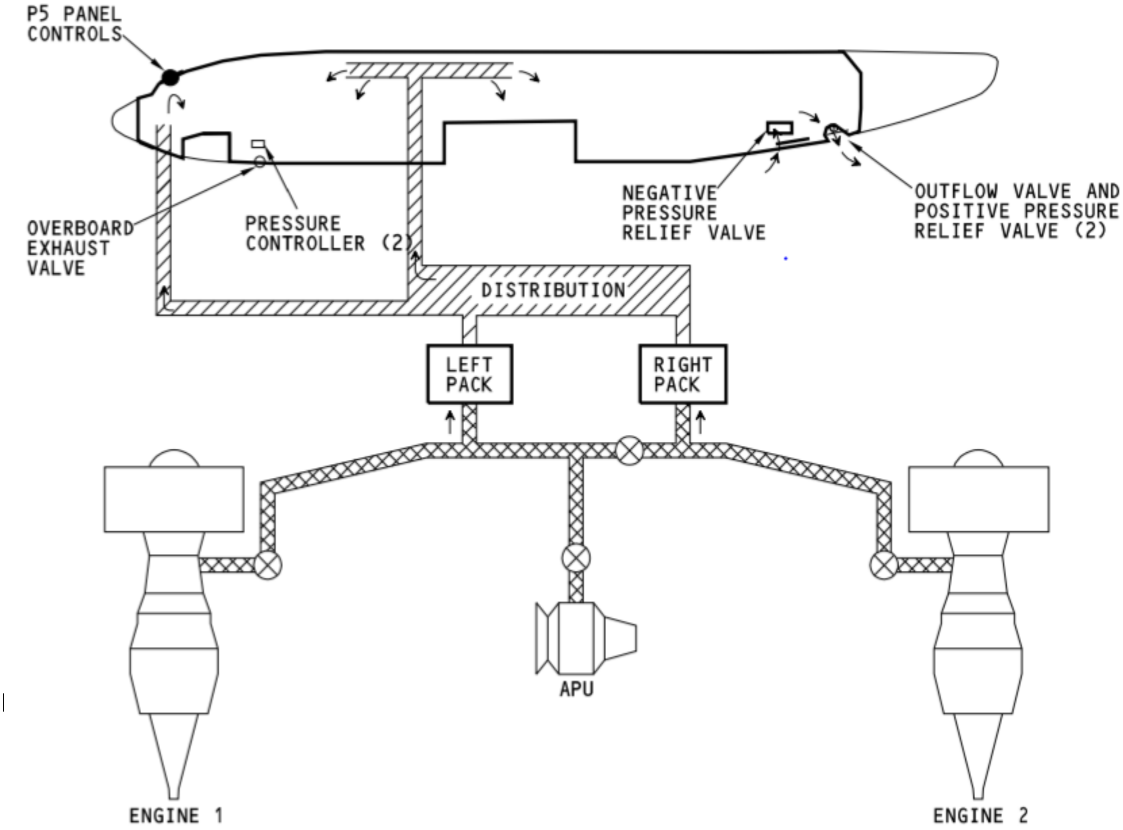
Engine No.2:

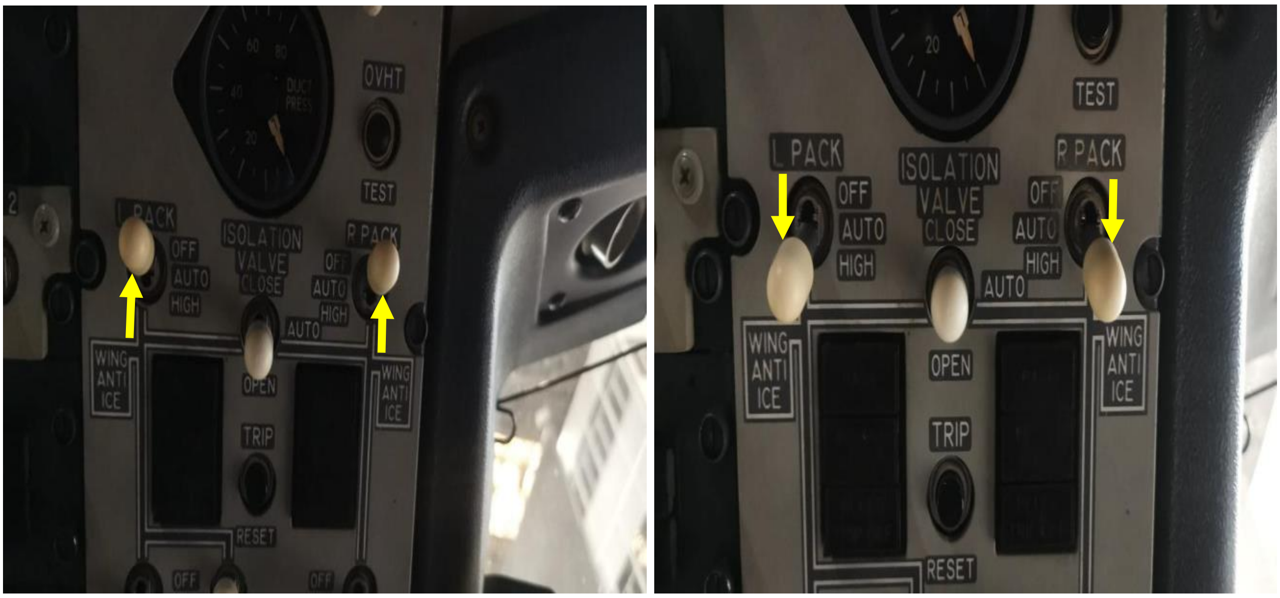
Type	CFM 56-7B26
Serial number	877632
Hours since new	46 714
Last scheduled inspection	A-check

1.6.2 Aircraft Systems Description according to the Boeing 737-600/700/800/900 Aircraft Maintenance Manual (AMM):

Description of the aircraft air-conditioning and pressurisation system:

The aircraft is equipped with two air-conditioning packs, which are independently controlled and provide conditioned, pressurised air to the cabin. The cabin pressure is regulated by the position of the outflow valve, which allows air in the cabin to vent to atmosphere. This valve, and hence the cabin pressure, is controlled by one of two redundant Cabin Pressure Controllers (CPC) when the automatic mode is used and directly by flight crew when the manual mode is used. Each pack is provided with bleed air taken from the 5th and 9th stages of the engine compressor, with the 9th stage providing compressed air at low engine speeds and the 5th stage at high engine speeds. The high stage regulator automatically opens a valve to switch between the two sources of air. The air then passes through the pressure regulating and shut-off valve, which controls the flow of air to the pneumatic manifold (duct). An isolation valve in the duct isolates the left- and right-side of the duct such that in normal operation, the left engine provides air to the left pack and the right engine to the right pack. A flow control and shut-off valve allows pressurised air in the duct to enter each pack. The air-conditioning packs can operate in one of two modes, 'LOW' and 'HIGH flow'. Normally, the packs are selected on auto and will operate in 'LOW flow'. If one pack fails, or is selected OFF, then the remaining pack will automatically switch to 'HIGH flow', provided the flaps are not extended. The flight crew can also switch each pack manually to 'HIGH flow'. The pneumatic manifold runs from each engine, along the wing leading edge to the air-conditioning packs, which are located at the bottom of the fuselage, outside the pressure hull. A firewire, routed alongside the duct, provides the flight crew with an overheat warning. The pressurisation system uses a variable cabin pressure differential schedule based on the aircraft cruise altitude to meet the design requirements. At cruise altitudes at or below FL280, the maximum differential is 7.45 psi, which will result in a cabin altitude of 8 000ft. At cruise altitudes above FL370, the maximum differential is 8.35 psi, which will result in a cabin altitude of 8 000ft FL410. The system has both an aural and visual warning for cabin altitude rising above 10 000ft. Above 10 000ft, flight crew are required to use supplementary oxygen. The system will also automatically deploy passenger oxygen masks once the cabin altitude rises above 14 000ft.





Figures 6 & 7: The aircraft pneumatic panel on the P5 cockpit overhead panel area showing the air-conditioning packs toggle switches (Bleed 1 & 2) on OFF (left) and HIGH (right).

