

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

July 22, 2016

SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT

A. **ACCIDENT:** ERA14LA424

LOCATION: Open ocean near Jamaica

DATE: September 5, 2014

AIRCRAFT: Socata TBM700, N900KN

B. **SYSTEMS GROUP:**

Robert L. Swaim
Washington, DC

Member: David Keenan
Federal Aviation Administration
Washington, DC

Member: Thierry Loo
Le Bureau d'Enquêtes et d'Analyses (BEA)
Toulouse, France

Member: Olivier Le Guennec
Liebherr Aerospace Toulouse SAS
Toulouse, France

Member: Catherine Herau
Daher Socata
Tarbes, France

Member: David Studtmann
Honeywell Aerospace
Phoenix, Arizona

C. **SUMMARY:**

On September 5, 2014, about 1410 eastern daylight time (EDT), a Socata TBM700 (marketed as TBM900), N900KN, impacted open water near the coast of northeast Jamaica. The commercial pilot/owner and his passenger were fatally injured. An instrument flight rules flight plan was filed for the planned flight that originated from

Greater Rochester International Airport (ROC), Rochester, New York at 0826 and destined for Naples Municipal Airport (APF), Naples, Florida. The personal flight was conducted under the provisions of 14 Code of Federal Regulations Part 91.

According to preliminary air traffic control (ATC) data received from the Federal Aviation Administration (FAA), after departing ROC the pilot climbed to FL280 and leveled off. About 1000 the pilot contacted ATC to report an "indication that is not correct in the plane" and to request a descent to FL180. The pilot became unresponsive while the controller issued instructions. Two Air Force jets intercepted the airplane at FL250 about 40 miles northwest of Charleston, South Carolina and were relieved by two jets from Homestead Air Force Base, Homestead, Florida. The jets followed the airplane to Andros Island, Bahamas, and disengaged prior to entering Cuban airspace. Photographic evidence from the Air Force showed that the emergency exit of the TBM900 was in a position consistent with a depressurized cabin and showed the unconscious pilot without an oxygen mask.

Radar records provided by the FAA showed that after over-flying Cuba, the airplane entered a high rate of descent from FL250 prior to impacting open water northeast of Port Antonio, Jamaica. The last radar target was recorded over open water at an altitude of about 10,000 feet at 18.3547N, -76.44049W.

The Jamaican Defense Authority and United States Coast Guard conducted search and rescue operations. Search aircraft observed an oil slick and small pieces of debris scattered over one-quarter mile that were located near the last radar target. Both entities concluded their search on September 7, 2014.

Eclipse Underwater Group was contracted to find and recover the wreckage, which was completed in January 2015 from a depth of about 10,000 feet. Evidence of high speed impact was found in the extremely fragmented lower forward and left structure which were in smaller fragments than those from the top, aft, and right of the fuselage. When initially recovered, specific engine bleed, cabin pressurization, and supplemental oxygen components were packed in fresh water and sent directly to the NTSB offices in Washington, DC for examination. The recovery did not include the wings or other components unrelated to the pressurization and supplemental oxygen systems. The rest of the recovered wreckage was brought to an Eclipse warehouse in Annapolis, Maryland, with additional components later removed for further examination.

This factual report contains the results of numerous examination activities in multiple locations. Accompanying NTSB investigators were representatives from the United States Federal Aviation Administration (FAA), the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA), Daher-Socata, Liebherr, and Honeywell. Components were examined in Washington, DC; Annapolis, Maryland; Redmond, Washington; Toulouse and Tarbes, France. The OTSW switch contacts were jointly examined by NTSB and United States Air Force Research Laboratory (AFRL) electronics failure specialists at Wright Patterson Air Force Base in Dayton, Ohio. Representatives of the airplane and component manufacturers were interviewed in Tarbes

and Redmond. Multiple test flights were conducted from the Daher-Socata facility at the Tarbes airport.

In addition to the Air Force photographs, the nonvolatile memory of the Global Air System Controller (GASC) electronic module recorded that the pneumatic bleed air system overtemperature switch (OTSW) opened, which was followed by indications that the pneumatic bleed stopped supplying air for cabin pressurization.¹ The airplane flew for approximately six hours and a distance of 2,574 nautical miles, which was the calculated range with the departure fuel quantity and power setting.² The investigation found that before the accident, 15 other TBM850 and TBM900 airplanes had recorded the loss of bleed airflow and of GASC faults; there were 3 additional reports following the accident.³

As a result of the investigation, Daher Socata made changes to the programming in the GASC and changed the aircraft wiring, which were designed to reduce the potential for the GASC to shut off the supply of bleed air. Revisions were also made to the Pilot's Operating Handbook and to the Aircraft Maintenance Manual.

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¹ The recorded Crew Alerting System (CAS) annunciations were a red BLEED TEMP and amber BLEED OFF.

² Based on Daher estimates, the power was set at about 83% when pilot contacted ATC to declare a problem and the corresponding fuel consumption at this point is consistent with the cruise total duration.

³ Most events are from pilots and or maintenance data. The NVM data is erased after each subsequent take-off so that NVM data was not available for most records.

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D.1 Bleed Air and Pressurization System

D.1.1 TBM700, TBM850, and TBM900 Differences

Daher-Socata customer service records and the FAA Registry showed that the pilot sold a non-Garmin G1000 equipped TBM850 in the months before the accident to purchase the accident TBM900. The FAA Type Certificate Data Sheet (TCDS) A60EU shows that the initial pressurized single engine turbo-propeller low wing Model 700 led to the similar Models 850 and 900. The six seat Models 850 and 900 share engines and numerous features. Early TBM850s were produced with “round dial” cockpit displays and avionics, as well as bleed and pressurization systems provided by a different vendor than Liebherr-Aerospace Toulouse SAS (LTS).

Liebherr designed and began to provide the GAS and pressurization systems in the TBM850 for Daher-Socata to introduce with the G1000 avionics suite. Daher-Socata marketing materials show that all TBM900 airplanes are delivered with the LTS systems, the G1000 electronic flight displays, a different propeller, and improved aerodynamics. Both the TBM850 with G1000 avionics suite and the TBM 900 were delivered in a configuration allowing single pilot operation up to 31,000ft.

The POH’s for the two models showed that difference between the TBM850 and TBM900 systems provided by LTS is that the TBM850 provides the pilot with manual control, while the TBM900 GASC provides automated control. Daher-Socata documents state that in the TBM900 “the cabin pressure control and cabin pressure rate of change

control is automatically ensured by the GASC to optimize comfort and to ensure that maximum differential pressure will never been exceeded, without any crew workload.” A TBM900 cabin pressure sensor, independent from the Global Air system (GAS), allows the display on the MFD of the following indications:

- Cabin Altitude (ALT FT)
- [Cabin] Rate of change (RATE FPM)
- Cabin differential pressure (DIFF PSI)

Additionally, a:

Pressure switch, independent from the Global Air system (GAS), generates the MFD display of the CABIN ALTITUDE red CAS message when cabin altitude is above 10000 ft.

Pressure switch, independent from the Global Air system (GAS), generates the MFD display of the CABIN DIFF PRESS red CAS message when the differential pressure between cabin air and outside air is above 6.4 psi +/- 0.2 psi”

The Daher Socata TBM900 Pilots Operating Handbook (POH) and the TBM850 Training Manual illustrations of these systems were used as references for component documentation. The illustrations also provided a reference numbering for each of the components in the system. (See Figures 1, 2, and 2A)

SECTION 7 DESCRIPTION	TBM 900 PILOT'S OPERATING HANDBOOK
1) Demisting outlets 2) Front vents 3) Cockpit ventilated temperature sensor (CKVTS) 4) Cabin ventilated temperature sensor (CBVTS) 5) Air ports 6) Cabin control panel 7) Global air system controller (GASC) 8) Out-flow valve (OFV) 9) Safety valve (SV) 10) Condenser fan 11) Condenser 12) High pressure switch 13) Drier filter 14) Cabin fan 15) Cabin evaporator 16) Cabin blown temperature sensor (CBTBS) 17) Cabin thermostatic valve 18) Low pressure switch 19) ECS panel 20) Cockpit thermostatic valve 21) Cockpit fan 22) Cockpit evaporator 23) Cockpit blown temperature sensor (CKBTS)	24) Demisting microswitch 25) Hot air distributor (HAD) 26) (Cabin) Inlet temperature Sensor (ITS) 27) (Cabin) Bleed temperature switch (BTSW) 28) Mixing ejector (MIXEJ) 29) Check valve 30) MFD unit 31) Ground safety microswitch 32) Differential pressure switch 33) By-pass valve (BPV) 34) Cabin altitude alarm switch 35) Emergency air supply system (EMERGENCY RAM AIR) 36) Main heat exchanger (MHX) 37) Ground fan (GF) 38) Flow control shut off valve (FCSOV) 39) Bleed differential pressure sensor 40) Compressor 41) Shut-off valve (SOV) 42) Overheat thermal switch (OTSW) 43) Non return valve (NRV) 44) Intermediate port pressure sensor (IPPS) 45) Cabin pressure sensor

Figure 7.9.1 (1/2) - GLOBAL AIR SYSTEM ITEMS LIST AND ABBREVIATIONS

Figure 1. A listing of engine bleed air and cabin pressurization system components, as shown on page 7.9.6 of the Socata TBM900 Pilots Operating Handbook. The reference numbers for the components were utilized as part of component documentation.

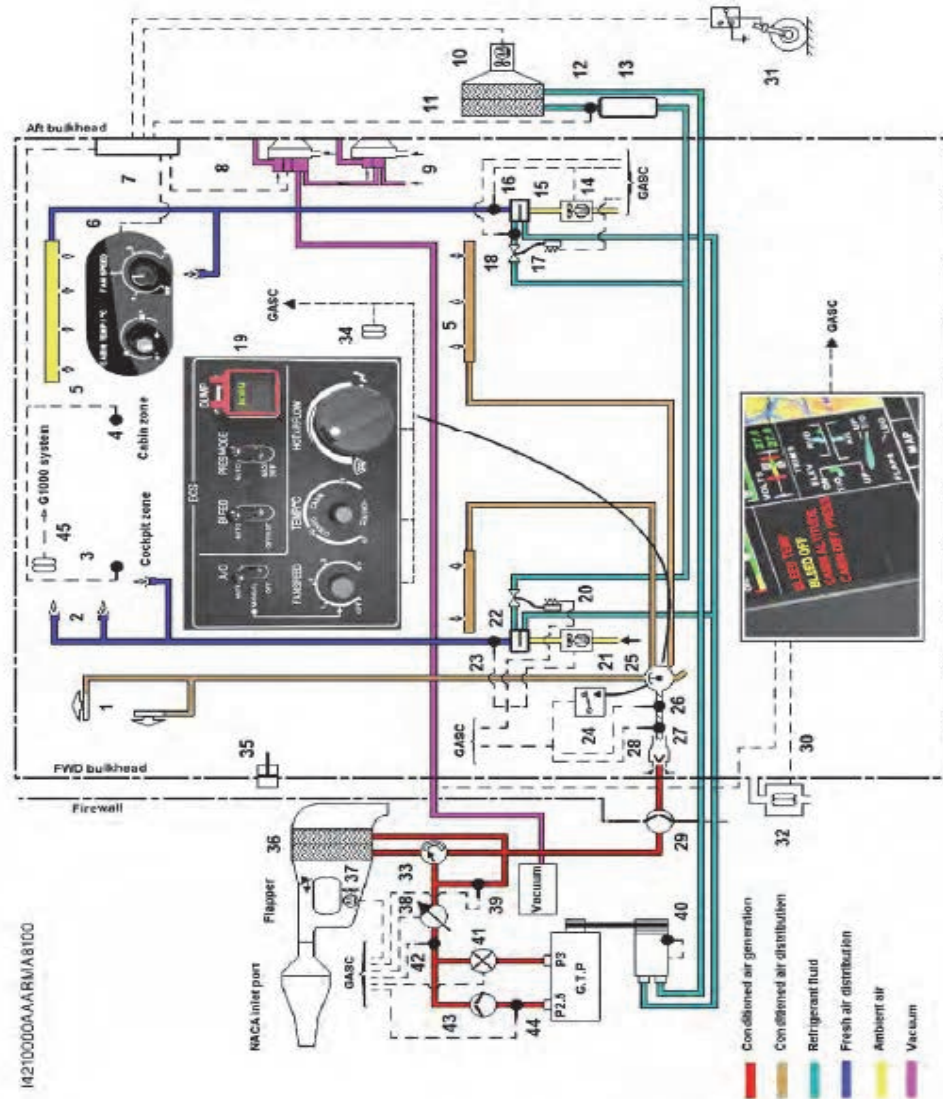


Figure 7.9.1 (2/2) - Global Air System

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Figure 2. An illustration of engine bleed air and cabin pressurization system components shown on Page 7.9.7 of The Socata TBM900 Pilots Operating Handbook. This illustration corresponds with the component numbering on the previous page.

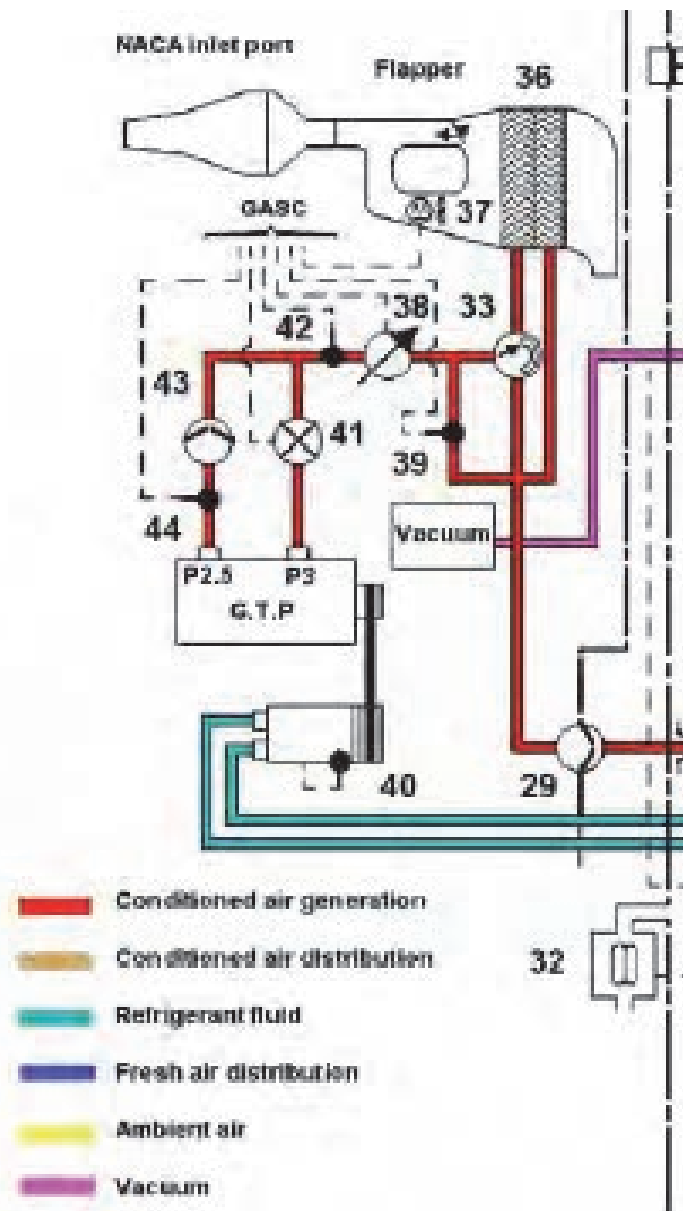


Figure 2A. An expanded view of the Figure 2 components which are located in the engine compartment. See Figure 1 for component nomenclature related to each number.