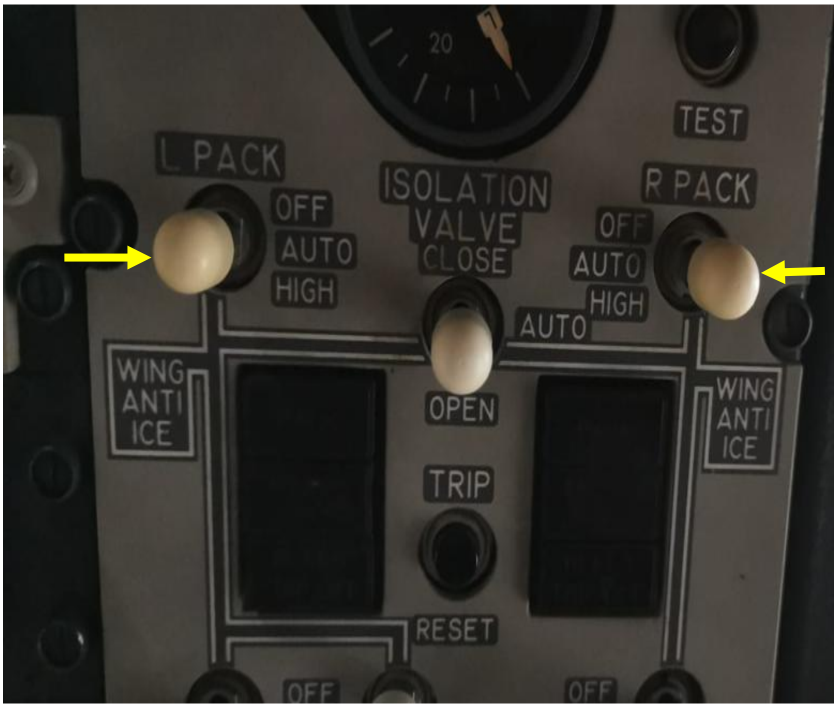


Figure 8: The aircraft pneumatic panel showing the pre-flight set position of the air-conditioning packs toggle switches (Bleed 1 & 2) on AUTO.

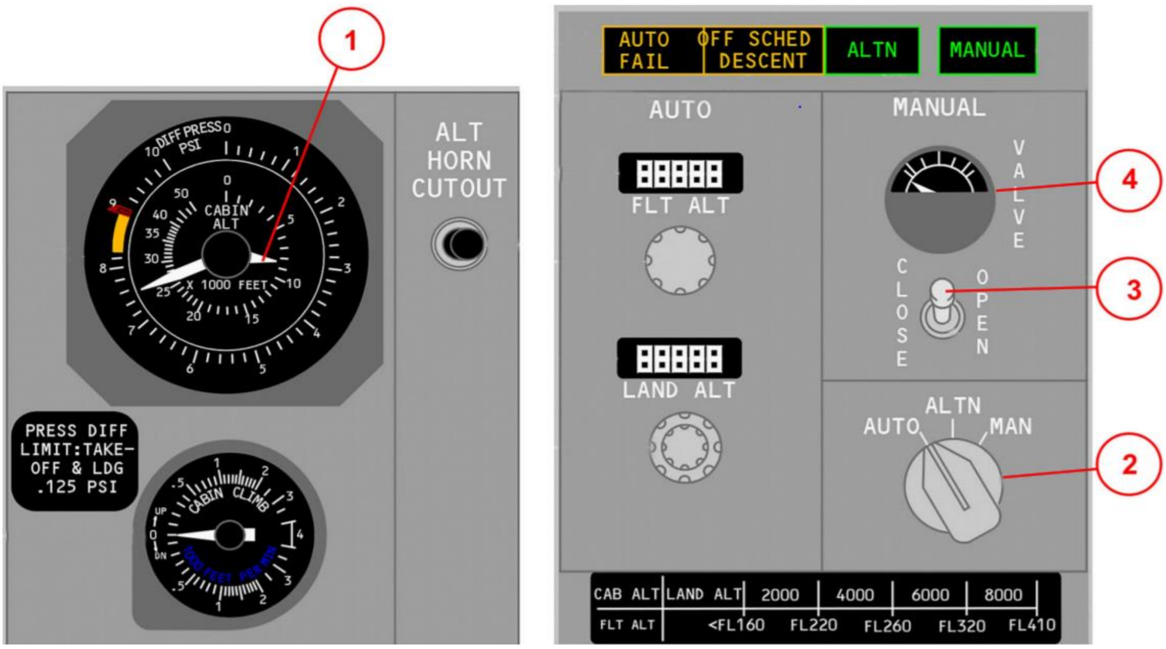
1.6.3 Purpose of Pressurisation System:

The purpose of the pressurisation system is to provide a safe comfortable cabin altitude at all aircraft altitudes. The air-conditioning system provides a constant flow of pressurised, conditioned air to the cabin. Normally, a small amount of air leaks overboard through door seals and other openings. The pressurisation system meters the amount of air exhausted from the aft outflow valve to control pressurisation to a prescribed schedule depending on the aircraft altitude, cruise altitude, and the altitude of the destination. Cabin pressurisation is controlled during all phases of aircraft operation by the digital cabin pressurisation control system (DCPCS). The system uses bleed air supplied by the engines and distributed to the air-conditioning system. Pressurisation and ventilation is controlled by modulating the outflow valve and the overboard exhaust valve.

1.6.4 A simple explanation of pressurisation system is that it regulates pressure in the aircraft by opening and closing a valve through which air is expelled from the aircraft (outflow valve). This valve can be operated automatically (AUTO and ALTN) by the system through two identical controllers or manually (MAN) by the pilot. In the cockpit, there is a pressurisation panel (Figure 10) where certain system parameters, such as cabin altitude (1 in Figure 9) can be monitored, and the system's mode of operation (manual or automatic) can be selected (2 in Figure 10). The system has two relief valves that limit the maximum differential pressure between the inside and the outside of the aircraft to prevent structural damage. In the automatic mode, the sequence of operation of the system is as follows:

- On the ground, with the aircraft stopped and at low power, the outflow valve opens completely to depressurise the aircraft and allow the internal and external pressures to equalise.
- On the ground at high thrust (as the aircraft starts its take-off run), the system starts to pressurise the aircraft by closing the outflow valve.
- In the air, the pressure in the cabin is regulated based on preset conditions.

When the pressurisation system is operated manually, the pressure in the cockpit is regulated by the crew's direct inputs to the outflow valve using associated switch (3 in Figure 10). The switch is located on the cabin pressurisation panel located in the overhead panel. The switch only works when MAN mode is selected (2 in Figure 10). To open the outflow valve, the switch has to be flipped to the right and held until the desired altitude is reached. When the switch is released, it returns to its central position. Manual control of the system requires monitoring the cabin altitude and differential pressure readings (1 in Figure 9) and the position of the outflow valve (4 in Figure 10).



Figures 9 & 10: Pressurisation system panel with cabin altitude and differential indicator shown on the left. (Source: Boeing)

1.6.5 Outflow Valve and Positive/Negative Pressure Relief Valves:

The outflow valve (OFV) is found on the aircraft aft-fuselage; it regulates the pressure inside the aircraft at a pressure altitude of 8 000ft (maximum). It operates pneumatically in response to the settings on the cockpit pressurisation panel that influence the balance between cabin and ambient pressure. When the aircraft climbs, so does the cabin altitude, and the same goes for descending.

Two spring-loaded positive pressure safety relief valves are used to prevent over-pressurisation of the aircraft. They are set to open at a predetermined pressure differential, meaning that they allow excess air to flow from the cabin to prevent internal pressure from exceeding design limitations. The safety pressure relief valves are set to open between 8 and 10 pressure per square inch (psi). The negative pressure relief valve prevents vacuum damage to the aircraft during rapid descent. It ensures that the air pressure outside the aircraft does not exceed cabin air pressure. The spring-loaded relief valve opens inwards to allow ambient air to enter the cabin when the situation arises.

1.6.6 Oxygen System:

To cater for loss in cabin pressure, the aircraft has two separate oxygen systems, one for the crew and the other one for the passengers. The cockpit and cabin passenger masks were cleaned and stowed after the serious incident flight and the oxygen generators were replaced.

1.6.7 Cockpit Oxygen System:

The cockpit oxygen system uses quick donning diluter demand masks/regulators located at each crew station. Oxygen is supplied by a single cylinder which is located in the forward cargo compartment. The cylinder has a maximum capacity of 115 cubic feet of free oxygen when pressurised to 1 850 psi. Oxygen pressure is displayed on the indicator located on the overhead panel. The oxygen mask/regulator is stored in a box immediately adjacent to each crew station. To remove the mask from its stowed position, the red levers around each mask must be squeezed with the thumb and forefinger. When squeezed, the harness inflates so it can be put easily over the face to allow breathing. During the investigation, it was determined that the captain and the two FO’s oxygen masks were full face with integral goggles fitted on them. Oxygen flow on the face mask is controlled by a regulator that is mounted on the oxygen mask. The regulator may be adjusted to supply 100% oxygen by pushing the NORMAL/100% selector.

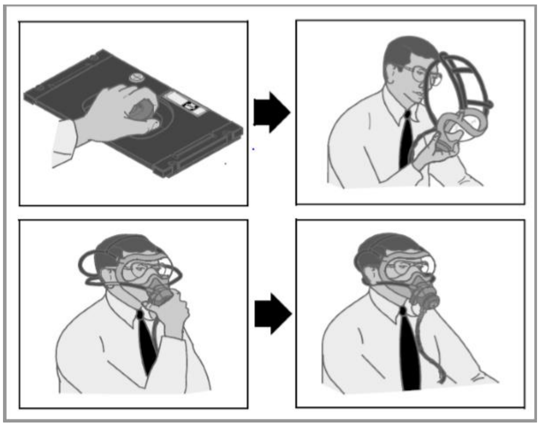
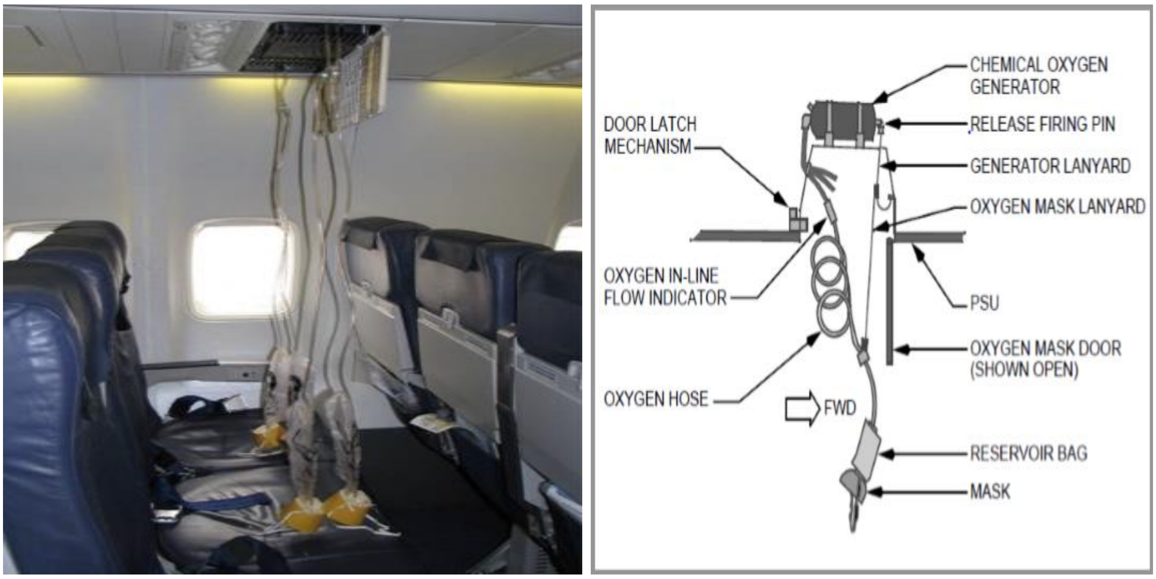


Figure 11: The process of putting on the oxygen face masks designed for the crew. (Source: Boeing)

1.6.8 Cabin Oxygen System:

The passenger oxygen is supplied by individual oxygen generators located at each passenger service unit (PSU). A generator with two masks is located above each cabin attendant station. The system is activated automatically when the cabin altitude climbs above 14 000ft, or when the switch on the overhead panel is positioned to ON by the flight crew. When the system is activated manually, the masks will drop, so the passenger has to pull the mask, put it on his/her face and start breathing. Once any of the four masks of a PSU is pulled, a continuous flow of oxygen begins. It lasts approximately 12 minutes and it cannot shut off. When the passenger oxygen system is activated, the following amber indicator lights illuminate on the flight deck: "MASTER CAUTION" and "OVERHEAD" on the pilot's glareshield and "PASS OXY ON" on the overhead panel. The cabin oxygen masks were manually deployed and were utilised without struggle.



Figures 12 & 13: On the left is a picture of the cabin oxygen mask deployed and on the right is the passenger oxygen sytem schematic. (Source: Boeing)

1.6.9 Passenger Portable Oxygen:

First aid and suplemental portable oxygen cylinders are installed at suitable locations in the passenger cabin. The number and location of portable oxygen cylinders varies with interior configuration. This aircraft is equipped with four cylinders located in the passenger cabin (two opposite the aft service door, and two next to the flight deck door). Each cylinder is fitted with a pressure gauge, pressure regulator and an ON/OFF valve. The cylinders have a maximum capacity of 311 litres (11 cubic feet) of oxygen when pressurised to 1 800 psi. The oxygen could be used either through a four-litre per minute outlet, or through a two-litre per minute outlet, resulting in an oxygen availability duration of 1 hour 17 minutes, respectively. The cabin crew members were moving around the cabin during the serious incident assisting and making sure that passengers, particularly those families with children, had their oxygen masks on correctly. It is during this time when the cabin crew members made use of the portable oxygen suppliers until they were confident that they can breath without support.

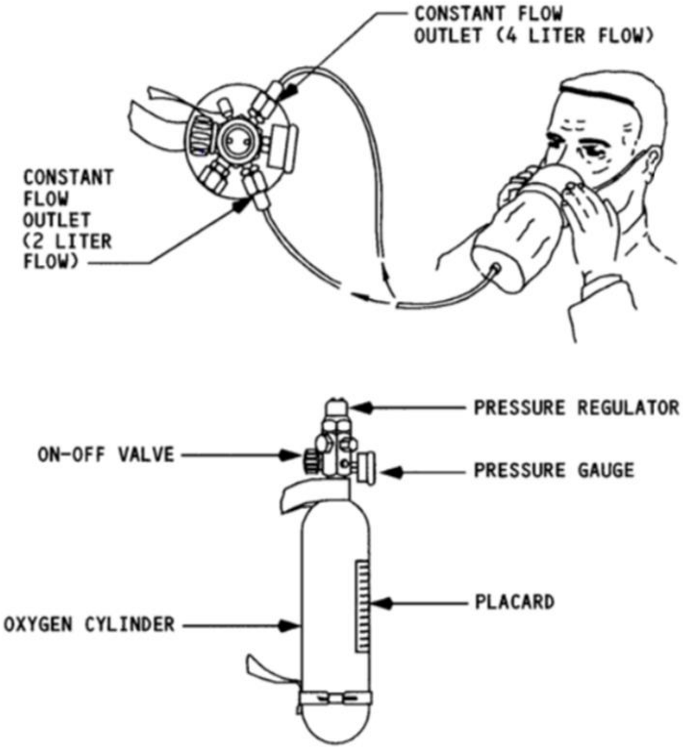


Figure 14: Passenger portable oxygen suppliers schematic. (Source: Boeing)

1.6.10 On-board Warning Systems:

The aircraft is equipped with the required warning systems, among others, a cabin altitude warning horn (signalling cabin altitude above 10 000ft), which was operative during the occurrence.

1.7 Meteorological Information

1.7.1 The weather information below was obtained from the captain questionnaire.

Wind direction	220°	Wind speed	11kts	Visibility	10KM
Temperature	21°C	Cloud cover	900 ft	Cloud base	900 ft
Dew point	19°C	QNH	Unknown		

1.8 Aids to Navigation

1.8.1 The aircraft was equipped with standard navigational equipment as approved by the Regulator (SACAA) for the aircraft type. There were no records indicating that the navigation equipment was unserviceable prior to or during the flight.