D.1.2 Bleed and Pressurization Function and Control

The Liebherr Component Maintenance Manual (CMM) shows that the GASC uses the inputs from various sensors to control the supply of pressurized engine bleed air to the cabin. The GASC also controls the flow of air from the cabin through the outflow valve (Figure 2, Item 8).

The sources of the pressurized air are two bleed air ports on the Pratt & Whitney PT6A-66D engine. The computerized Global Air System Controller (GASC) electronic module located in the rear of the cabin is designed to maintain a safe cabin altitude of less than 10,000 feet (msl). For most operations, the lower pressure port (Figure 2, Item P2.5) is sufficient to pressurize the cabin until the airplane is at high altitude with reduced throttle settings. As the cabin altitude rises, the GASC determines when to open the solenoid-actuated shutoff valve (SOV, Item 41) and introduce the higher pressure bleed air from the P3 port. The difference in pressures between P2.5 and P3 shuts a check valve for the P2.5 source.⁴

Downstream of where the low and high pressure supplies meet, the GASC regulates the selected pneumatic bleed air supplies to the cabin with a motorized flow control shutoff valve (FCSOV, Item 38). The GASC can also command the FCSOV to halt the flow of selected pressurized pneumatic bleed air.

Between the junction of the engine bleed sources and the FCSOV is an over-temperature switch (OTSW, Item 42). If the GASC software perceives an overheat or fire, the GASC is designed to use the OTSW, SOV and FCSOV to provide protection against hot supply air from entering the cabin.

The GASC provides power through the OTSW to operate the SOV, so that if the bleed air from the engine exceeds an allowable temperature value, the OTSW contacts open to remove the electrical power which holds the spring-loaded SOV open.

If the GASC determines that the OTSW does not reset (the contacts close) within thirty seconds, the GASC will also cause the FCSOV to close, which terminates the supply of bleed air from the engine.⁵ The GASC indirectly determines whether the OTSW contacts are open (detection of an overheat condition) or shut (normal state of operation) through a separate parallel circuit. To determine the position of the OTSW contacts, the voltage across the contacts is calculated by monitoring the amperage and indirectly measuring the resistance.

Complete loss of bleed air supply, such as by closure of the FCSOV will result in the cabin altitude rising to the altitude of the outside environment. The rate of cabin depressurization depends upon the differential between the cabin and atmospheric pressures, and upon the cabin leakage rate. When the SOV closes and the P3 supply is no longer available, the cabin altitude may begin to ascend to the cabin altitude at which cabin leakage is balanced by the P2.5 bleed supply for the throttle setting in use (typically at idle to low power settings, unless near maximum altitude). Independently, the CAS will display the corresponding caution and warning CAS messages BLEED TEMP in red and BLEED OFF in amber.

⁴ Liebherr calculations indicated that the P2.5 low pressure supply was sufficient for the accident flight.

⁵ A cabin inlet temperature sensor (ITS) failed during a flight test, which led the GASC to command the same result. The state of the ITS was recorded by the GASC memory in the flight test airplane. A similar record did not exist in the memory of the N900KN GASC.

D.2 Supplemental Oxygen Description

The TBM850 and 900 are equipped with a gaseous oxygen system which provides a means to maintain oxygen partial pressure to occupants as a backup for bleed and pressurization systems or in case of air contamination, such as smoke. The gaseous oxygen system is provided for use when the cabin altitude exceeds 10000 ft. or in case of cabin air contamination.

The TBM900 Pilot's Operating Handbook contains a procedure to follow when the red "CABIN ALTITUDE" warning illuminates. The first step is to check the pressurization indicator and the second states "OXYGEN – USE, if necessary" before the procedure calls for any other action, including an emergency descent. The "BLEED OFF" procedure also calls for use of supplemental oxygen and an emergency descent. The emergency descent procedure states "2. OXYGEN USE if necessary"

The section describing use of the masks states that if emergency oxygen is used, then an emergency descent must be performed "...to the "En route" minimum altitude and, if possible, below 10,000 ft."

Section 7.10 of the POH, titled EMERGENCY OXYGEN SYSTEM states in part that:

A control panel located in the cockpit overhead panel at the disposal of the pilot includes:

- a two-position valve ON/OFF ("OXYGEN" switch) to permit the supply of the front seats occupiers masks,
- a two-position valve ON/OFF ("PASSENGERS OXYGEN" switch) with guard to permit the supply of the passengers four masks, when the first valve is open.

Oxygen pressure is displayed on the GDU 1500 MFD.

An altimetric valve provides an automatic passengers masks actuation function at a cabin altitude between 13000 and 14000 ft when "OXYGEN" switch is set to ON.

Two pressure-demand type masks allowing quick donning with only one hand, covering the nose and the mouth, as well as two pairs of smoke goggles are at disposal of the pilot and of the R.H. front seat occupier. Masks are installed in cups on the cabin walls aft of the front seats. Permanently connected to the oxygen system, they are equipped with a micro controlled by the switch ("MICRO/MASK" micro inverter) under cover located on the instrument panel near the pilot's control wheel. The

cockpit masks are equipped with a microphone, a three-position selector NORMAL, 100 % and EMERGENCY and with a push-button "PRESS TO TEST". The proper flow is signaled by a flow indicator (blinker) into the oxygen tubing.

Four passengers' constant-flow type masks, covering the nose and the mouth and permanently connected, are installed in two containers on the cabin ceiling. The opening of these containers and the descent of the masks are controlled by the pilot, when both switches at its disposal are set to ON, or automatically at a cabin altitude between 13000 and 14000 ft with the "OXYGEN" switch set to ON. The oxygen flow is obtained by pulling on the mask bounded by a lanyard cord to a pin. A proper flow is signaled by the filling of the green bag located on each passenger mask.

D.3 Flight Tests

Daher Socata conducted flight tests as part of the investigation, first with NTSB investigators, then independently and with French Government representatives. The independent work was part of additional company-planned engineering for changes to the OTSW and GASC.

D.3.1 Flight Test With NTSB

The May 20, 2015 flight in a TBM900 (msn 1073, F-WWRK) with NTSB investigators was conducted from the Daher-Socata manufacturing facility in Tarbes, France, following pre-flight planning for each task. At the airport, the sky was dark and overcast with minimal wind.

Notes taken during the flight:

14:22 Take off. At 100% torque and 1980 RPM, the gas generator speed (NG) was 96.2% and the intermediate turbine temperature (ITT) was 730°C.

The overcast was entered at 4,500 feet msl.

14:25 At about 6,000 feet msl pressurization was noticed to be 2.1 psi differential pressure (DP).

14:30 On top of overcast at FL150 (15,000 feet msl) the cabin altitude was 4,000 feet.

14:37:44 Reached FL 280 after about 15 minutes of climb and the cabin altitude rose to 8,300 feet. Conditions were -39 °C OAT, 6.0 psi DP, 60 GPH fuel flow, 95% torque, 2010 RPM, 793 °C ITT.

The parking brake was activated to demonstrate the function of the Master Warning visual and audio cues.

Participants noted that in comparison with the weather on the ground, on top of the overcast was a bright and sunny day, the engine sound was smooth, and the navigation display provided a course line to follow. (See Figures 3 and 4)



Figure 3. View from cockpit at FL280. (1) denotes Master Warning annunciator in red and Master Caution annunciator in amber.



Figure 4. Left and center flight displays at FL280. (1) denotes Master Warning annunciator in red and Master Caution annunciator in amber. (2) denotes CAS message area. (3) denotes pressurization display.

- 14:41 Initial power reduction to a cruise setting of 75% torque, 2010 RPM, 95.7% NG, cabin altitude of 8,300 feet, 6 psi DP, TAS 295 KT
- 14:43 Power reduction to a long range cruise setting of 56% torque, 2000 RPM, 90.8% NG, ITT 632 °C, cabin altitude of 8,300 feet, 6 psi DP
- 14:45 Power reduced slowly until the “BLEED HI” message on the top and right of the engine torque display, indicating opening of the P3 bleed valve. Conditions were 37 GPH, 49% torque, 612 °C ITT, 89.1% NG, 2000 RPM, 8,300 feet cabin, 6 psi DP, 240 KT. Torque was reduced and the aircraft descended at 4,150 fpm with the cabin descending at -780 fpm. (See Figure 5)



Figure 5. Master Warning Annunciator illuminated (see circle) and CAS message (see arrow) being displayed. The engine torque display is not visible.

- 14:50 0% torque, 2010 RPM, 72.4°C NG, 521 °C ITT, 278 KT,
- 14:52 Altitude 9,000 feet and 194 KT. Pilot donned oxygen mask.
- 14:54 With the airplane at 9,000 feet, the cabin altitude was 4,100 feet, displaying 2.2 psi DP, with a cabin descent rate of -330 fpm. 41% torque, 52 GPM
- 14:57 The pressurization dump valve was intentionally opened and the bleed supply was closed. The cabin altitude rose to the airplane altitude of 8,900 feet. After stabilizing for about 90 seconds a climb was initiated at 1,000 fpm.

The CAB ALT flashing annunciation was seen on the MFD pressurization display, a CAS message was displayed, the master warning light illuminated, and audio warning chimed. (See Figure 6)



Figure 6. Master Caution Annunciator illuminated, (see circle) CAS message (see single arrow), and double pressurization message (see double arrow).

15:03 At FL 140 the passenger oxygen masks dropped from the storage containers in the ceiling and a 1,500 fpm descent was initiated.

15:06 All warnings ceased as the airplane passed through 9,200 feet.

15:16 The flight landed.

D.3.2 Daher-Socata Flight Tests

Two flight tests were performed with TBM700 S/N 1096 registered F-WWRO on October 22 and 23, 2015, capturing 2 hours and 20 minutes of data. The data and test conduct are proprietary, so only certain points are shown here.

Test instrumentation included electrical parameters for the OTSW and three sources for bleed temperature obtained by thermocouples. Thermocouples were located near the

stage 2.5 (parameter T_{AIRP2_5}) and stage 3 (parameter T_{AIRP3}) engine bleed ports, with a third thermocouple (parameter $T_{AIRBLEED}$) located between the FCSOV and BPV (see Figure 3), about 65 cm downstream of the aircraft's P3 temperature measurement point.

The Daher-Socata report generated from these tests showed maximum $T_{AIRBLEED}$, T_{AIRP2_5} and T_{AIRP3} temperatures in climb and cruise (test points 3-10), stating that the "OTSW temperature threshold of 315°C is never reached." Further examination found that the parameter T_{AIRP3} in test point 7 at FL280 reached 312 °C. This exceeded the 310°C lower production limit for the OTSW switches.⁶ This temperature was at the bleed port and the calculated temperature at the OTSW was estimated to be less than 310°C.⁷

When the SOV was energized, the GASC is designed to provide about 0.5 amperes of current through the OTSW / SOV series circuit at 28 VDC.⁸ A flight test recorded that the current passing through the switch in service varied between 0.4 to 5.7 amperes.⁹

When the SOV was not energized in the flight test airplane, the current in the circuit crossing the OTSW was found to be in the milliamperage range, as specified by the design. With a serviceable OTSW, the measured OTSW voltage and current during the flight at FL310 were 0.25 volts and 0-0.4 amperes during test points 12-14.

An OTSW was installed which had been previously been removed from a different airplane after that GASC registered a fault. The peak voltage variations were measured and the flight test report noted that "Flight with invalid OTSW shows that [the flight test] FTI record of OTSW voltage are more populated than the GASC records." Oscilloscope data were also collected to detect peaks during the oscillations.

The Daher flight test report provided the following text as test conclusions:

- During valid OTSW overheat detection (Ground Test), Voltage raises up to 452 Volts and 5,7 Amp,

Liebherr subsequently asked that the statement be qualified with the following proposed edit: "The GASC supplies OTSW with 28 VDC 0.45 A. During valid OTSW overheat detection (Ground Test), Voltage raises up to 452 Volts and 5,7 Amp, during a transient of approximately

⁶ T_{AIRP3} is measured 65 cm upstream of OTSW, and $T_{AIRBLEED}$ 20 cm downstream of OTSW. When T_{AIRP3} = 312°C, $T_{AIRBLEED}$ = 276°C. As a consequence, Daher-Socata noted that temperature at OTSW is expected to be lower than the temperature measured by T_{AIRP3} .

⁷ The temperature at the switch was not measured. Liebherr estimated that the OTSW temperature would have been "<288C."

⁸ The installed OTSW is supplied by a nominal 0.45A by the GASC when the SOV activates, at least once per flight.

⁹ After Honeywell noted that 5.7 amperes exceeded the OTSW drawing rating for an inductance load, Liebherr noted that the maximum duration was 200 useconds. Based in the proprietary results of endurance testing provided by Honeywell on March 21, 2016 and previous data, Liebherr considers that the OTSW switch has been qualified to withstand static conditions 30 V, 0.5 Amperes, L/R < 0.026 and transient conditions corresponding to such static conditions.

200 μ second. This behavior, happens only in case of overheat protection activation.”

- With an invalid OTSW, voltage oscillates between -4/+16 Volts and could raise up to 125 Volts in flight during OTSW opening,
- In flight, maximum input air temperature (P3) is 312°C and is associated to a maximum Air Bleed temperature of 276°C. [Note: The $T_{AIRBLEED}$ thermocouple was located 20 cm downstream of the OTSW and after the flow passed through the FCSOV.]

Factual Report Note: The precise temperature at the OTSW was not measured. Liebherr asked that the statement end with the following proposed edit: “The T_{AIRP3} thermocouple was located 65 cm upstream of the OTSW. From these distances, OTSW temperature can be estimated <288°C”

D.4 Examinations

D.4.1 Air Force Photographs

Air Force jets followed the airplane from South Carolina to Andros Island, Bahamas. Photographic evidence from the Air Force showed that the emergency exit of the TBM900 was in a position consistent with a depressurized cabin and showed the unconscious pilot without an oxygen mask. (See Figure 7A and 7B)



Figure 7A. This Air Force photograph shows the airplane when at about 28,000 feet. The red arrow shows the frame of the emergency exit enlarged in Figure 1B. The passenger and rear cabin oxygen masks were not visible. The image of the pilot has been redacted by the black rectangle.



Figure 7B. The red arrow in this enlarged and cropped photo shows sunlight reflecting off of the emergency escape hatch frame. The hatch is designed to slightly protrude when the cabin is pressurized and the sunlight reflection would not be possible in that position.

D.4.2 General

Portions of the cabin, the engine, the engine bleed air system, the cabin pressurization system, and supplemental oxygen system components were recovered to an Eclipse Underwater Group warehouse in Annapolis, Maryland. The Systems Group Chairman and Investigator In Charge examined the components on February 5, 2015.

The components had been extensively fragmented consistent with high speed impact. The general direction of crush and displacement in the fragmentation of components was from slightly left of forward to slightly right of aft. The upper fragments of the cabin were found in larger sections than were the lower fragments. The outflow valve and safety valve were removed for the investigation from where they had been mounted next to each other on the aft pressure bulkhead.

The parts examined at the NTSB headquarters had been packed in sealed boxes of fresh water. After opening the boxes and finding that some components had corroded, an anti-corrosion spray was applied to parts to retard the rate of degradation.¹⁰ The material was not directly sprayed into the open ports of the outflow or safety valves.

¹⁰ The brand name of the anti-corrosion material was ACF-50, which meets MIL SPEC 81309 Type II and III approvals. The material is widely approved and used in aircraft corrosion control, water-dispersive, and able to enter between mating parts.

D.4.3 Global Air System

The Liebherr training manual for the Cabin Pressure Control System (21-30-00-L1, September 2007) provides the text within the rest of this section of this report¹¹:

General

On the SOCATA TBM850 aircraft, the Global Air System (GAS) shall provide the following functions:

- To ensure the cabin pressurization.
- To ensure the fresh air supply at a minimum of 3.3 lbs/mn.
- To ensure the heating and/or the cooling of the cabin at a controlled level.
- To control cockpit and cabin temperature within a comfortable range, in heating and cooling modes.
- To allow a controllable differential temperature between cockpit and cabin of ± 5 °C.
- To provide demist capability of the windshield.
- To provide fast pull down / pull up temperature capability.
- To provide comfortable ventilation.
- To provide dedicated faults indication signals.
- To provide trouble shooting information.
- To provide cabin pressurization functions as cabin versus aircraft altitude control, cabin altitude limitation, high differential cabin pressure limitation, negative pressure relief and dump capability.

System Description

The Global Air System (GAS) is composed of three main subsystems:

- the Engine Bleed Air System (EBAS) (ATA 36-10-00),
- the Environmental Control System (ECS) (ATA 21-50-00), including heating and cooling functions (VCS),
- the Cabin Pressure Control System (CPCS) (ATA 21-30-00),
- these three subsystems are managed by the Control System (ATA 21-60-00). The Control System is composed of a single digital controller which receives the information coming from the sensors set in the sub-systems and from the human interfaces set in the aircraft, and elaborates the proper commands to the sub-system actuators, and indication or warning elements.

Operation

¹¹ Note that this training manual describes the GAS as initially introduced on the TBM850 with G1000. Differences may exist between the established training information and the continuously updated POH, maintenance information, customer records, and test data shown elsewhere in this report.

The cabin pressure and cabin pressure rates of change control are automatically ensured by the Global Air System Controller (GASC). The opening of the Outflow Valve (OFV) is controlled by the GASC through a torque motor fitted on the OFV. The GASC includes the cabin pressure sensor.

As far as the aircraft is "on ground" (Weight On Wheels (WOW) indication), and the GASC is power supplied, and the vacuum is applied on the OFV (engine on), the OFV is full open, then the cabin is not pressurized.

The cabin pressure altitude demand being selected by the pilot on the Cabin Pressurization Control Panel (CPCP), when the aircraft leaves the ground (WOW condition), the GASC controls the aperture of the OFV in order to reach the selected cabin altitude at a controlled rate.

The altitude rates of change are automatically managed by the GASC within comfortable limits. The rates values are +525 ft/min in climb and - 525 ft/min in descent.

The overpressure and negative relief safety are managed by both OFV and Safety Valve (SFV). The safety functions are ensured by independent pneumatic modules fitted on the valves, and override the GASC control.

The cabin altitude limitation is independently performed on the OFV by a separate pneumatic module which overrides GASC operation and DUMP function.

The DUMP function allows the pilot to open the OFV in order to depressurize the cabin. This may be used in case of emergency landing, or in order to evacuate accumulated smoke in pressurized area. This function is overridden by the cabin altitude limitation module. In other words, even by dumping action, the cabin will not pass above 14500 ft.

IMPORTANT NOTE: Operating DUMP function requires a 28VDC power supply, and is therefore not operational in case of electrical power lack.

D.4.3.1 GASC Non-Volatile Memory

Nonvolatile memory (NVM) was recovered from the GASC and the following data was obtained.¹² (See Table 1) This data was utilized during examination of components and the general accident investigation.

Hexa-decimal Memory Address	Current Leg Faults Recorded, followed by descriptions provided by Liebherr Engineering	GASC NVM record, shown as Fault Position In Word 1:
0x00008003	SW-ECS_HEATING_FAULT This code is recorded when the SW_BLEED_TEMP bit is set.	0
	SW_BLEED_TEMP Records when the SW_BLEED_OVHT fault exists for 30 seconds.	1
	SW_BLEED_OVHT Records when the OTSW is detected by the GASC to be open ($T > 315^{\circ} \text{C} \pm 5^{\circ}$). Consequence: SOV loses power to remain open.	5
0X00008000	SW_CPCS_FAULT May result from multiple CPCS failures, including SW_PC_COMP_OOR	24
	SW_PC_COMP_OOR Cabin altitude out of range, triggered below - 3,550 feet or above 15,960 feet.	26
	SW_GASC_FAULT Known software bug unrelated to functional operation and correction previously planned for next software update. Cause is insufficient voltage to operate a discrete maintenance function.	28
0X0000807	SW_AVIONICS_VZA_F Recorded when ARINC data is lost or outside of -20,480 fpm to +20,480 fpm	Fault Position In Word 2: 3

Table 1. Faults recorded by the GASC during the accident flight.

¹² The NVM is an electrically erasable programmable read-only memory (EEPROM). The GASC erases and reprograms the memory contents with voltage pulses.

D.4.3.2 GASC Overheat Circuit

D.4.3.2.1 Functional Description

The P3 high pressure bleed air supplied through the SOV is designed to be shut off when the OTSW opens ($T^{\circ} > 315^{\circ}\text{C} \pm 5^{\circ}\text{C}$), since the OTSW is the path to ground for SOV power. This power is provided by the GASC. The GASC non-volatile memory (NVM) stores the failure code SW_BLEED_OVHT even if the switch re-closes.

A 30 second timer begins within the GASC when the GASC registers the open OTSW. At the end of the 30 second period and if the OTSW remains open, the GASC performs the following actions:

1. The GASC removes power from the circuit to the SOV. The OTSW already removed the ground, so this step ensures termination of the hot P3 high pressure bleed air supply to the bleed air system.

NOTE: While other failures may also lead to the BLEED OFF CAS message and NVM code, the others are not shown because they were not recorded during the accident flight and no other indications were found. A more encompassing list of conditions which would cause the GASC to remove power to the SOV and cause it to close while the OTSW is closed would include the following:

- Intermediate Port Pressure Sensor (IPPS) fault or
- Inlet Temperature Sensor (ITS) fault or
- Hot Air Distributor (HAD) position fault or
- By-Pass Valve (BPV) position fault or
- Bleed OVHT (OTSW contacts registered as open, as was found in the NVM from the accident flight) or
- Bleed OFF selected by the pilot

2. The GASC commands the FCSOV to close.
- 2A. Closure of the FCSOV illuminates the cockpit BLEED OFF and BLEED_TEMP CAS messages, records an NVM failure for BLEED_TEMP, and causes the cockpit master caution warning to sound/illuminate.¹³
3. The GASC non-volatile memory (NVM) retains failure codes for:

SW_BLEED_TEMP. Recorded after expiration of the 30 second timer for an open OTSW.

¹³ Although other failures may also lead to the BLEED OFF condition, the NVM did not record other failures.

SW_ECS_HEATING FAULT. This failure message is a general message which may be recorded for a number of conditions.

With finding that the GASC recorded the SW_BLEED_OVHT fault, Liebherr personnel showed how the GASC determines the state of the OTSW contacts by electrically determining whether the OTSW switch is open or closed. The GASC infers the state of the OTSW by applying 28 VDC to a circuit which branches into parallel paths and measures voltage in one of those paths.

The path through the SOV and OTSW to ground is one leg of the parallel circuit (See Figure 8, red arrow to right). The GASC monitor circuit (light blue arrow to left) is a low current path for voltage measurement, isolated by a combination of diodes and resistors. This path through pin X1-9 leads to cockpit illumination of the BLEED OVHT caution message.

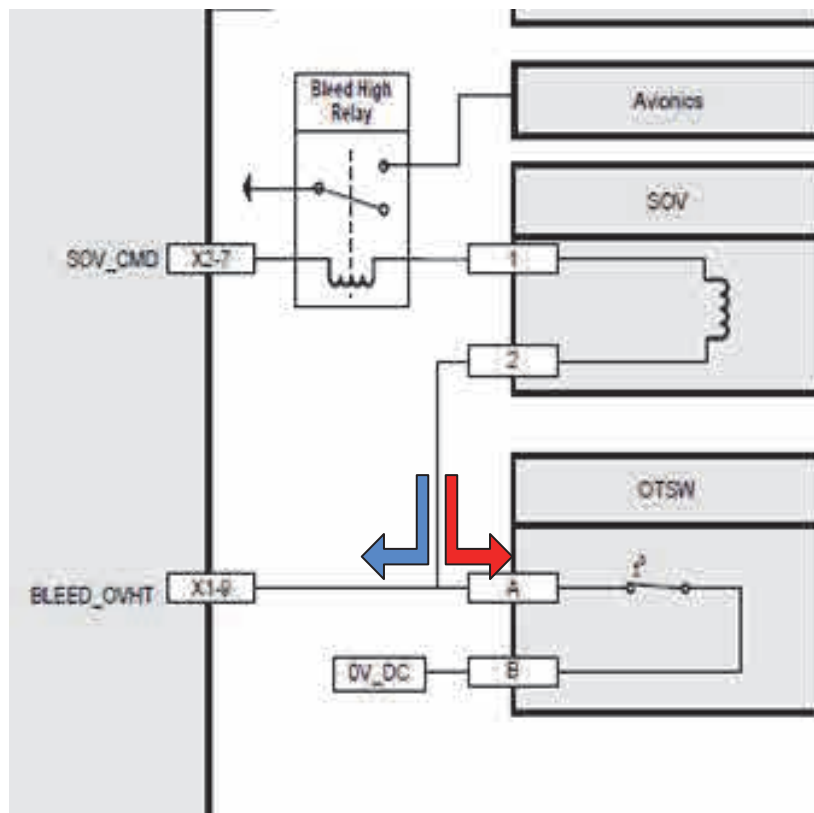


Figure 8. Liebherr-provided circuit diagram which shows the GASC along the left, P3 shutoff valve (SOV), and over temperature thermal switch (OTSW). The same circuit diagram also shows that when the OTSW contacts are open the SOV circuit is opened, shutting the source of P3 bleed air.

Closing of the OTSW contacts reduces resistance in the SOV/OTSW leg, permitting current to flow through those devices. When the OTSW contacts are not open, then milliamperes of current from the 28 VDC GASC source pass through the circuit to keep the monitor active (See Table 2). Closing the contacts results in a nominal increase to .45 amperes of current flow through it and the SOV. The monitor senses when the input voltage crosses thresholds which produce a digital "1" or "0" state for the microprocessor software to interpret as an open or closed OTSW.

D.4.3.2.2 Examination and Test Results

Finding that the state of the OTSW is a measured value, data and testing examined the points at which the state of the switch changes. The testing found that the point at which the GASC determines the OTSW state could vary between 25Ω and 12,500Ω. (See Table 2)

	Voltage level in the Liebherr GASC requirement document based on a discrete input to the GASC from the 28 VDC system	OTSW resistance level based on the Liebherr engineering design hypothesis	Actual OTSW resistance values based on the Liebherr post-accident GASC test. A variable resistor was used to represent the OTSW.
OTSW Open	Equal or greater than 13.5 VDC	> 1 Mega Ohms	> 12,500 Ohms. GASC pin X1-9 had 1mA at 13.5 VDC
			Between 25 Ohm and 12,500 Ohms, the GASC registered the OTSW as either open or closed.
OTSW Closed	Equal or lower than 4 VDC	< 2.5 Ohms	< 25 ohms. ¹⁴ GASC pin X1-9 had 140 mA at 3.5 VDC.

Table 2. Values relating the point at which the GASC determines the OTSW state to be open or closed.¹⁵

¹⁴ A Liebherr email to the Group Chairman on August 28, 2015 provided this value as 20 Ohms from an earlier test.

¹⁵ Limited data are shown in order to not reveal proprietary portions of the source documents and identifying features. Liebherr provided the following comment "...as per specifications, the OTSW contact resistance is 0.125 Ohm maximum; and the GASC considers that OTSW as closed up to a contact resistance of 25 Ohm; which represents a margin factor of 200 for the OTSW closed contact detection. Based on the above, Liebherr is in the opinion that the OTSW position monitoring characteristics used by the GASC are appropriate, and with a sufficient margin."

Examination of the GASC circuit tracks which monitor the SOV revealed that the conductor cross sections were less than what could carry the full operational power which the SOV experienced during tests. The size of the tracks was a Liebherr design choice based on power which would be applied for discrete input management and appropriate to the intended loads, according to Liebherr personnel.

Indirect measurement for the state of switches is commonly used by utility companies and other applications when the amount of current or voltage is great enough to damage the circuits used to perform measurements. Basic web searches return extensive documentation which relates potential issues in this technique. (Footnotes show two examples) As a voltage calculation, a documented potential issue is that variations at milliampere current levels can greatly change the perceived amount of resistance and therefore the state of the contacts.