I. Magnetic compass.

II. Panel-mounted Garmin GPS.

III. Mode S transponder.

IV. ADF (automatic direction finder).

V. DME (distance measuring equipment).

VI. VOR (variable omni-range) finder.

VII. ILS (instrument landing system).

1.9 Communication

1.9.1 The aircraft was equipped with standard communication equipment as approved by the Regulator for the aircraft type. There were no recorded defects with the communication equipment prior to the flight.

1.9.2 Communication between FALE approach controller on the VHF 125.75MHz and the crew was recorded by ground-based automatic voice recording equipment. The quality of the recorded aircraft transmissions was good.

1.10 Aerodrome Information

1.10.1 The serious incident occurred during the descent to FALE abeam Dundee, about 70nm north of TGV - VOR beacon at GPS determined to be South 28°07'.6" East 030°22'.2".

Aerodrome Location	King Shaka International Airport (FALE)	
Aerodrome Co-ordinates	S29°36'42.38" E031°07'09.53"	
Aerodrome Elevation	304 feet AMSL	
Runway Dimensions	3700 x 60m	
Runway Designations	24/09	

Runway Used	24
Runway Surface	Asphalt
Aerodrome Status	Licensed
Approach Facilities	ILS, DME, VOR, PAPI's, Runway light

1.11 Flight Recorders

1.11.1 The ZS-SJF aircraft is equipped with a flight data recorder (FDR) and cockpit voice recorder (CVR) capable of recording a minimum duration of 25 hours of data and 120 minutes of audio, respectively. The FDR, a Solid-State Model, Serial No. SSFDR-19722, was removed from the aircraft and downloaded at South African Airways Technical (SAAT) facility on 28 January 2021. An analysis of the FDR and previous flights showed that the pressurisation and air-conditioning system had functioned normally. In addition, there were no bleed defects reported in the past six months before the serious incident on either engine.

1.11.2 From the FDR graph below (Figure 15), it is evident from the Aircraft Information Management System (AIMS) that the aircraft packs were operating engine 1 Low and engine 2 High, which is in correlation to the aircraft's configuration as it departed FAOR. At 1232Z, the crew commenced their descent, and while passing FL270, the crew got a "Cabin Altitude Warning" and, according to the captain's written report, declared an emergency. The crew continued with the descent at a maximum of 330kts to FL110 where a deceleration to 250kts was made.

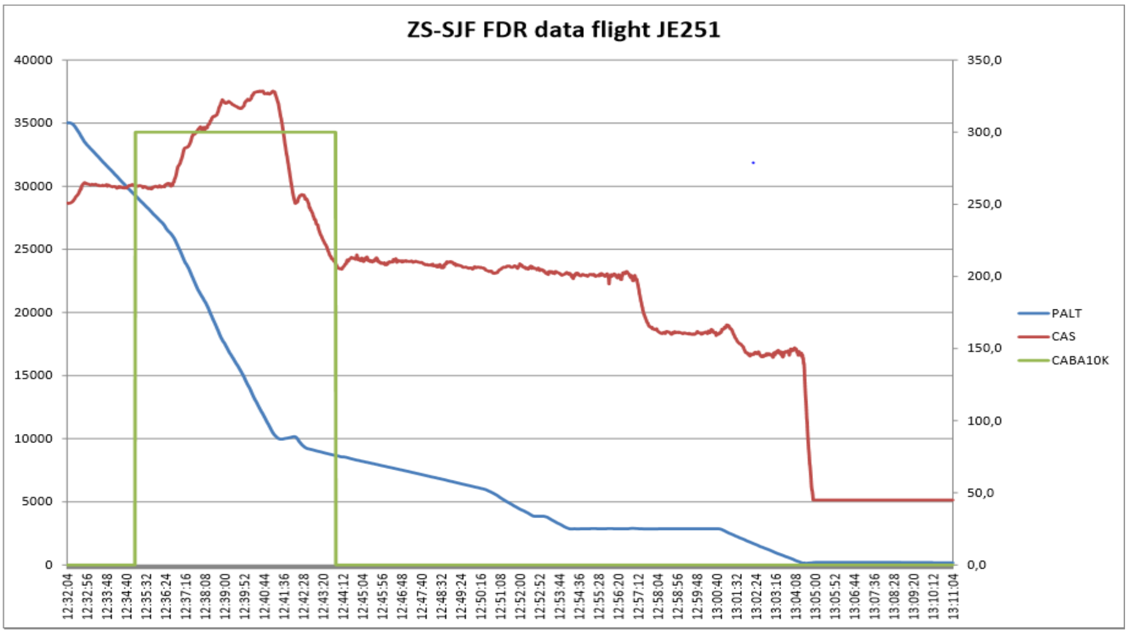


Figure 15: The graph of the serious incident flight with the captured essential data. (Source: (SAAT)

1.12 Wreckage and Impact Information

1.12.1 The aircraft had maintained flight and, following a MAYDAY call, the crew had assessed the situation and landed the aircraft safely at FALE.

1.13 Medical and Pathological Information

1.13.1 None.

1.14 Fire

1.14.1 There was no evidence of a pre- or post-impact fire.

1.15 Survival Aspects

1.15.1 The serious incident was considered survivable as no damage was caused to the cockpit and cabin structure of the aircraft. The captain and the FO had donned their oxygen masks and had deployed the passengers' oxygen masks timeously IAW the QRH.

1.16 Tests and Research

1.16.1 The aircraft is designed in such a way that should one air-conditioning pack fail, the remaining pack should automatically switch to HIGH air flow mode to maintain the required cabin pressure. The aircraft departed FAOR with deferred snags IAW MEL 30-03-03B. One of the snags was the APU which was inoperative, and the crew started the engines using compressed bleed air from the air start unit (ASU). Another snag was the No.1 engine nose cowl anti-ice amber light that remained illuminated and as a result, the No.1 engine low stage bleed air valve (5th stage) was locked open so that the nose cowling does not incur icing in-flight and the high stage bleed air valve (9th stage) was locked in a closed position. The No.1 engine high stage bleed-air system (9th stage) was, thus, isolated in this flight. The intention of the MEL was that the No.1 engine low stage bleed air (5th stage) could still be used except in certain circumstances. The No.2 engine had both the low stage and high stage bleed valves working. Each pack operates independently and is pneumatically operated and electrically controlled by switches located on the cockpit overhead panel. The associated valve position indicator lights and warning lights are located adjacent to the switches. During take-off, climb and cruise conditions, low pressure bleed air from the 5th stage compressor is adequate and the high stage valve (9th stage) remains closed. During the descent and other low power setting operations, the high stage modules (9th stage bleed valves) open to maintain the required bleed air pressure. The aircraft departed FAOR with both air-conditioning packs selected to AUTO with bleed air supplied from both engines' 5th stage compressors.

1.16.2 During the descent, the crew retarded the throttles back and only the right-side pack went into HIGH air flow mode (9th stage bleed air) because the No.1 engine 9th stage bleed valve was locked. The aircraft, during the descent, experienced a loss of cabin pressure with warnings inside the cockpit. The crew followed the necessary checklist and landed the aircraft safely at FALE. After landing, the aircraft was subjected to a thorough engineering investigation by a team of engineers from the South African Airways Technical (SAAT). No signs of skin cracks and raptures were observed on the fuselage. No signs of detachment or incorrect fitting were found on the pneumatic system and associated components. The OFV and other safety valves (positive/negative safety valves) sustained no damages.

1.16.3 Examination of the aircraft TL indicated no air-conditioning/pressurisation snags. There were also no bleed defects reported for the past six months on either engine. On 27 January 2021, the No.1 engine 9th stage bleed air valve was put on open position. That was followed by a short engine ground run by SAAT engineers IAW the AMM task 71-00-00-800-810-F00 Ref. 73. During the engine run, the No.1 engine duct pressure recorded 15 psi and the No. 2 engine duct recorded 5 psi (low). This was an indication that there was an anomaly on the right-side pack. Another engine ground run was performed, followed by leak checks/pneumatic health confidence check IAW the AMM 36-11-00-700-803. A leak was detected on the No. 2 air-conditioning pack air cycling machine (ACM) sense line. A leaking sense line, Part No - AS141G0120N045L was replaced with a serviceable one IAW the AMM 21-51-04. In addition, multiple cracks were detected on the No.2 air-conditioning pack primary heat exchanger. The primary heat exchanger, Part No:182820-2 and the secondary heat exchanger Part No: 182820-3 were replaced with serviceable ones IAW the AMM 21-51-03.