NOTE: Consensus was not reached within the group on the *italicized* text shown. Liebherr stated that certain text should be deleted, relating that the company position was that the information is not relevant. The information has been retained with *italics* to show the text which Liebherr referred to.

Resistance measurements of an OTSW and contacts from two others resulted in finding high resistance when millivolts were applied with multimeters for initial measurements, and then low resistance was measured when re-tested at one ampere.¹⁶ The GASC monitor circuit provides milliamperes for the measurement, one ampere is within the functional range of the SOV-OTSW circuit, and the OTSW circuit operates at up to five amperes.

Remote measurements of resistance may appear to change when utilizing various low-current-high-resistance measurement techniques.¹⁷ Ohm's Law is also temperature-based, in part because current passing through a resistance creates heat which directly alters the value of measurements. Other variables may include the dimensions and stress of the material being measured. As summarized in 1948 by the National Bureau of Standards "In some cases the resistance of a conductor depends upon the magnitude of the current flowing through it. That is to say, Ohm's law is not applicable, and the resistance must be determined under the conditions of use."¹⁸

¹⁶ Production and component maintenance documents call for testing the OTSW in the operational range, not with multimeters which operate in the milliampere range. The three described were not from N900KN. The N900KN values were disregarded, since the switch was found full of seawater.

¹⁷ One basic description of electrical nonlinearity and difficulties with measurements may be reviewed at <http://www.allaboutcircuits.com/textbook/direct-current/chpt-2/nonlinear-conduction/> and at <http://www.seaward.co.uk/resistance-measurement#six>

¹⁸ Other methods may also be used to measure resistance directly or indirectly. Content in this paragraph and other text describing measurement of resistance values and potential measurement error is quoted or summarized from Circular 470, titled "Precision Resistors and Their Measurement, by James Thomas, U. S. Department of Commerce, National Bureau of Standards, October 8, 1948

A common reason provided for higher apparent resistance measurements is application of insufficient current to exceed the threshold which energizes the surface irregularities created by oxidation or wear. The phenomenon of increasing current to exceed the threshold and energize constituent materials is intentionally used as the basis of design in some electronic components, such as varistors. The literature provides other potential causes for apparent measurement errors can exist internal to the measurement device, within the general circuit being measured, from external sources, or from combinations.

Once Daher Socata developed a revision to the POH and issued a service bulletin which prevented deactivation of the pneumatic bleed air system for reasons which included detection of an OTSW switch anomaly, examination ceased into the measurement technique used by the GASC to determine the open/closed state of the OTSW switch contacts.

D.4.3.2.3 GASC Circuit Inductive (Reactive) Load

The switch receives an inductive load from the electrical series installation with the SOV. In researching the origin of the basis for establishing the electrical load of the switch, Honeywell personnel noted that the relevant tests and qualifications for the contacts were described by MIL-R-6106C titled "Military Specification, Relays, Electric, Aircraft, General Specification for," and AN3179, "Inductor, 30V Laboratory Test."

The statement "L/R=0.026 MINIMUM" found on OTSW drawing 975-4150-201, was associated with the "0.5A INDUCTIVE LOAD" current rating and called for the AN3179 test. The units associated with the L/R item in the OTSW drawing is in seconds, which is the time constant of the inductive circuit loading the switch contacts. The drawing states 30 VDC, 0.5A and L/R-0.026 seconds or 26 ms for the units as the rated load where the contact endurance would be valid at 50,000 cycles. Voltage and current in excess of the BP characterization are conditions of use that will degrade the life of the OTSW based on arc damage to the contacts.

Liebherr conducted testing and provided a report titled "OTSW Current Characterization Report" (T-91138-DTR-0003), which identified the following:

- Brief current peaks up to 3.5A – 4A during a time of 150 to 200 μ s [were measured at the OTSW] (the time for the current to decrease from its nominal value to zero)*
- Voltage reaching approximately 420V [were measured at the OTSW]*

The actual voltage/amperage found in this report exceeds the electrical characteristics for which the switch was designed, as stated in Note 5 of the 975-4150-201 drawing, which states:

5. *ELECTRICAL CHARACTERISTICS*

CONTACT LIFE: 50,000 CYCLES AT RATED LOAD
VOLTAGE: 30 VDC / 125 VAC RMS
CURRENT: 0.5A INDUCTIVE LOAD (L/R= .026 MINIMUM)
3.0A RESISTIVE LOAD.
0.5A TUNGSTEN LAMP LOAD

The Air Force Research Laboratory (AFRL) reviewed the circuit and provided the NTSB with assistance by examining the OTSW switch contacts. (See Appendix A). An AFRL report contained the following recommendation:

Due to the reactance of the shut-off valve, consider installing a snubber component or circuit in parallel with the shut-off valve or in parallel with the OTSW. This will reduce the arcing energy across the OTSW contacts when they open, thereby minimizing arc erosion and the deposition of SiO₂. While a 1000 V silicon diode (e.g., 1N4007) will likely offer better performance than a resistor-capacitor circuit, the former may not allow the system to pass electromagnetic interference testing due to the high levels of reverse voltage applied during testing. Consideration must also be given to how the inclusion of a snubber component or circuit would affect the overall reliability of the system, and whether or not its inclusion is fail-safe. If a snubber cannot be installed, consider changing the composition of the contacts in the OTSW to an alloy that is more arc-resistant, such as silver cadmium oxide or silver tin oxide.

In an email of May 24, 2016, from Dave Studtmann of Honeywell to the Group Chairman, Mr. Studtmann stated that Honeywell intended to discuss with LTS the inclusion of an electrical snubber.

D.4.4 OTSW Switches

This section pertains to the OTSW portion of the above GASC overheat circuit. In summary for the investigation into the OTSW switches, post disassembly microscopic examinations of the N900KN OTSW and three other switches removed from service following GASC records of failure only revealed small amounts of contact wear, consistent with switches that had been in service and which had passed long term endurance testing. The switch contacts were not burned, welded, or otherwise abnormal for contacts which had been in service. Examination at the United States Air Force Research Laboratory (AFRL) similarly was summarized as follows:

The overall condition of the N900KN (incident) contacts was considered average. Though the contacts showed evidence of arc erosion, it was deemed typical for a used switch and not excessive. Material transfer between the two contacts was also not excessive. In addition, a black "halo" observed around the OTSW contacts' mating

surfaces was shown to be comprised of silicon dioxide (SiO₂), which is an electrical insulator.

The N900KN OTSW passed the electrical contact resistance test and after removing sea water from the switch housing the switch functioned when heated, although the opening temperature was 2% above the maximum specification limit.

D.4.4.1 OTSW General

The OTSW is manufactured by Honeywell Aerospace and similar switches are utilized throughout the aerospace industry. In 1970, the Honeywell Redmond manufacturing facility, then United Control (a Sundstrand company), qualified thermal switch modules P/N 617-3128 in accordance with Hamilton Standard specifications for eventual installation in the Lockheed L1011 airliner. The general configuration of the switches was similar to the Liebherr 975-4150 assembly.

Honeywell does not hold a TSO/PMA on the 975-4150, which is installed in the Daher-Socata airplanes, since the TSO/PMA was not required. The design was based on customer requirements, with the design and prototypes approved by the customer, Liebherr. The Honeywell Aerospace internet web-site shows that generally similar thermal switches are used in numerous aircraft and military applications.

The OTSW switch is a stainless steel tube with a 3-pin threaded connector at one end. The opposite end contains the thermal disc and is inserted into the stream of air for which the temperature is to be sampled. (See Figures 9 and 10) In the case of the TBM900, the assembly is threaded into a pneumatic bleed tube of the airplane, so that the tip of the switch module is flush with the inner wall of the tube.



Figure 9. OTSW switch prior to removal from wreckage on June 4, 2015.



Figure 10. OTSW switch from N900KN and an exemplar. The electrical connector is at top and the capsule with the switch contacts is at the bottom.

In the middle of the OTSW is hexagonal shape for a wrench to fit, and at the opposite end from the electrical connector is a module containing an internal thermal switch which is moved indirectly by a bimetallic disc. The contacts capsule is manufactured first and then welded to the portion which houses the wiring.

As the module heats to $315^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ($599^{\circ} \pm 9^{\circ}\text{F}$), the bimetallic disc is designed to change from a concave to a convex shape. A pin on the armature is pushed by the disc during this shape change to move a mechanical switch to the open position. As the switch cools to $295^{\circ}\text{C} \pm 5^{\circ}\text{C}$ ($563^{\circ} \pm 9^{\circ}\text{F}$) the disc is designed to revert to the original shape and the switch closes. (See Figures 11 and 12). The difference in temperatures is intended to prevent rapid cycling wear on the switch.

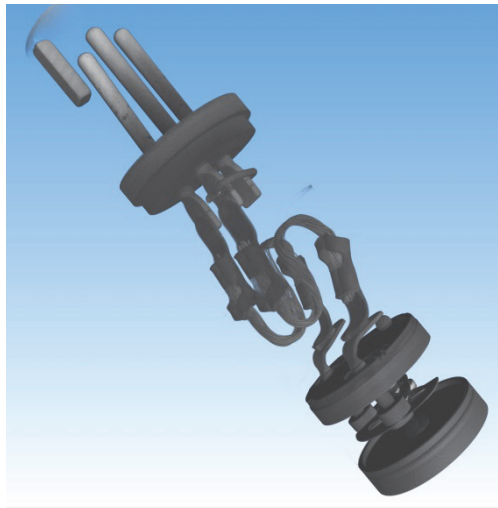


Figure 11. Computerized tomography (CT) image of the N900KN OTSW created by NTSB and used by the group to discuss various components within the body of the OTSW.

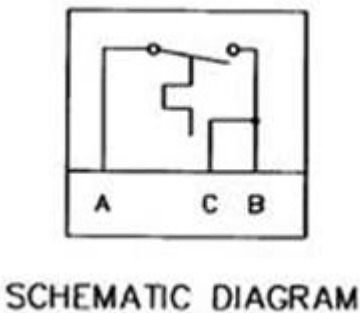


Figure 12. Electrical circuit of the OTSW.

D.4.4.2 N900KN OTSW Examination and Test

The N900KN OTSW was found to be comprised of two chambers, one of which held wiring and the other contained the switch contacts. The wires within the switch were found to be electrically insulated by two layers of woven glass fibers and the connector pins are held in place by a rubber-like material. Red material resembling room temperature vulcanizing (RTV) rubber coated each end of the internal exposed wiring. (See Figure 13)



Figure 13. This photo of the disassembled N900KN OTSW shows the capsule containing the thermal switch at the left, the mounting body to the left of center, an insulating Kapton liner to the right of center, and the electrical connector (shown at top in previous photo) on the right. The wires had to be cut during the examination at the base of the electrical connector and a small split in the Kapton was created.

The first test was to check electrical resistance through the pins and switch body, with the following results. Note that later the switch was found to have contained sea water after this test.

	N900KN part	Exemplar
Pin A to B	2.0 Ω	3.4 Ω
Pin A to C	2.0 Ω	3.3 Ω
Pin A to case meter)	Varied from 3.4 Ω to 70k Ω	Open (beyond range of
Pin B to C	1.9 Ω	2.0 Ω
Pin B to case	55 k Ω	Open
Pin C to case	65 k Ω	Open

The switch was mounted on a rack and placed into a wind tunnel heated to 636F, next to the exemplar switch. The exemplar electrically opened after 2:47.¹⁹ At 3:25 the N900KN part burst with a loud bang and sufficient force to bend the test fixture. Examination revealed that a welded joint near the wrenching flat had burst and the switch body had bent at the split. (See Figure 14)



Figure 14. N900KN OTSW after the welded area burst when heated.

Repeating the resistance measurements provided the following results:

	N900KN part
Pin A to B	1.8 Ω
Pin A to C	1.9 Ω
Pin A to case	Varied then near 83 k Ω
Pin B to C	1.8 Ω
Pin B to case	76 k Ω
Pin C to case	80 k Ω

The group had planned to conduct a functional test procedure (FTP) but with the burst in the case the full FTP was not possible. For example, the leakage test could not be performed and the electrical resistance already failed the requirements of the dielectric and insulation resistance tests, so these tests were not performed.

¹⁹ 2:47 denotes two minutes and forty seven seconds.

The contact resistance test in the FTP called for less than 60 millivolts at 1 amp and 28 VDC and the part test result was 29.3 millivolts.

The switch was cut open at the failed weld on the connector side of the wrenching flat. A lathe was used by hand to create the cut, and then the three interior wire lugs were cut. Imaging from computerized tomography previously indicated that the connector on one wire had a 0.014" dimension to the metal tube of the switch body. (See Figure 15) After removal of the connector end, the wires were visible and they were resting against a layer of Kapton insulation which lined the tube interior. (See Figure 16)



Figure 15. CT images with arrows showing .014" measurement.

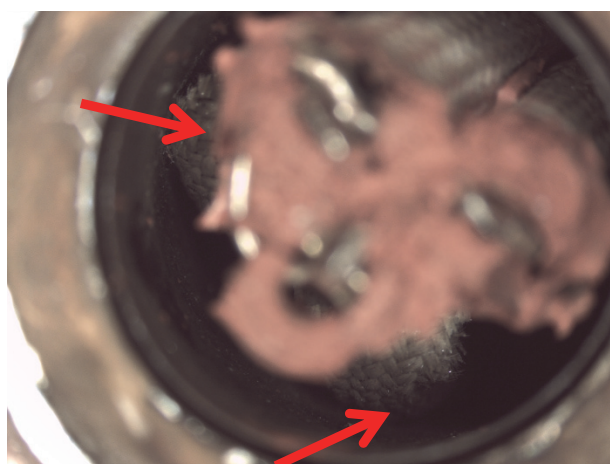


Figure 16. Wires in switch body resting against Kapton liner of tube wall. (See arrows)

The module end was then cut from the tubular body and the wires pulled out with the module. The wires were found to have two layers of woven fiberglass as insulation. (See Figure 17)

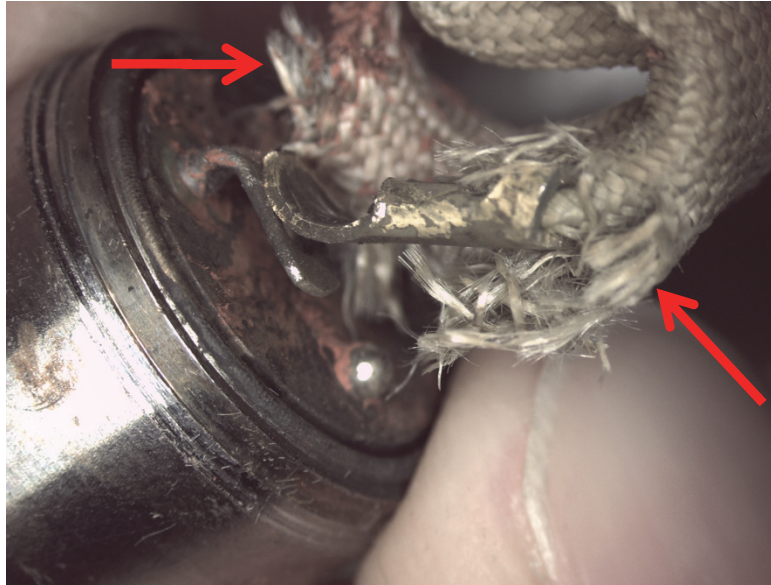


Figure 17. Layers of fiberglass insulation on wire after pulling apart the outer layer.