1.16.4 The right ACM, Part No: 2206400-2 was replaced IAW the AMM 21-51-04 rev 73 because of its intermittent reluctance to operate. The No.2 air-conditioning pack trim air check valve was found unserviceable. A defective trim air check valve, Part No: 3202444-1 was replaced with a serviceable one IAW the AMM 21-61-03. The trim air check valve test was later carried out and it operated normally. This was followed by an extensive ground run and pressurisation/cabin altitude test using the APU and the engines as the pneumatic source. The bleed air and air-conditioning system were configured in various combinations and temperature selections. The systems operated normally and nothing unusual was observed. On 7 February 2021, a pre-flight inspection was carried out in preparation for a test flight. The cabin altitude tested normal with nil defects reported. Before the aircraft was released to service on 8 February 2021, two serviceable recorders (FDR and CVR) were fitted IAW the AMM 31-3171PO401.

1.16.5 Examination of the aircraft TL showed that the aircraft was maintained IAW the manufacturer's approved maintenance schedules and practices. In addition, all applicable Airworthiness Directives (ADs), mandatory Service Bulletins (SBs) on the aircraft and its engines were complied with. The aircraft maintenance organisation (AMO) that performed the last maintenance inspection (A-Check) on 13 January 2021 at 49 862.40 airframe hours was in possession of a valid AMO certificate No:

0001. The A-check scheduled maintenance inspection conducted does not require an inspection of the bleed air system and associated components. The No. 1 and 2 bleed health system checks were last conducted on 11 July 2019 at 47 490.30 airframe hours, work order number 1880360R1, IAW AMM task:36-11-03/401 Rev: 069. The repeat inspection is required to be conducted every 730 days or within 6000 flight/airframe hours (FH) IAW the original equipment manufacturer (OEM – Boeing) and the operator's aircraft maintenance program (OAMP). According to the operator's maintenance planning records, the next bleed health system checks are planned to happen between 11 May 2021 and 14 June 2021, work order 1880361R1. The aircraft had flown a total of 2440,11 and 565 days since the last bleed health checks were performed.

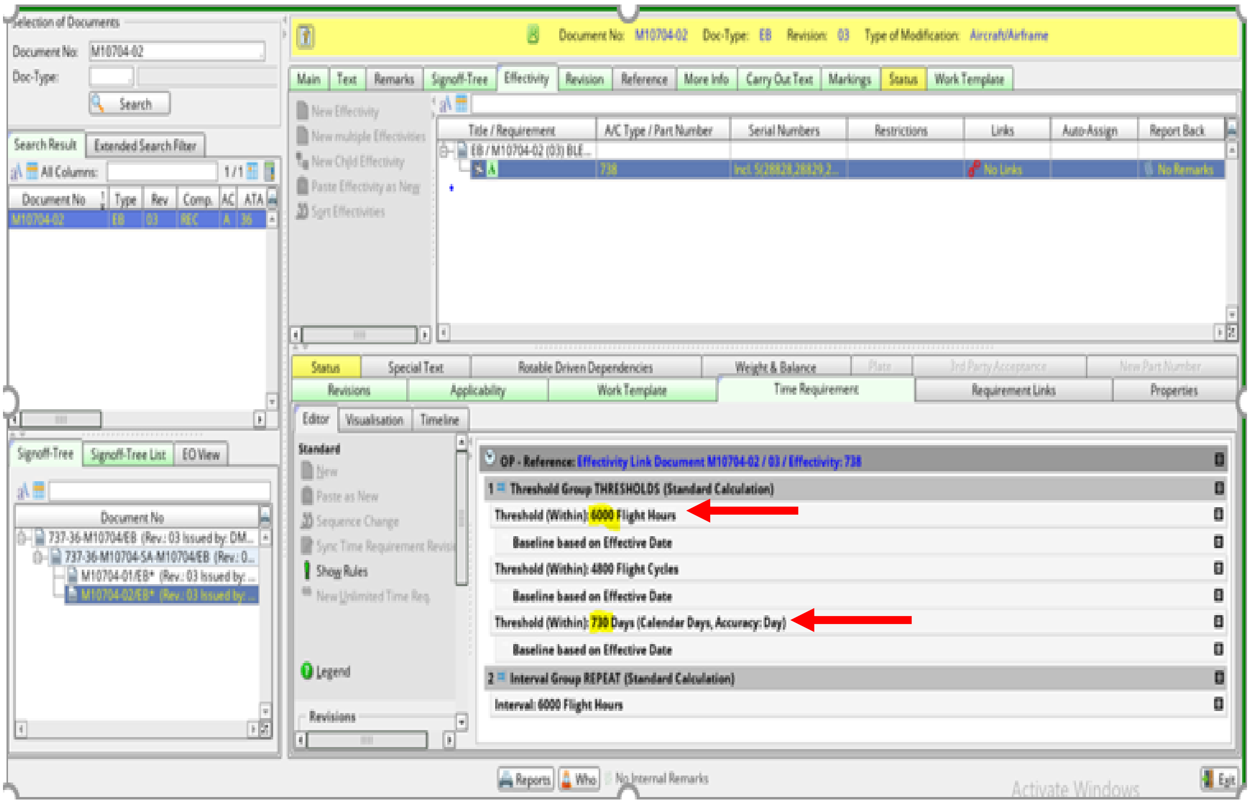


Figure 16: Print out of the OEM and OMPD program.

1.16.6 Below is the schematic of an aircraft air-conditioning pack showing (in red) replaced components during post-serious incident maintenance.

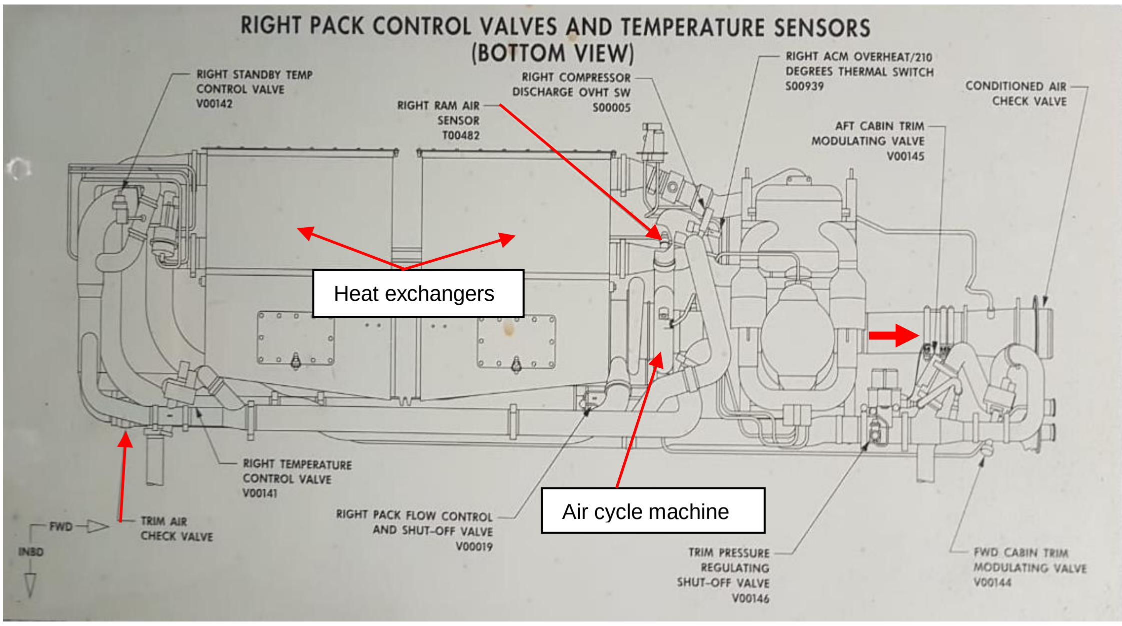


Figure 16: The air-conditioning pack.