The outer layer of some fibers had minor areas where they had worn though, flattened, or become dark in locations where the switch rested against the Kapton. (See Figure 18) The interior layer of wire insulation remained intact, as had the Kapton where the wire had been in contact, and no short circuits of the wires or connectors to the switch housing were seen.



Figure 18. Worn area of wire insulation. (typical)

The interior surfaces of the switch body were blackened with residue. The Kapton was unrolled and found to have a split near the module end. The unrolled Kapton was translucent and exhibited a very thin layer of residue. (Figure 19)



Figure 19. Residue on unrolled Kapton liner.

The top of the switch module, called a header, was covered in black residue. The header also had extensive surface pitting, with larger pits near the wire connectors and near a ball which sealed the module during manufacture. The two biggest pits beneath the wire terminals were 0.007 inches and 0.011 inches deep. Microscopic examination revealed no evidence of heat or molten globules and undercutting with flaking consistent with corrosion was noted. (See Figure 20)



Figure 20. Blackened surface of the switch module header, with visible pitting (upper arrows), undercutting, and flaking (lower arrow). This surface was beneath one of the terminals where a wire had been attached.

Electrical continuity measurements across the module were taken with the following results:

Between wires was 0.2Ω

The B-C wire to case was 0.46 Meg-ohms.

The A wire to case started at 1.3 Meg-ohms then dropped to 0.5 Meg-ohms, then to 0.436 Meg-ohms.

The exemplar showed an open circuit for each measurement of the wire to the case.

During the disassembly, the wires were intentionally broken off of the welds at the switch module terminals for examination of the module. The ball was removed from the module and pressurized water sprayed out of the module. (See Figure 21)



Figure 21. Water on surface of switch module.

The vented module was then tested by slowly increasing the temperature with the following results:

	Actual	Specification
Switch opening temperature	620.2°F	599°F (+/- 9°F)
Switch closing temperature	558° F	563°F (+/- 9°F)

The interior surfaces of the switch module had brown deposits and extensive rust deposits on them. The sleeve which held the thermal disc in place was found to be a rusted steel material. The armature and switch were removed by drilling out the rivets.

The switch contact had no weld marks. It did have pitting and material transfer. (See Figures 22 through 24)



Figure 22. Material transfer pit on contact surface denoted by circle. The armature which the contact is mounted to is normally shiny, but was coated with brown rust.



Figure 23. Contact material.



Figure 24. Contact material transferred.

D.4.4.3 AFRL Examination of OTSW Switch Contacts

D.4.4.4 Overheat Thermal Switches From Other Airplanes

The group examined records from pilots, maintenance data, and Honeywell, LTS, and Daher Socata. The review found records of 18 prior OTSW switch replacements from 2008 through October 16, 2015, some of which had maintenance records or write-ups similar to that recorded by the GASC from the accident airplane.²⁰ (See Table 3 for ten examples.) Twelve of the records included statements from pilots or mechanics that the pneumatic bleed air system ceased to function at altitude. Records from two of those twelve showed that the removed OTSW switches had been found out of specification, and two others had passed the acceptance test procedure. (The other eight were less descriptive.)

²⁰ The NVM data is erased after each subsequent take-off so that NVM data was not available for most records.

Systems Group Chairman's Factual Report ERA14LA424

Date	Model	Report Title	Exemplar Abstracts	Depressurization	Parts removed
27/03/2015	TBM900	PRESSURIZATION SYSTEM FAIL OTSW	@FL270 CAS – AIR BLEED OFF cass mess followed by depressurization	Yes	OTSW
26/03/2015	TBM900	Bleed Off Warning	@FL270, CAS messagesCAB ALT & bleed temp recycled the bleed	Yes	OTSW
17/11/2014	TBM900	CAS CABIN ALTITUDE Message	@FL280, CAB ALT increase & CAB ALT CASS MESS	Yes	ITS small drift OTSW NFF
19/06/2013	TBM850	BLEED TEMP CAS message - S207	BLEED TEMP CAS message at 27,000	Yes	OTSW
10/6/2013	TBM850	S207 Bleed air overtemp switch	at FL270, the bleed temp CAS warning illuminated at 27000 ft , and the bleed air shut off	Yes	OTSW FAULTY
20/03/2012	TBM850	Bleed off CAS message in flight followed by BLEED TEMP after 30	BLEED TEMP + BLEED OFF CAS Message reset and bleed	Yes	OTSW FAULTY
27/04/2010	TBM850	BLEED TEMP and BLEED OFF on ground	CAS message BLEED TEMP often displayed during the start up sequence The bleed was	No	OTSW
13/03/2009	TBM850	Overheat Thermal Switch	on cold starts 30- 35F bleed temp	Yes	OTSW NFF
11/4/2008	TBM850	DEPRESSURIZATION	@FL280, CAB ALT CASS MESS, cab alt 14000ft. Bleed CAUTION ON (Yellow).	Yes	OTSW
10/4/2008	TBM850	Allumage du voyant Bleed Temp et Bleed Off (bleed Temp	BLEED TEMP + BLEED OFF CAS Message Reset and system	Yes	OTSW

Table 3. Ten examples of maintenance records with ownership and identification details omitted.

In addition to the 15 reported OTSW replacements from prior to the investigation, during the investigation the GASC in three airplanes indicated that an OTSW was detected to remain in the open state. The three switches were obtained for the group to test, disassemble, and examine at Honeywell.

Two passed functional testing (at 28 VDC, 1 A) and one did not. The third of the collected OTSW switches (not from N900KN) was initially checked multiple times with an available multimeter as an impromptu test when the factory test protocol was not

available. The multimeter tested with milliamperes of current, not the 1 ampere specified in the test plan.

Prior to receipt by the group, the aircraft mechanic who originally identified and removed one of the switches from an in-service airplane had been checking continuity with a multimeter when he inadvertently tapped the switch as it sat on his workbench. He reported that the resistance of the switch contacts changed each time the switch was tapped and provided a video which showed the resistance of up to 6,120 ohms.

When the switches were at Honeywell the group recorded the electrical continuity of pins A to B in each, and then the continuity was monitored while each switch was tapped lightly on a table top. As reported by the mechanic, large variations in resistance values from tens to thousands of Ohms were seen on the digital display repeatedly over multiple samplings, and the following values were recorded:

DATE CODE OF SWITCH:	1416	1333
DATE CODE OF MODULE:	1412	1149
A-B	0.1 Ω	0.1 Ω
A-C	0.2 Ω	0.2 Ω
B-C	0.2 Ω	0.1 Ω
A - case	Open	Open
B - case	Open	Open
C - case	Open	Open

During tapping of switch 1416 the resistance went from 0.1 Ω to zero ohms in a transient manner.

During tapping of switch 1149 the resistance went from 0.1 Ω to 1.4 Ω maximum in a transient manner.

The NTSB further examined the accident and incident OTSW contacts with electronic failure specialists at the Air Force Research Laboratory (AFRL). Post disassembly microscopic examinations of all four switches only revealed small amounts of contact wear consistent with switches that had been in service and which had passed long term endurance testing. The switch contacts were not burned, welded, or otherwise abnormal.

D.4.4.5 Exemplar Wear, OTSW Contacts After Laboratory Endurance Tests:

Honeywell provided contacts from two test OTSW which had accumulated 100,000 resistive load cycles at 28 VDC and 5 amperes.²¹ The features of both contact assemblies in general were shiny and clean, as opposed to the dull brown features of the N900KN internal components. The group noted that while the N900KN switch was relatively new and had only about 141 flight hours, it had been recovered from months of time in ocean water. The contact set (called Set #1) from one switch had a roughened appearance in the wear area which covered more than half of the contact pad with very little depth. (See Figure 25)

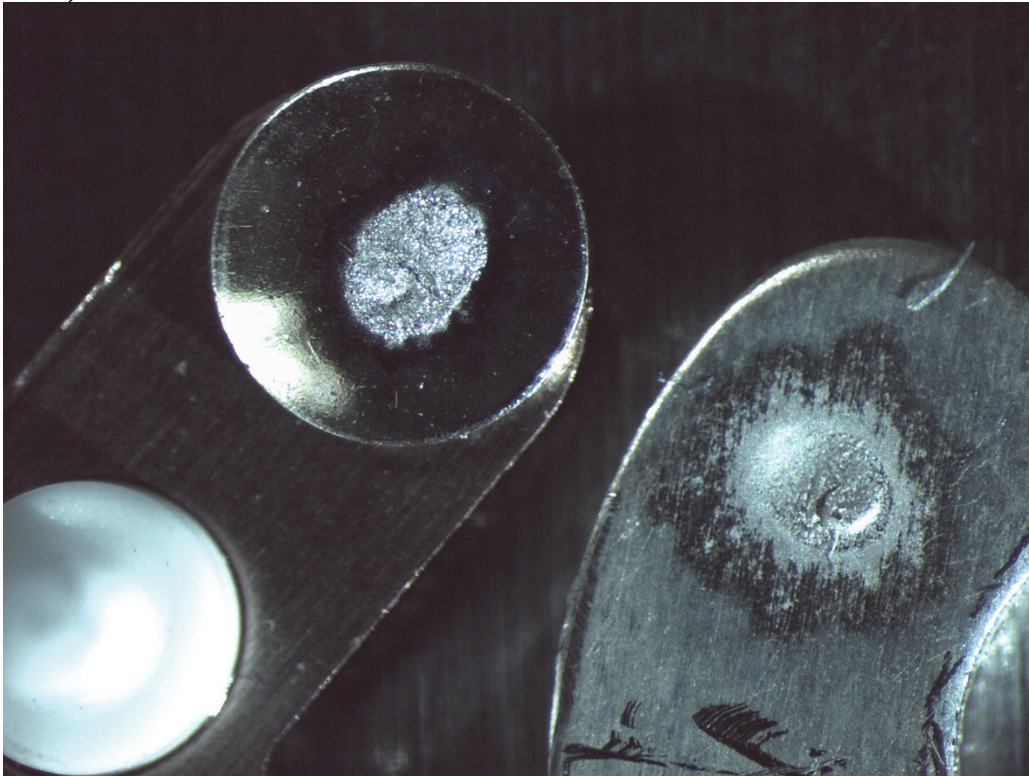


Figure 25. Endurance test contact Set #1.

The wear area in the set of contacts from the second (called Set #2) was slightly smaller in diameter. (See Figure 26) The wear area was surrounded by a slightly darkened ring and the wear area had material transferred from one contact to the other with a depth similar to that seen in the N900KN contacts.

²¹ One party noted that the test set-up should be included in the report. This data is proprietary and therefore not shown.



Figure 26. Endurance test contact Set #2.

D.5 Other Components and Examinations

This section lists markings found on each of the individual components, followed by examination features and photographs. The outflow valve, overpressure safety valve, and emergency oxygen switch were imaged by computerized tomography (CT). For nomenclature and descriptions, some component listings include information from the TBM850 Training Manual.²²

The OTSW was recovered from wreckage at the Eclipse warehouse and had dried, months after the recovery. When recovered from the ocean, the rest of the pressurization components had been placed in cooler boxes which were filled with water and sealed shut. (See Figure 27). Some parts had extensively corroded and had a slippery coating on the surfaces. Once removed from the water, most parts were sprayed with a water-dispersing anti-corrosion spray. Surfaces of the parts which the spray did not contact visibly corroded or oxidized within a day.

²² The TBM850 and TBM900 features described are similar.



Figure 27. Examples of the sealed cooler boxes filled with water and pressurization parts.

D.5.1 Outflow Valve

Figure 3, Item: 8
Manufacturer: Liebherr
Part Number: 81146A010101
Serial Number: 81146-00363
Manufacturing Date: 082013

TBM850 Training Manual (21-30-00-L1, Page 18, Sep 07) provides the following general functional description and list of major outflow valve components:

The Outflow Valve (OFV) modulates the discharge airflow to control the cabin pressure through the torque motor channel.

The OFV controls the cabin outlet airflow, the opening of the OFV is a function of the torque motor current delivered by the Global Air System Controller (GASC).

This valve also ensures safeties for overpressure relief, negative pressure relief and cabin altitude limitation.

The OFV is composed of:

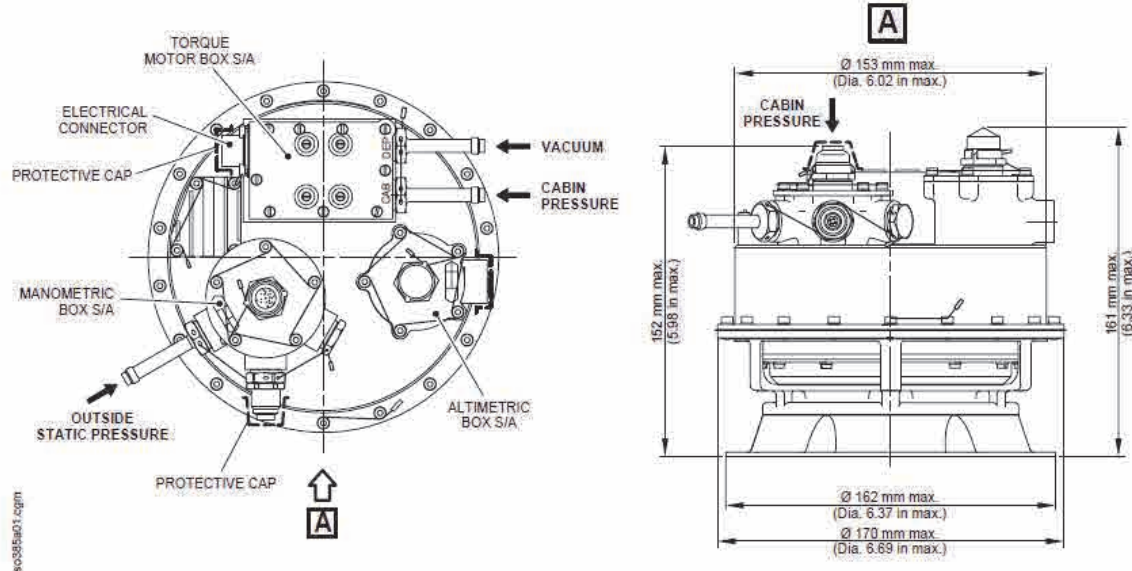
- A body which enables the OFV to be fitted on a bulkhead flange attached to the aircraft structure.
- A cover on which 3 boxes are fitted.

- A three boss-box performing the following functions:
 - ✓ Overpressure relief: This safety is performed by a manometric capsule driving a valve. Inside the capsule, there is the cabin pressure; outside the capsule, there is the static pressure.
 - ✓ Negative pressure relief: This function is performed by the N/R valve which connects the diaphragm chamber to the cabin pressure when the cabin pressure becomes lower than the outside static pressure.
- A torque motor box:
 - ✓ The torque motor is fitted inside this box. The torque motor shaft drives a quadrant which controls the area of the cabin pressure and the vacuum nozzles.
 - ✓ The cabin pressure nozzle is supplied with cabin air cleaned by the air filter.
 - ✓ The vacuum nozzle needs to be connected to a vacuum source providing at a minimum -50 hPa relatively to the cabin pressure, with a minimum of 300 l/h air flow.
 - ✓ The vacuum nozzle also includes a N/R valve allowing the negative pressure relief to operate in case of failure of the vacuum source.
- A cabin altitude limitation box:
 - ✓ This function is performed by the aneroid capsule driving a valve. Outside the capsule, there is the cabin pressure.
 - ✓ The main poppet including the main diaphragm, the top of the main poppet and the diaphragm form, with the cover, the diaphragm chamber.
- A deflector.
- A spring.

Illustrations from the TBM850 Training Manual were used for nomenclature and descriptions of exterior and functional main valve components. (See Figures 28 and 29)

OUTFLOW VALVE

Detailed description



OVERALL DIMENSIONS

EFFECTIVITY

ALL

LIEBHERR-AEROSPACE Toulouse 2007

FOR INFORMATION ONLY

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Figure 28. External features and nomenclature for the outflow valve

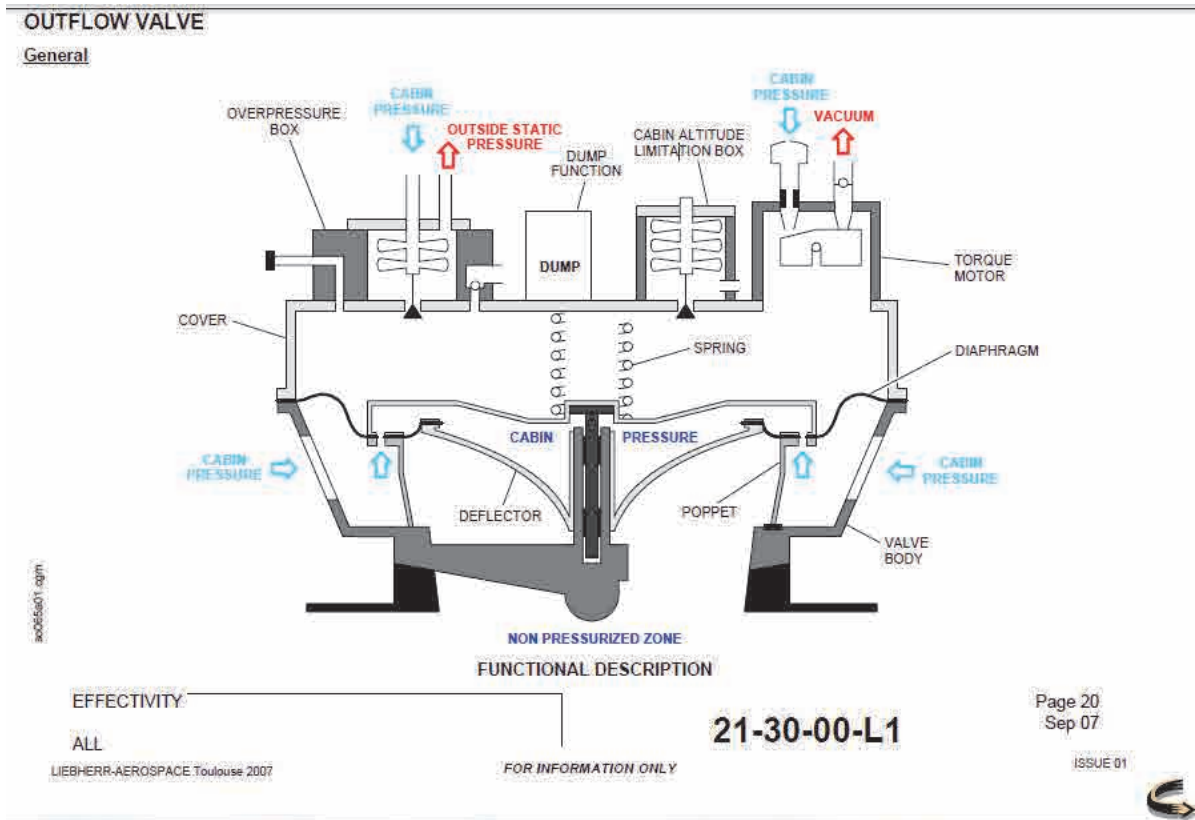


Figure 29. Outflow valve functional components and nomenclature.

The outflow valve and safety valve were removed from their mounting points, which were next to each other on the aft pressure bulkhead. The outflow valve was found in one piece and the safety valve had broken in two.

When removed from water in the packing box, the outflow valve assembly was found to have little deformation or other types of impact damage and was visually in good condition. The exterior was coated with a slippery substance and had minor white deposits on various surfaces. Exposed steel parts had rusted. Five yellow Liebherr anti-tamper sleeves existed on segments of safety wire at the fasteners. (See Figure 30)



Figure 30. The complete outflow valve assembly.

Water ran freely from the open ports of the valve and the valve was rotated to facilitate draining the water. After no further water could be drained, water could be heard sloshing inside the valve body.

The large valve poppet moved on the central shaft and during the examination the opening was photographed at two positions. As received, the large valve poppet was loosely closed and with close examination a paper-thin line of light could be seen between the main valve body and the seat. Measuring the exposed center shaft position between the frame and the large valve poppet, the exposed shaft was slightly more than 0.07" in length.

When the main valve body was placed with the mounting surface upward so that the weight of the valve body (poppet) rested on the large interior spring, the poppet would slowly move to about 0.07" (about 2 mm) from the closed position. (See Figure 31) Seeing that the poppet would move on the central shaft, light finger pressure was applied to the deflector surface and the main valve body opened. When the finger pressure was removed the internal spring returned the main valve body consistently to the 0.07" opening.



Figure 31. Close-up view of the 0.07” opening of the outflow valve main valve body when placed with the poppet resting on the internal spring. The white areas are organic ocean material and corrosion.

During examination at Liebherr in Toulouse on May 20, 2015, the valve was found closed and functionally sealed within the limits of the specification for leakage. Upon disassembly, the accumulated organic ocean material prevented testing the torque motor for leakage and the altitude limitation function. The material adhered in a manner that the non-return valve remained shut. The manometric capsule was in one piece but the aneroid capsule had collapsed. The evidence indicated that the valve was shut at impact, due to scars at the contact interface.

D.5.2 Safety Valve (SFV)

Figure 3, Item: 9
Manufacturer: Liebherr
Part Number: 81147A010101
Serial Number: 81147-00367
Manufacturing Date: 062013

While the safety valve was physically similar to the outflow valve, the TBM850 Training Manual (21-30-00-L1, Page 25, Sep 07) provides the following general functional description and list of major safety valve components:

The Safety Valve (SFV) ensures safeties for the overpressure relief and the negative pressure relief.

The SFV is composed of:

- A body which enables the SFV to be fitted on a bulkhead flange attached to the aircraft structure.
- A cover on which one box is fitted and performed the following functions:
 - ✓ Overpressure relief: This safety is performed by a manometric capsule driving a valve. Inside the capsule, there is the cabin pressure; outside the capsule, there is the static pressure.
 - ✓ Negative pressure relief: This function is performed by the N/R valve which connects the diaphragm chamber to the cabin pressure when the cabin pressure becomes lower than the outside static pressure.
- The nozzle is connected to the cabin air filter.
- The main poppet including the main diaphragm, the top of the main poppet and the diaphragm form, with the cover, the diaphragm chamber.
- A Filter which enables to avoid any pollution induced by cabin air in the Outflow Valve (OFV). It consists of an housing containing a removable paper filter. The paper cartridge is recommended to be changed every year at a periodic aircraft revision.
- A deflector.
- A spring.

General

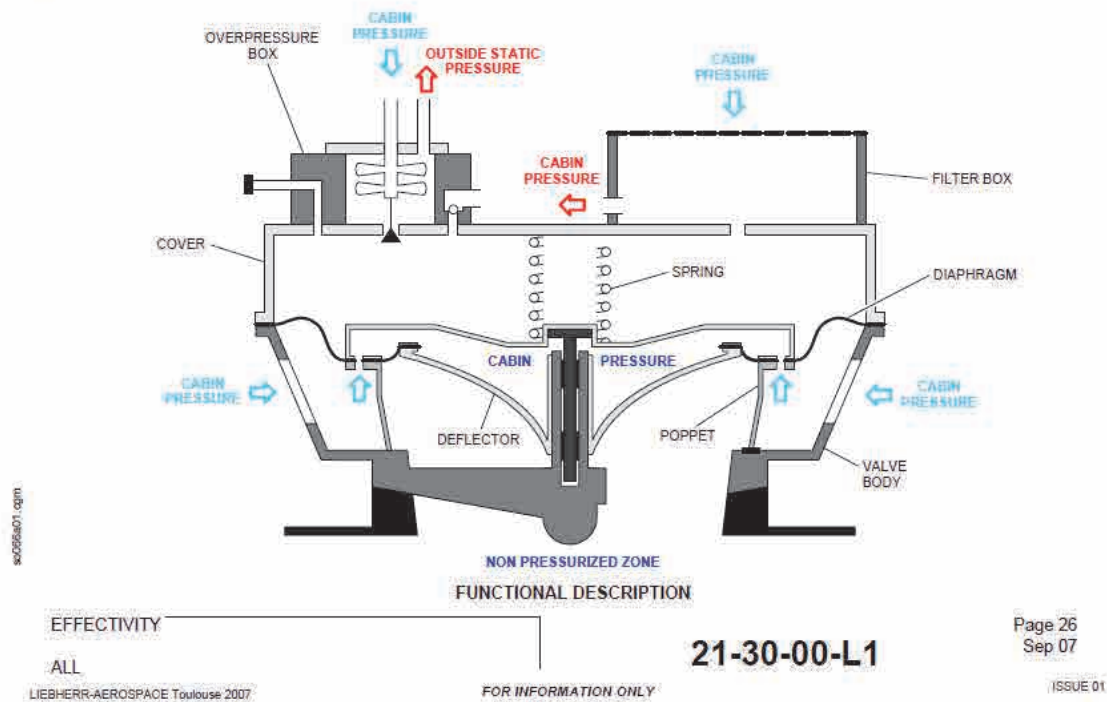


Figure 32. A general description of the safety valve functional components.

The valve was received as two major segments, with each in good condition visually. As with the outflow valve, the safety valve had minor white deposits, rusting of steel, and yellow Liebherr anti-tamper sleeves were found on segments of safety wired fasteners. The poppet and control portion comprised one segment, with the valve seat and frame as the second segment. (See Figure 33)



Figure 33. The complete two portions of the safety valve.

Water ran freely from the open ports of the valve and the valve was rotated to facilitate draining the water. The filter appeared to be clear and water drained freely through it.

After no further water could be drained, water could be heard sloshing inside the valve body.

As opposed to the nearly closed outflow valve, the main safety valve body was received in a nearly full open position with respect to the poppet position on the central shaft. To measure the extent of the valve opening, the main valve body was 0.52" from a step in the shaft diameter and about 0.72" from the fracture at the frame end on the center shaft. (See Figure 34)



Figure 34. The main valve body on the broken central shaft. The shaft broke flush with where it had entered the mounting flange visible in the next photo.

The shaft and six frame legs had overload types of fractures. The shaft broke where it had entered the mounting portion of the frame. Firm finger pressure on the deflector surface of the main valve body (poppet) did not move the surface along the central shaft. The poppet and shaft did move as one unit against the internal spring. (See Figure 34)

Having the valve in two pieces allowed visibility of where the outflow and safety valves seal when shut. (See Figure 35)



Figure 35. The calipers are set to the diameter of the main valve body knife-edge, and placed on the seating surface which the knife-edge would rest against in an intact valve.

During detailed examinations at Liebherr, the sub-components passed functional tests. The valve sealing faces did not have the clear contact marks found on the outflow valve.

D.5.3 By-Pass Valve (BPV)

Figure 3, Item: 33
Manufacturer: Liebherr
Part Number: 6043A010001
Serial Number: 6043-02375 (may be -03375)
Manufacturing Date: 072013

The stainless steel valve body and rotational inner sleeve were received intact and in a position which did not change with strong finger pressure. A portion of the plastic housing remained with a gear set. The motor portion of the plastic housing was not with the received valve. (See Figure 36)

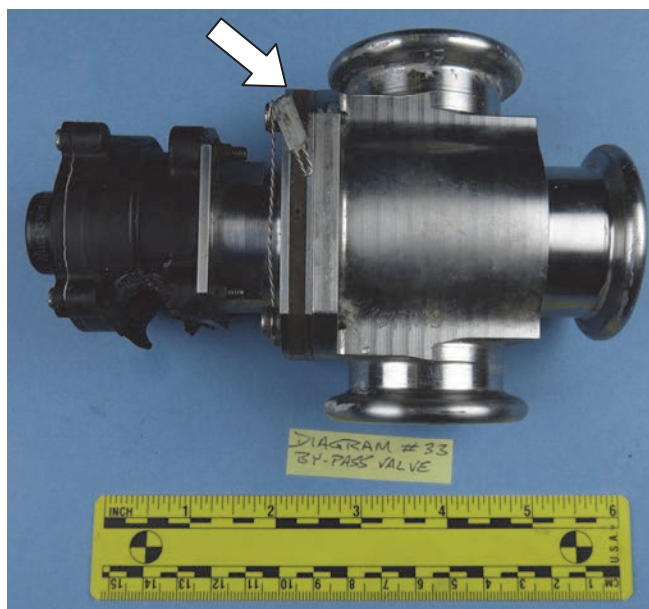


Figure 36. Overall bypass valve as received. An arrow points to a projecting segment of safety wire as a common reference feature for comparison of valve orientation in the photographs.