1.17 Organisational and Management Information

1.17.1 The flight was conducted IAW the provisions of Part 121 of the CAR 2011 as amended.

1.17.2 The AMO that carried out the last maintenance inspection (A-Check) prior to the serious incident flight was in possession of an approved AMO certificate number 0001 that was issued by the SACAA on 14 January 2020 with an expiry date of 31 October 2021.

1.17.3 The operator was in possession of an approved Class 1 Air Service Licence No. S890D for domestic schedule, which was issued on 18 November 2020 by the Department of Transport. The licence authorised the carrier to operate under the following categories: Type S1 – transport of passengers between two or more specified points, and Type S2 – transport of cargo or mail between two or more specified points. The aircraft used under this operation should meet category A1 provisions – any aircraft, excluding a helicopter, with a maximum certificated mass exceeding 20 000 kilograms.

1.17.4 The operator was in possession of an Air Operating Certificate (AOC) No. CAA/N891D, which was issued on 19 November 2020 by the SACAA with an expiry date of 30 November 2021. The aircraft was duly authorised to operate under the AOC.

1.18 Additional Information

1.18.1 Aircraft operating manual of the Boeing 737-800 aircraft:

The manual specifies that in the event of sudden decrease in cabin pressure, oxygen masks should be put on immediately, and if decompression occurs, speed brakes should be fully extended and an emergency descent made to 10 000ft, with the aircraft flown either at maximum airspeed or at an appropriate airspeed (if there are concerns about structural failures, airspeed should be decreased to a suitable value while paying attention to controlling the aircraft).

ATC should be notified beforehand with the intentions of the pilot, etc. reported clearly. Further, it is specified that at the time the cabin altitude reaches 13 000ft or below, the cabin crew should be notified that oxygen masks may be released.

1.18.2 Effects of decompression in the cabin on the human body:

According to Aerospace Medicine: Flight and the Human Body (by Haruo Ikeda, published by Houbun-Shorin, November 1971), the effects of cabin decompression on the human body are as follows.

(1) Hypoxia:

The table below summarises the stages of hypoxia in relation to the altitude of occurrence, breathing air, and the arterial oxygen saturation.

Altitude (ft)	Stage	Symptoms
0–10,00	Indifferent	None, but visual sensitivity reduced at night.
10,000–15,00	Compensatory	Major symptoms may not appear due to compensatory mechanisms.
15,000–20,00	Disturbance	Hazards of visual disturbance and intellectual impairment, etc.
above 20,00	Critical	Danger of rapid loss of consciousness with little or no warning and loss of life.

The Time of Useful Consciousness (TUC) is that period between an individual's sudden deprivation of oxygen at a given altitude and the onset of physical or mental impairment which prohibits his/her taking rational action. It represents the time during which the individual can recognise his problem and re-establish an oxygen supply, initiate a descent to lower altitude, or take other corrective action. TUC is also referred to as effective performance time.

Altitude (ft)	Time of useful consciousness
22,000	5 minutes
25,000	2–3 minutes
28,000	1 minute 30 seconds
30,000	1 minute 15 seconds
35,000	45 seconds

(2) Decompression Sickness

Decompression sickness results from the expansion and contraction of gases trapped in the ears, nasal passages, etc. and from nitrogen and other gases dissolved in the blood, tissues, etc. coming out of solution. Trapped gases cause symptoms of earache, nose ache, stomach ache, etc. Bubbles formed by gases coming out of solution cause symptoms of arthralgia of the shoulders, elbow, hands, etc. and also difficulty in breathing, aching lungs, etc. due to the restriction of blood vessels. Although rare, restriction of blood vessels in the brain by evolved gas bubbles can cause loss of consciousness and visual impairment.

1.18.3 Classification of “Abnormal drop of cabin pressure in an aircraft” specified by the United States Federal Aviation Administration (FAA):

Advisory Circular (AC) 61-107 issued by Federal Aviation Authority (FAA) of the United States contains the following classification of degrees of decompression rate:

(1) Explosive Decompression

This is a phenomenon in which cabin pressure equalises with ambient pressure in less than 0.5 seconds. There is a high probability of damage to the human body by decompression sickness, etc. Because it is considered that unsecured objects will fly around, all loose items such as baggage should be properly secured before flight. Also, aircraft with smaller pressurised cabin volumes are more prone to this type of decompression.

(2) Rapid Decompression

This drop of cabin pressure is not as abrupt as in the case of explosive decompression, and the likelihood of damage to the human body by decompression sickness, etc. is significantly lower.

(3) Gradual Decompression or Slow Decompression

This decompression is difficult to perceive by bodily sensations as opposed to cases (1) and (2) above. The consequent possibility that recognition will be late makes this type of decompression dangerous. Generally, automatic visual and aural warning systems provide indication of decompression so that it may be detected even if the pilot does not recognise it through bodily sensations.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 General

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

2.2 Analysis

2.2.1 Man (Crew)

The crew was properly rated and qualified to conduct the flight. The aircraft was operated under Instrument Flight Rules (IFR). Take-off from FAOR was uneventful and the aircraft had climbed to FL350. During the descent phase to FALE at 1232Z and after passing FL270 abeam Dundee, the “Cabin Altitude” rapid decompression warning light illuminated, and audio/aural warning sounded. The crew broadcasted a Mayday call requesting an emergency descent on the VHF 125.75MHz. The aircraft was cleared for an unrestricted emergency descent with no conflicting traffic, and FALE Aircraft Rescue and Fire-Fighting (ARFF) team was put on standby. The captain called for the “Cabin Altitude Warning” emergency descent checklist as stipulated in the QRH. Passengers were instructed to remain seated and calm. The crew continued with the descent at a maximum airspeed of 330kts to FL110 and then to 7000ft. An uneventful landing was later executed on Runway 24 at FALE. No structural damage was noted during the visual external inspection of the aircraft and the crew taxied to the allocated parking stand (A16) where the passengers disembarked the aircraft normally. The investigation determined that the loss of cabin pressure was caused by bleed air leak on the right-side air-conditioning pack, which resulted in cabin pressurisation system being unable to maintain the required pressurisation level for a safe environment of the passengers and the crew members. The left pack was unable to compensate for a leaking right pack due to the No.1 engine’s 9^{th} stage bleed air valve being locked closed prior to departing FAOR.

2.2.2 Mission

This was a scheduled domestic flight from FAOR to FALE under IFR. The flight plan was filed with Johannesburg briefing. On-board the aircraft were six crew members (two pilots and four cabin crew) and 119 passengers. As part of the pre-flight procedure, the air-conditioning packs were switched to AUTO position. The cabin pressurisation panel was also configured with the cruise altitude (FL350) and destination altitude set (304ft AMSL). The pressurisation mode selector was set to AUTO for normal operation. Take-off from FAOR Runway 03L was uneventful and the aircraft climbed to FL350. During descent to FALE abeam Dundee, a rapid decompression warning light illuminated, and audio/aural warning sounded.

2.2.3 Environment

Moderate weather conditions prevailed at the time of the flight. The weather was not considered to have had any bearing on the serious incident.

2.2.4 Investigation revealed:

The aircraft was unable to maintain the required cabin pressure for a safe environment of the passengers and the crew members due to the right-side air-conditioning pack bleed air leak and the left-side pack was unable to compensate for a defective right-side pack due to the No.1 engine's 9th stage bleed air valve being locked closed prior to departing FAOR.

3. Findings

3.1 General

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

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

- **Findings —** are statements of all significant conditions, events or circumstances in this serious incident. The findings are significant steps in this serious incident sequence, but they are not always causal or indicate deficiencies.
- **Causes —** are actions, omissions, events, conditions, or a combination thereof, which led to this serious incident.
- **Contributing factors —** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the

serious incident occurring, or mitigated the severity of the consequences of the serious incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.1.1 The flight was conducted IAW the provisions of Part 121 of the CAR 2011 as amended.

3.1.2 Moderate weather conditions prevailed at the time of the flight and had no bearing to this serious incident.

3.1.3 The captain had a valid Airline Transport Pilot Licence (ATPL) and the aircraft type was endorsed on his licence. He also had a valid Class 1 aviation medical certificate issued on 5 October 2020 with an expiry date of 31 October 2021.