A set of exposed switch contacts were found at the end of the plastic housing furthest from the stainless steel valve body. (See Figure 37)



Figure 37. Exposed switch contacts.

The sleeve valve was found at a rotational position which closes the port on the side of the exposed gear. On the port opposite the gear, the rotational position closed 5mm of the 17mm opening width. (See Figures 38 through 40)



Figure 38. Internal bypass valve orientation.



Figure 39. Partially closed bypass valve opening.



Figure 40. Closed bypass valve opening.

The orientation of the BPV valve was set in an exemplar BPV while being examined at Tarbes. The physical position of the valve was measured at 72% open at 12.92mm of the 18mm total and electrically, the valve was 39 to 40.7 degrees open. It was noted that the housing for the electrical mechanism was physically broken. (See Figure 40) The GASC recording had indicated the BPV position to be 34°. Testing an exemplar BPV verified the specification that when BLEED_TEMP annunciation was created, the exemplar BPV position was between 40 and 45 degrees.

D.5.4 Main Heat Exchanger

Figure 3, Item: 36

The heat exchanger was found with the fuselage debris in one piece with impact and localized crushing which was consistent with impact. No other types of potential pre-impact types of damage were noted, such as localized rupture, leakage stains, or failed seams.

D.5.5 Flow Control Shut Off Valve (FCSOV)

Figure 3, Item: 38
Manufacturer: Liebherr
Part Number: 6784A010001
Serial Number: 6784-00364
Manufacturing Date: 082013

Note, the data plate had separated from the valve and was found loose in the bag with the assembly. As an additional method of identifying the valve, the following data were on an attached small duct:

Part Number: 12783A020001
Serial Number: 1366987301
Manufacturing Date: 072013

The complete valve assembly removed from water used for shipment had an overall slippery coating and extensive white deposits. Liebherr anti-tamper sleeves were on safety wire. (See Figure 41)

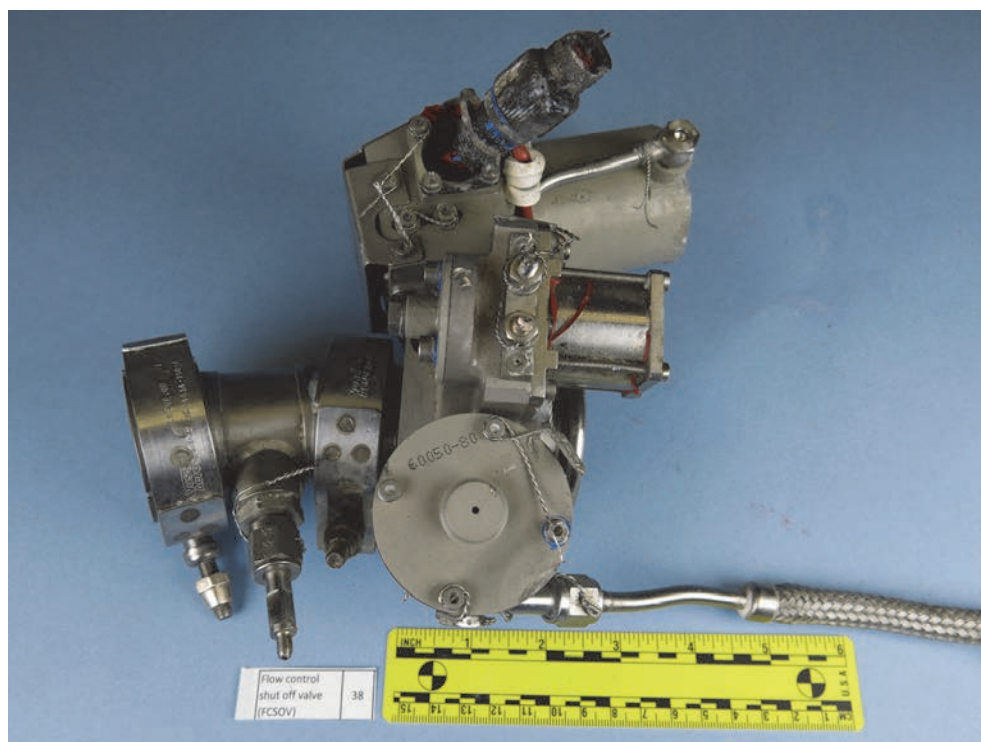


Figure 41. Overall FCSOV.

The movable portion of the valve was found in the closed position and sealed in that position by oceanic types of deposits. (See Figure 42) Examination of the area around the valve actuation shaft for marks other than at the closed position revealed nothing.

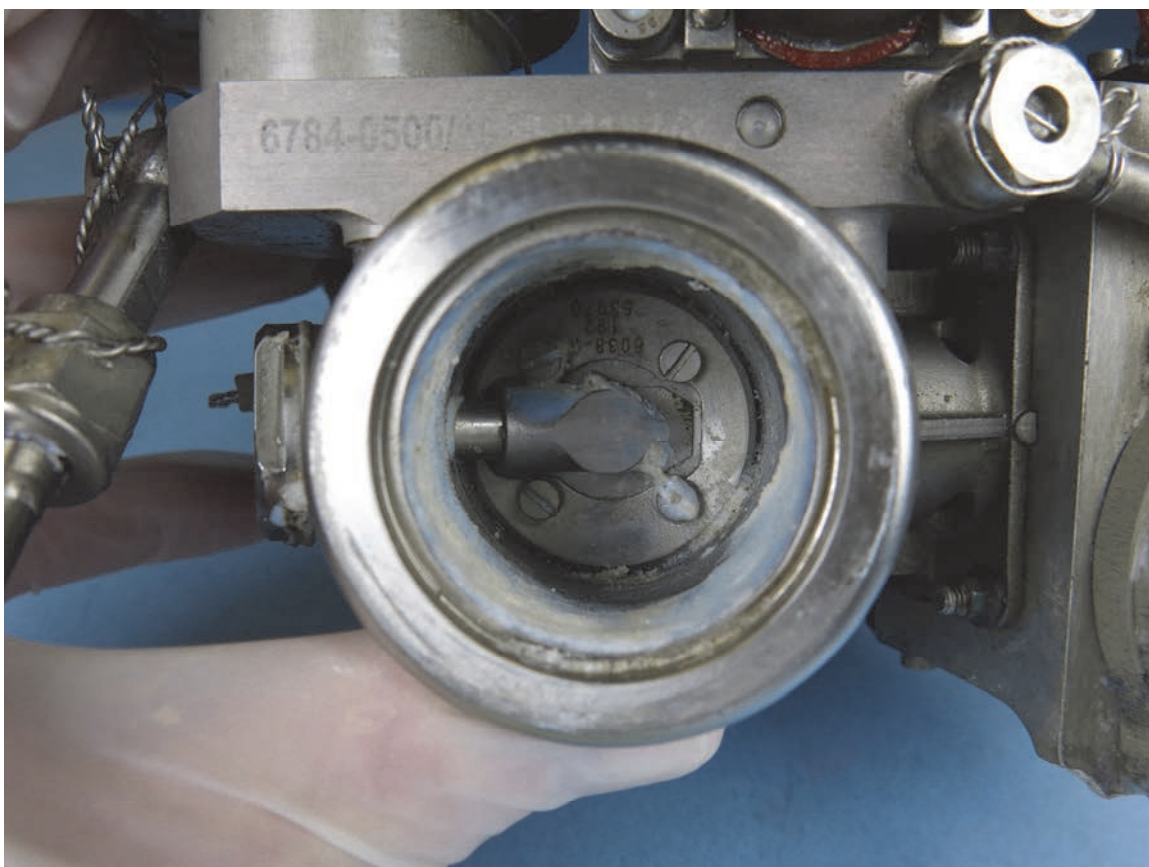


Figure 42. Butterfly valve in closed position within the FCSOV. The white deposits were found on numerous parts recovered from the ocean and the slippery surface is not visible.

The valve was disassembled at Toulouse and the actuator components were found in the closed orientation. Microscopic examination for witness marks found nothing relating to other positions existing at impact.

D.5.6 Bleed Differential Pressure Sensor

Figure 3, Item: 39
Manufacturer: Liebherr
Part Number: 93558A010001
Serial Number: 93558-10089
Manufacturing Date: 09 /2013

The stainless steel housing of the switch assembly was found crushed to the inner components. Beyond noting the marked information and visual condition, no further testing or examination was attempted due to the damage. (See Figure 43)



Figure 43. Bleed differential pressure sensor.

D.5.7 Stage 3 Bleed Shut Off Valve (SOV)

Figure 3, Item: 41
Manufacturer: Liebherr
Part Number: 4589A010001
Serial Number: 4589-00366
Manufacturing Date: 062013

The Stage 3 bleed shut off valve was found with the separate data plate in a plastic bag, and with the electrical connector attached only by internal wiring. The valve was covered with a slippery coating and extensive white accretions. (See Figure 44)



Figure 44. Stage 3 bleed shutoff valve.

Examination of the SOV revealed that the interior poppet was in the closed position. (See Figure 21) The poppet would not move with firm finger pressure.



Figure 21. Closed poppet within the SOV.

D.5.8 Hot Air Distributor (HAD)

Figure 3, Item: 25
Manufacturer: Liebherr
Part Number: 6044A010001
Serial Number: 6044-00371
Manufacturing Date: 062013

The hot air distributor was found in an intermediate position, consistent with delivering a controlled amount of heat to the cabin. (See Figures 45 through 48)



Figure 45. HAD data plate.

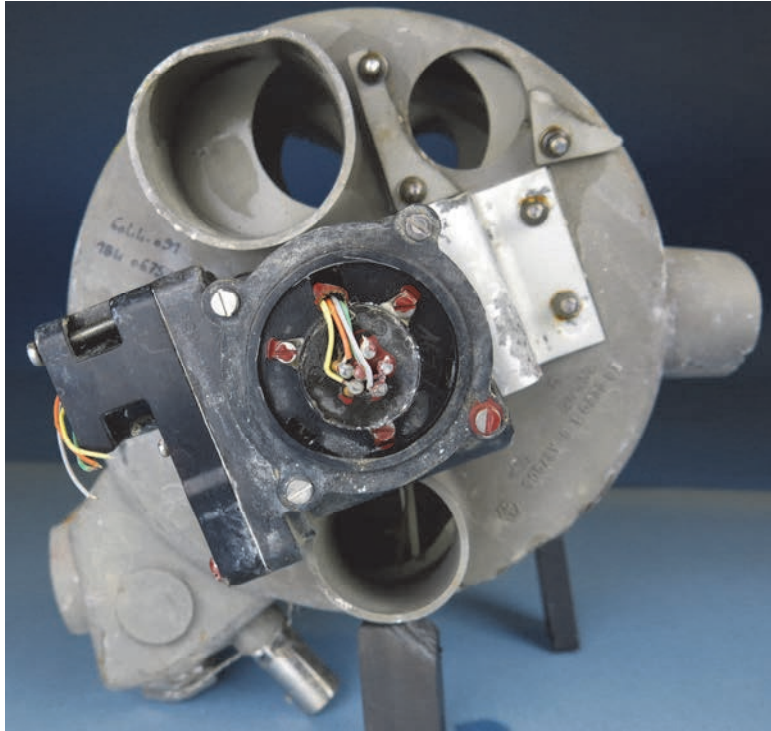


Figure 46. Position of hot air distributor valve.



Figure 47. Position of hot air distributor valve.



Figure 48. Position of hot air distributor valve.

D.5.9 ECS Control Panel

Figure 3, Item: 6
Manufacturer: Daher
Part Number:
Serial Number:
Manufacturing Date:

When removed from the water it had been shipped in, the backshell of a large electrical connector and other steel parts had rusted and a slick film of rusty deposits was noted on all surfaces. (See Figures 49 through 51) The control panel was locally cleaned for photos of details. Switch toggles without locking gates were found to be loose.



Figure 49. Face of the ECS Control Panel with brown rust deposits.

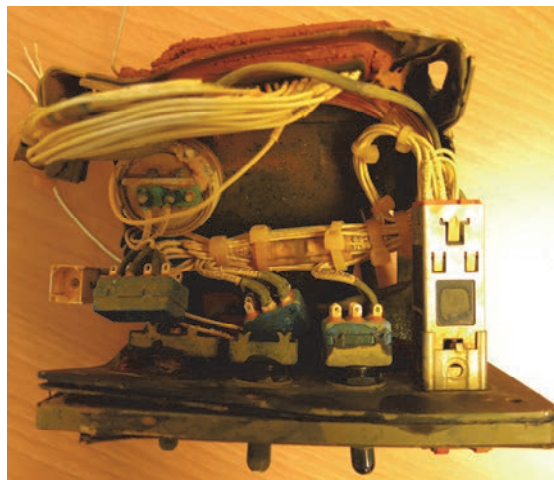


Figure 50. This view of the top of the ECS Control Panel shows the rusty connector across the top of the photo.

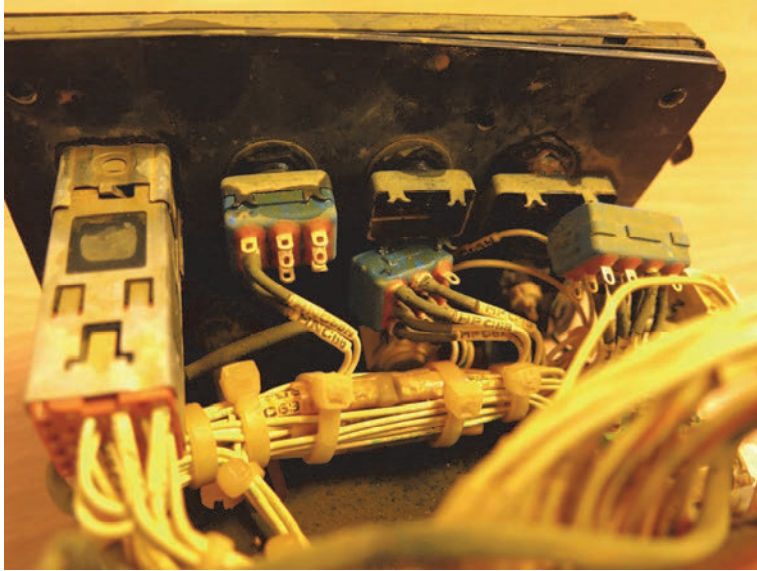


Figure 51. Broken switch bodies are visible.