3.1.4 The FO had a valid ATPL and the aircraft type was endorsed on his licence. The FO had a valid Class 1 aviation medical certificate issued on 7 October 2020 with an expiry date of 31 October 2021.

3.1.5 Records kept at the SACAA facility showed that the captain's last proficiency check on B737-800 was provided by Mango Airlines ATO No. CAA/0307 on 26 and 27 October 2020, and the candidate was assessed as competent in all aspects. The Boeing 737-800 pilot proficiency check had a validity date of 30 April 2021.

3.1.6 Records kept at the SACAA facility showed that the FO's last proficiency check on B737-800 was provided by Mango Airlines ATO No. CAA/0307 on 15 July 2020, and the candidate was assessed as competent in all aspects. The Boeing 737-800 pilot proficiency check had a validity date of 31 January 2021.

3.1.7 The cabin crew members on-board the aircraft all met the operator's proficiency check and medical requirements.

3.1.8 The cabin pressurisation was configured with the cruise altitude (FL350), and the destination airport altitude (304ft AMSL) was set. The pre-flight checklist was executed accordingly.

3.1.9 During the descent phase to FALE at 1232Z and after passing FL270 abeam Dundee, the "Cabin Altitude" rapid decompression warning light illuminated, and audio/aural warning sounded. The captain instantly cross-checked the position of the outflow valve before broadcasting a MAYDAY call three times on the VHF frequency 125.75 megahertz (MHz) to the area controller who had the aircraft on primary surveillance radar.

3.1.10 The cabin oxygen masks were deployed during the serious incident and oxygen generators activated on all the masks that dropped. Some oxygen masks did not drop, resulting in the cabin crew moving some passengers to the unoccupied seats with deployed masks.

3.1.11 The No. 1 and 2 bleed health system checks were last conducted on 11 July 2019 at 47 490.30 airframe hours, work order number 1880360R1, IAW AMM task:36-11-03/401 Rev: 069. The aircraft has flown a total of 2 440.11 since the last bleed health checks were performed and had not reached their limit of 6000 hours or 730 days.

3.1.12 The aircraft had a valid Certificate of Airworthiness (C of A), which was initially issued on 31 October 2004 with an expiry date of 31 October 2021.

3.1.13 All concerned Airworthiness Directives (ADs) and mandatory Service Bulletins (SBs) were complied with as on date of the event.

3.1.14 The last weekly maintenance inspection that was carried out on the aircraft prior to the serious incident flight was certified on 21 January 2021 at 49 912.20 airframe hours.

3.1.15 The last A-check inspection that was carried out on the aircraft prior to the serious incident flight was certified on 13 January 2021 at 49 862.40 airframe hours. Following the inspection, a further 68.01 hours were flown with the aircraft.

3.1.16 The AMO that carried out the last maintenance inspection (A-Check) prior to the serious incident flight was in possession of an approved AMO certificate number 0001 that was issued by the SACAA on 14 January 2020 with an expiry date of 31 October 2021.

3.1.17 The operator was in possession of an Air Operating Certificate (AOC) No. CAA/N891D, which was issued on 19 November 2020 by the SACAA with an expiry date of 30 November 2021. The aircraft was duly authorised to operate under the AOC.

3.1.18 The operator was in possession of an approved Class 1 Air Service Licence No. S890D for domestic schedule, which was issued on 18 November 2020 by the Department of Transport. The licence authorised the carrier to operate under the following categories: Type S1 – transport of passengers between two or more specified points, and Type S2 – transport of cargo or mail between two or more specified points. The aircraft used under this operation should meet category A1 provisions – any aircraft, excluding a helicopter, with a maximum certificated mass exceeding 20 000 kilograms.

3.1.19 The investigation determined that the loss of cabin pressure was caused by bleed air leak on the right-side air-conditioning pack, which resulted in cabin pressurisation system being unable to maintain the required pressurisation level for a safe environment of the passengers and the crew members. The left-side pack was unable to compensate for a defective right-side pack due to the No.1 engine's 9th stage bleed air valve being locked closed prior to departing FAOR.

3.2 Probable Cause/s

3.2.1 The aircraft was unable to maintain the required cabin pressure for a safe environment of the passengers and the crew members due to the right-side air-conditioning pack bleed air leak and the left-side pack was unable to compensate for a defective right-side pack due to the No.1 engine's 9th stage bleed air valve being locked closed prior to departing FAOR.

3.3 Contributory Factors

3.3.1 Defective right-side air-conditioning pack components that included the primary heat exchanger, air cycle machine, sense line and the trim air check valve.

4. SAFETY RECOMMENDATIONS

4.1 General

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

4.2 Safety Recommendation/s

4.2.1 **Safety message:** In the interest of safety for operators of similar type aircraft, similar action taken by the operator in question should be considered in order to prevent such incidents from reoccurring.

4.2.2 Action taken by the operator

The operator resorted to review air-conditioning/pressurisation and pneumatic task cards in heavy maintenance checks with an emphasis to components and system operational leak checks.

5. APPENDICES

5.1 Annexure A – Cabin Altitude warning checklist.

5.2 Annexure B – FALE layout as per the Aeronautical Information Publication (AIP).

Annexure A: Cabin Altitude Warning Checklist

Non-Normal Checklists - Air Systems

BOEING

737 Flight Crew Operations Manual

Table of Contents

Intentionally Blank

Boeing Proprietary. Copyright © Boeing. May be subject to export restrictions under EAR. See title page for details.

2.TOC.2 D6-27370-800-NGO May 21, 2020

BOEING 2.1

737 Flight Crew Operations Manual

CABIN ALTITUDE WARNING or Rapid Depressurization

CABIN ALTITUDE **(If installed and operative)**

Condition: One or more of these occur:
- A cabin altitude exceedance
- In flight, the intermittent cabin altitude/configuration warning horn sounds or a CABIN ALTITUDE light (if installed and operative) illuminates.

1 Don oxygen masks and set regulators to 100%.

2 Establish crew communications.

3 Pressurization mode selector . . . . MAN

4 Outflow VALVE switch . . . . Hold in CLOSE until the outflow VALVE indication shows fully closed

5 **If** cabin altitude is **uncontrollable**:

Passenger signs . . . . ON

PASS OXYGEN switch . . . . ON

►►Go to the Emergency Descent checklist on page 0.1

■ ■ ■ ■

▼ Continued on next page ▼

Boeing Proprietary. Copyright © Boeing. May be subject to export restrictions under EAR. See title page for details.

May 21, 2020 D6-27370-800-NGO 2.1

2.2 BOEING

737 Flight Crew Operations Manual

▼CABIN ALTITUDE WARNING or Rapid Depressurization continued▼

6 **If** cabin altitude is **controllable**:

Continue manual operation to maintain correct cabin altitude.

When the cabin altitude is at or below 10,000 feet:

Oxygen masks may be removed.

7 **Checklist Complete Except Deferred Items**

Deferred Items

Note: Use momentary actuation of the outflow valve switch to avoid large and rapid pressurization changes.

Descent Checklist

Pressurization . . . . **Move outflow VALVE switch to OPEN or CLOSE as needed to control cabin altitude and rate**

Recall . . . . Checked

Autobrake . . . . ___

Landing data . . . . VREF ___, Minimums ___

Approach briefing . . . . Completed

Approach Checklist

Altimeters . . . . ___

▼ Continued on next page ▼

Boeing Proprietary. Copyright © Boeing. May be subject to export restrictions under EAR. See title page for details.

2.2 D6-27370-800-NGO May 21, 2020

BOEING 2.3

737 Flight Crew Operations Manual

▼CABIN ALTITUDE WARNING or Rapid Depressurization continued▼

At Pattern Altitude

Outflow VALVE switch . . . . Move to OPEN until the outflow VALVE indication shows fully open to depressurize the airplane

Landing Checklist

ENGINE START switches . . . . CONT

Speedbrake . . . . ARMED

Landing gear . . . . Down

Flaps . . . . ___, Green light

■ ■ ■ ■

Boeing Proprietary. Copyright © Boeing. May be subject to export restrictions under EAR. See title page for details.

May 21, 2020 D6-27370-800-NGO 2.3

Table of Contents

Intentionally
Blank

Emergency Descent

Condition: One or more of these occur:
- Cabin altitude cannot be controlled
- A rapid descent is needed.