The functional portions of the switches were found broken. (See Figures 52 through 59)



Figure 52. The AC switch toggle had recessed into the panel and was loose. The impact position was indeterminate.

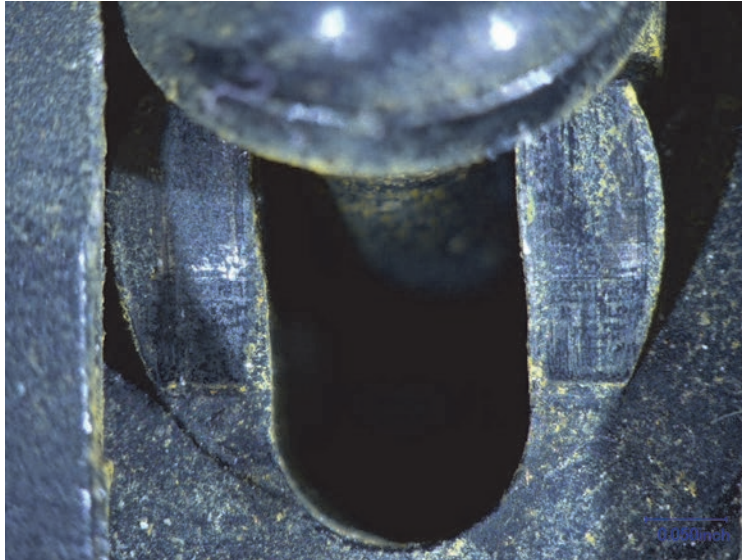


Figure 53. The BLEED switch was found in the AUTO position. The locking gate had no imprints or scars on the OFF/RST side of the lock.

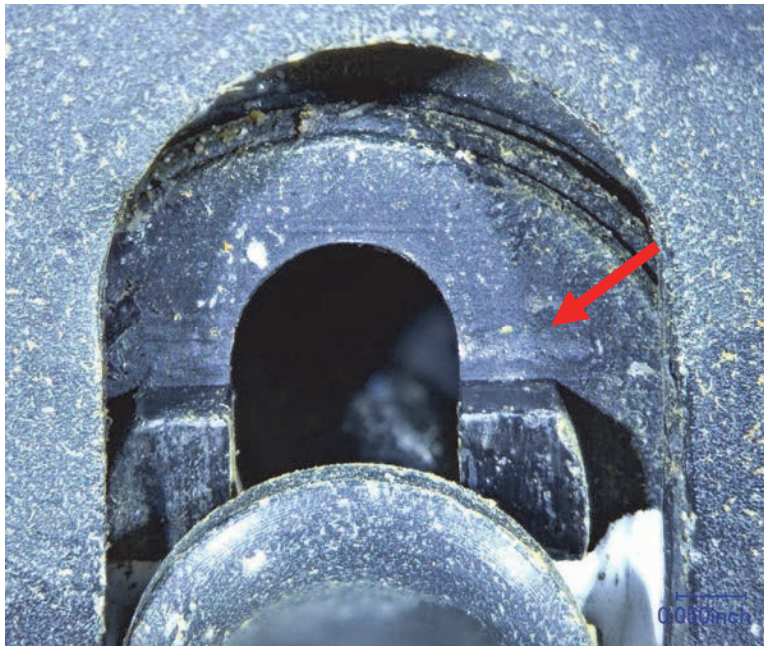


Figure 54. The BLEED switch had an imprint on the AUTO side of the locking gate.



Figure 55. The PRES MODE switch was found in the AUTO position. The locking gate had no imprints or scars on the MAX DIF side of the lock shown here.

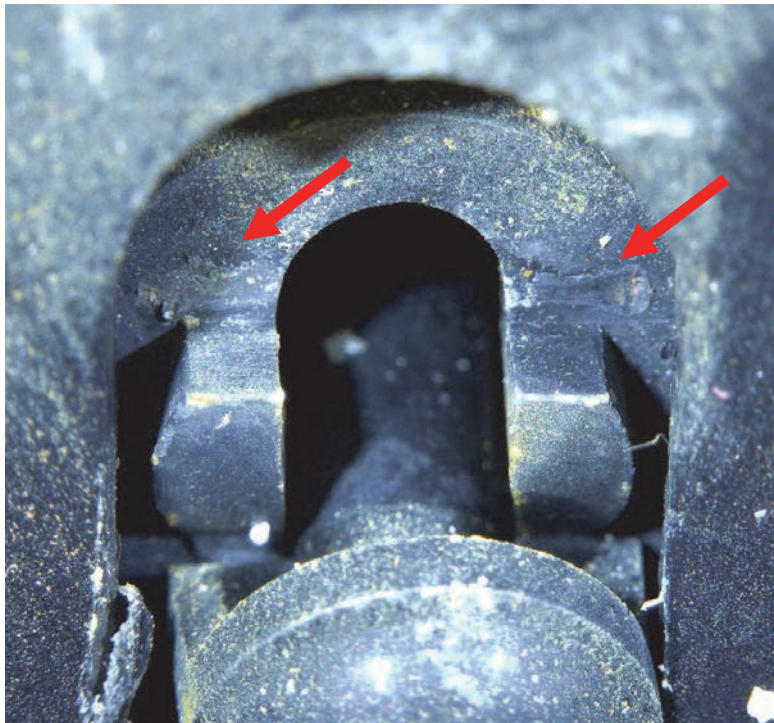


Figure 56. The PRES MODE switch had imprints on the AUTO side of the locking toggle.

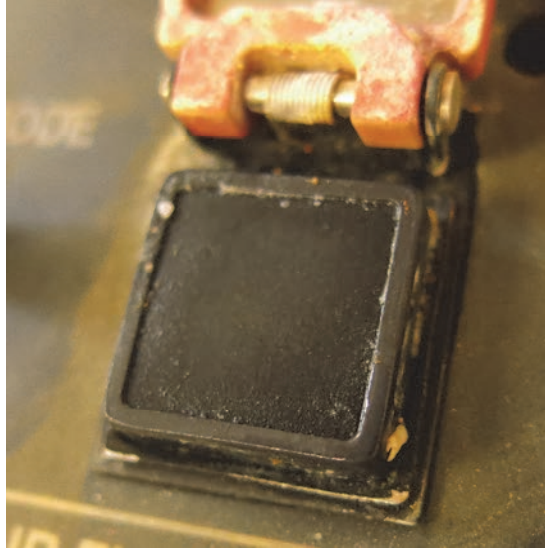


Figure 57. The DUMP switch body was intact. The button was found immobilized in the extended position and was not disassembled.

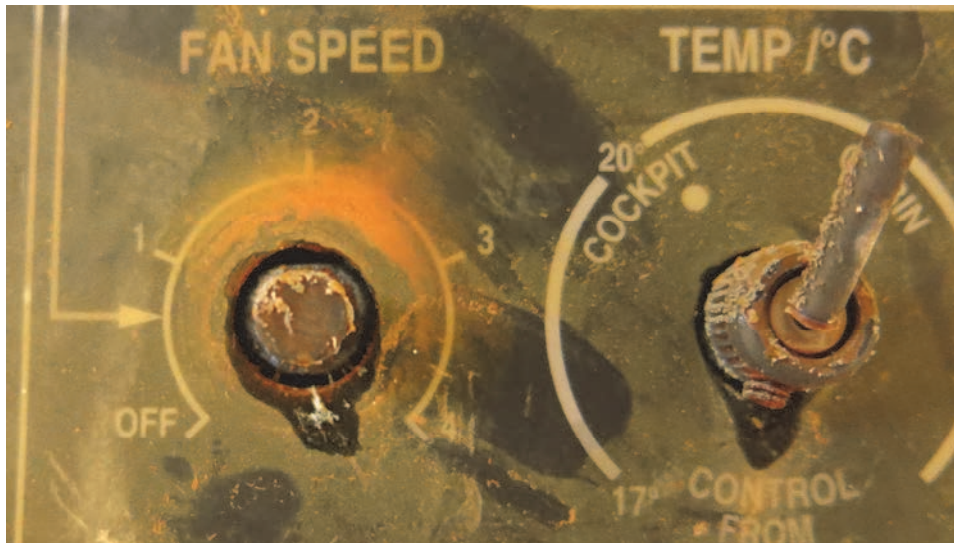


Figure 58. The photo shows the positions of the FAN SPEED and TEMP knobs.

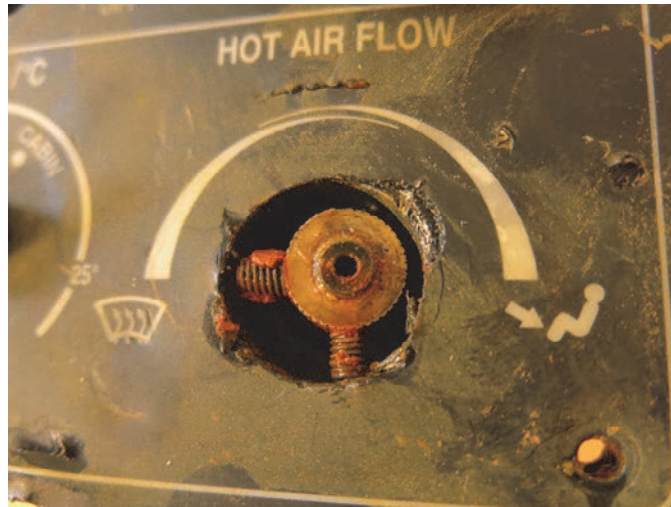


Figure 59. The HOT AIR FLOW knob was found with set screws at the 6 and 9 o'clock positions.

D.5.10 Pressure Transmitter

Figure 3, Item: unknown
Manufacturer: Intertechnique
Part Number: 452065
Serial Number: 36707130004
Manufacturing Date: 112013



Figure 60. Intertechnique pressure transmitter. Note: The wire is loosely attached to keep the switch from being lost.

This component was found loose in the wreckage.

D.5.11 Supplemental Oxygen System Containers

Two supplemental oxygen mask boxes from the cabin were found and in each were two connectors for oxygen and for a communication jack. (See Figure 61)



Figure 61. Right side supplemental oxygen mask box.

The similar boxes in an exemplar airplane were found to not have contained the oxygen masks. At the upper forward corner of each was a connection point for a cockpit oxygen mask and the orientation was such that the mass of the connectors would have been displaced forward in a forward deceleration at impact. (See Figure 62)



Figure 62. Left side cockpit mask connection box in an exemplar airplane. Forward in the airplane is to the right of the photo.

Note: The Pilot's Operating Handbook calls for donning the mask from the opposite side of the airplane, which is easier to reach than the mask immediately behind and above the head of each seat.

D.5.12 Supplemental Oxygen Switch

Manufacturer: Pacific Precision Products
Part Number: P21030-2
Serial Number: 0920
Manufacturing Date: 08/13

The oxygen switch was found in the closed position and did not pass air from one end to the other. As described in Section D3.2, this position prevents oxygen from reaching the oxygen masks. The valve was imaged with computerized tomography (CT), which identified foreign material against the poppet on the inlet side of the valve.



Figure 63. Supplemental oxygen switch. The scale at the bottom is marked in inches.



Figure 64. A switch installed in an exemplar airplane with the toggle in the OFF position. The view is from the copilot seat, so forward would be to the right of the photo.

Following removal of the fittings from each side, the interior of the passages were found filled with organic material associated with the ocean. The group found the switch to be in the closed position. Microscopic examination of the base of the toggle did not reveal impressions or other potential indications that the switch had previously been in any other position at impact.

D.5.13 Throttle Pedestal

The throttle pedestal was found with extensive damage consistent with impact. (See Figures 65 through 67) The power lever was at the feather gate, the flap switch full up, and the manual throttle over ride was found in the mid-portion of the range of travel.



Figure 65. Throttle quadrant position of power lever, manual over-ride, and missing pitch trim indicator.



Figure 66. Tearing and displacement of throttle quadrant axle.



Figure 67. Overall view of throttle quadrant.

D.6 Unrecovered Components

The following is a list of items sought in the recovered wreckage which were sought and not found in the recovered items. When available, the part acronyms and reference numbers shown in Figures 2 and 3 are shown in parenthesis.

Condenser (11)

Cockpit blown temperature sensor (23) (Note: Part of cooling system.)

Demisting Microswitch (24)

Mixing Ejector (MIXEJ, 28)

Bulkhead Non-Return Valve (29)

Cabin altitude alarm switch (34)

Stage 2.5 Bleed Non-Return Valve (NRV, 43)

Intermediate port pressure sensor (IPPS, 44)

Oxygen shutoff valve

Oxygen cylinder

Oxygen overboard discharge indicator

Oxygen high pressure gauge

Oxygen charging valve

Supplemental oxygen masks

D.7 Changes Resulting From Investigation

D.7.1 Service Bulletin SB 70-226

In October 2015 Daher Socata issued Temporary Revision Z00.DMHFM00EE1T18EN to the Pilot's Operating Handbook and issued Service Bulletin SB 70-226, titled "GAS CONTROLLER UPGRADE" on November 15, 2015. These changes address cessation of pressurization which may be created by detection of an open OTSW for more than 30 seconds, as well as a cabin inlet temperature sensor (ITS) fault. The three parts of the modification provided a revision to the GASC software, replacement of a cabin inlet temperature switch, and movement of a wire in an electrical connector.²³ The SB stated:

- A. PROBLEM
Pilot reports of inadequate cabin heating temperature regulation.
Recent increase of "Bleed Off" pilot reports.
- B. REASON
GAS system heat protections may cause a "Bleed Off" situation when maximum temperature demand is selected.
- C. SOLUTION
Upgrade the GAS controller to provide adequate heating temperature regulation and to reduce possible "Bleed Off" situations.

The changes resulted in the system no longer de-activating bleed air for GASC detection of an open OTSW switch circuit or for detection of an ITS fault when the airplane was already in flight. Cockpit annunciations remained unchanged.

D.7.2 Pilot's Operating Handbook (POH) Revision

Daher Socata issued Temporary Revision No. 18 (Z00.DMHFM00EE1T18EN), dated October 2015. The title of the POH revision was "Inadequate cabin heating temperature regulation and increase of BLEED OFF pilot reports." The reason given for the revision was "To upgrade the GAS controller to provide adequate heating temperature regulation and to reduce possible "Bleed Off" situations."

The revision replaced system description and procedural pages to show the changes resulting from the service bulletin.

Robert Swaim
National Resource Specialist
Aircraft Systems Engineering

²³ The SB 70-226-21 requirement to change the cabin inlet overtemperature switch (BTSW) relates only to airplanes not previously modified by SB 70-180-21, which was issued in Nov 2009.