1 Announce the emergency descent. The pilot flying will advise the cabin crew, on the PA system, of impending rapid descent. The pilot monitoring will advise ATC and obtain the area altimeter setting.

2 Passenger signs . . . . ON

3 **Without delay**, descend to the lowest safe altitude or 10,000 feet, whichever is higher.

4 ENGINE START switches (both) . . . . CONT

5 Thrust levers (both) . . . . Reduce thrust to minimum or as needed for anti-ice

6 Speedbrake . . . . FLIGHT DETENT

If structural integrity is in doubt, limit speed as much as possible and avoid high maneuvering loads.

7 Set target speed to Mmo/Vmo.

▼ Continued on next page ▼

▼Emergency Descent continued▼

YC708 - YC711, YC720, YC721, YD023, YD024

Caution! When gross weight is greater than 70,308 kgs, speed brake will autostow to the 50% flight detent if airspeed exceeds 320 knots. Do not override autostow function unless airspeed is less than 320 knots.

8 **When** approaching the level off altitude:

Smoothly lower the SPEED BRAKE lever to the DOWN detent and level off. Add thrust and stabilize on altitude and airspeed.

9 Crew oxygen regulators. . . . . Normal

Flight crew must use oxygen when cabin altitude is above 10,000 feet. To conserve oxygen, move the regulator to Normal.

10 ENGINE START switches (both) . . . . . .As needed

11 The new course of action is based on weather, oxygen, fuel remaining and available airports. Use of long range cruise may be needed.

■ ■ ■ ■

Intentionally
Blank

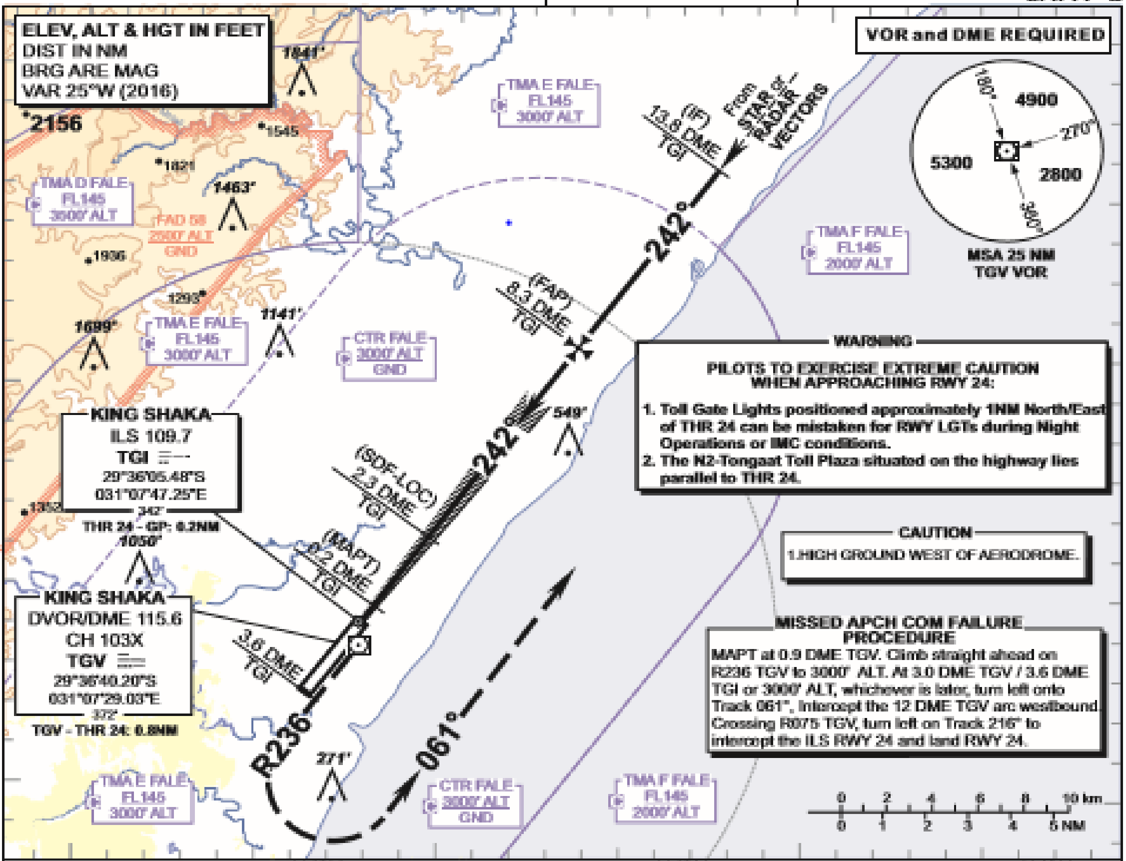
Annexure B: FALE layout

INSTRUMENT APPROACH CHART

AERODROME ELEV 304'
HEIGHTS RELATED TO THR RWY 24 - ELEV 301'

RADAR APP 125.75
TWR 118.45
GND 121.65
ATIS 127.00

DURBAN
(KING SHAKA INTERNATIONAL)
ILS Z RWY 24 CAT II
CAT A - D



TGI ILS/DME	8.3	8	7	6	5	4	3	2.3	2	1
ADVISORY ALT (HGT)	***3000*** (2699)	***2910*** (2609)	***2580*** (2279)	***2250*** (1949)	***1930*** (1629)	***1600*** (1299)	***1280*** (979)	***1050*** (749)	***950*** (649)	***620*** (319)

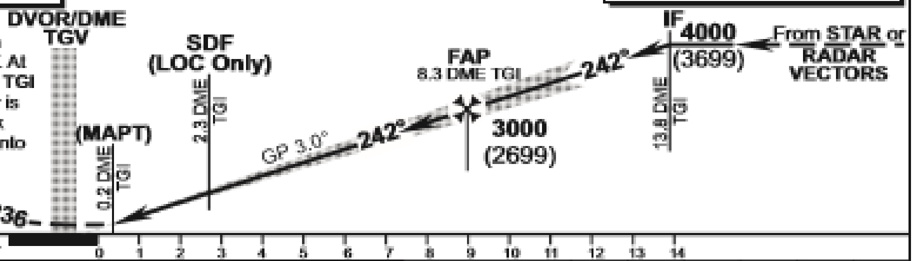
TRANSITION ALT **5500**
TRANSITION LEVEL **ATC**

INA ALT: via **STAR** or **RADAR VECTORS**

MISSED APPROACH: Climb straight ahead on R236 **TGV** to 3000' ALT. At 3.0 DME TGV/3.6 DME TGI or 3000' ALT, whichever is later, turn left onto Track 061° for radar vectors onto the ILS RWY 24.

ILS RDH **54**

THR ELEV 301



OCA (H)			A	B	C	D/DL
Straight-in Approach	With 2.5% Missed APCH Gradient	CAT I	***1188*** (887)	***1188*** (887)	***1188*** (887)	***1194*** (893)
		CAT II	***1088*** (787)	***1094*** (793)	***1103*** (802)	***1122*** (821)
		GP INOP	***1420***(1133)	***1420***(1133)	***1420***(1133)	***1420***(1133)
	With 3.4% Missed APCH Gradient	CAT I	***501*** (200)	***501*** (200)	***501*** (200)	***507*** (206)
		CAT II	***401*** (100)	***407*** (106)	***416*** (115)	***435*** (134)
		GP INOP	***730*** (443)	***730*** (443)	***730*** (443)	***730*** (443)
Circling: AD ELEV			***1000*** (696)	***1000*** (696)	***1270*** (966)	***1350*** (1046)

GS	KT	80	100	120	140	160
FAP to THR	M:S	**6:05**	**4:52**	**4:03**	**3:29**	**3:02**
Rate of descent	FPM	**435**	**544**	**652**	**761**	**870**

NOTE:
1. **PROCEDURE ONLY APPLICABLE VIA STAR OR RADAR VECTORS.**
2. In the event of Radio Communication Failure complete the turn on to the ILS and complete the ILS/LOC RWY 24 approach and land RWY 24.
3. Circle to land at the discretion of the pilot in command.

CHANGE: OCA(H)/ Advisory ALT Table/ VAR

EFF: 08 DEC 16

ILS-03