



Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Report – 200403238 / 200404436

Final

**Abnormal airspeed indications
En route from/to Brisbane Qld
31 August 2004 / 9 November 2004
Bombardier Aerospace DHC8-315
VH-SBJ / VH-SBW**



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Abstract

In August and November 2004, two Bombardier DHC8-315 aircraft, VH-SBJ and VH-SBW, experienced similar abnormal airspeed indications during flight. At the time, both aircraft were being operated in instrument meteorological conditions in cloud and conditions conducive to icing. Examination of flight data recorder information suggested that the pitot heads had become blocked, most probably by ice, preventing air pressure being sensed by the instruments.

The investigation found that the aircraft maintenance manual contained inadequate guidance regarding the continued airworthiness of the pitot head and associated electrical system and that the Quick Reference Handbook for the DHC8-300 did not contain adequate guidance for the flight crew to resolve the abnormal operation of the aircraft systems.

Following the reported incidents, Bombardier, the manufacturer of the DHC8 series aircraft, published a service letter, DH8-SL-34-023. The service letter advised of new procedures regarding the maintenance of pitot head assemblies and associated electrical connectors.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the Transport Safety Investigation Act 2003 and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

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Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

#About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

EXECUTIVE SUMMARY

In August and November 2004, two Bombardier DHC8-315 (Dash 8) aircraft, VH-SBJ and VH-SBW, experienced similar abnormal airspeed indications during flight. At the time, both aircraft were being operated in instrument meteorological conditions (IMC) in cloud and conditions conducive to icing. Examination of flight data recorder information suggested that the pitot¹ heads had become blocked, most probably by ice, preventing air pressure being sensed by the instruments.

Engineering examination by the company of VH-SBJ did not reveal any defects, however, the electrical connector to the pitot head on the other aircraft, VH-SBW, was found to have a loose socket. In both cases, the pitot heads were replaced.

Following these incidents, during an engineering examination, it was discovered that a third DHC8-315, VH-SBI, had a problem with the pitot heater electrical connections. The sockets in the aircraft wiring connector showed evidence of the tines² expanding and one socket had suffered thermal stress. The solder joining the wire to the socket had melted and flowed from the joint.

The investigation found that for the two incident aircraft:

- The aircraft maintenance manual contained inadequate guidance regarding the continued airworthiness of the pitot head and associated electrical system.
- Although serviceable and selected ON, the electric pitot heating elements were not able to prevent the build up of ice over the pitot head.
- The Quick Reference Handbook for the DHC8-300 did not contain adequate guidance for the flight crew to resolve the abnormal operation of the aircraft systems.
- Control of the aircraft was assured by the crew maintaining an appropriate flight profile and power settings while fault finding the aircraft.
- Use of solder, other than that recommended by the pitot system manufacturer, lowered the tolerance to elevated temperatures of the soldered joint at the pitot heater electrical connector.

Following the reported incidents, Bombardier, the manufacturer of the DHC8 series aircraft, published a service letter, DH8-SL-34-023. The service letter advised of new procedures regarding the maintenance of pitot head assemblies and associated electrical connectors. The new procedures were also promulgated as revisions to the aircraft maintenance manual (AMM). Further information regarding the service letter is contained in section 1.6 and 4.1 of this report.

1 The basic pitot tube consists of a tube connected to an air speed indicator with the tube pointing directly into the air flow. The resultant pressure can be measured and displayed on the indicator as a speed unit. Dash 8 aircraft have two pitot tubes (see 1.4 below).

2 The electrical connector consisted of two tubular sockets mounted in an insulated housing. Each tubular socket was split part way down its length to form four tines, or prongs, which gripped the mating pins on the pitot head. An illustration can be found on page 21.

1 FACTUAL INFORMATION

1.1 Bombardier DHC8-315 VH-SBJ

1.1.1 History of the flight

On the 31 August 2004, Bombardier DHC8-315, VH-SBJ, was being operated on a scheduled passenger service from Brisbane to Rockhampton, Qld. The pilot in command reported the weather conditions as light turbulence and light rain with overcast cloud cover. The takeoff and climb was uneventful with normal radar vectors and level changes to intercept the Maroochydore track. The autopilot was engaged using indicated airspeed for vertical control (IAS Mode)³ and lateral navigation for tracking control (LNAV Mode)⁴. Anti Ice was selected ON by the crew at +10°C static air temperature. Shortly after, a loud noise was heard that appeared to come from an engine. Instrument panels and the cockpit were checked; all systems and instruments indicated as expected.

As the aircraft approached FL140, the autopilot and yaw damper disengaged without being commanded by the crew. The pilot in command acknowledged the associated aural warning and took manual control of the aircraft. The flight director advisory panel indicated the yaw damper and autopilot were disengaged, while a digital air data computer (DADC) invalid warning was also displayed.

After several attempts, the copilot was able to re-engage the yaw damper. When the crew attempted to re-engage the autopilot to maintain the climb, the aircraft entered a 1,000 ft/m descent. The pilot in command's airspeed indicator (ASI) indicated a lower than expected reading. The pilot in command asked the copilot for his airspeed indication and was advised it was indicating zero. Subsequently, the pilot in command's airspeed indication also fell to zero. However, altitude and vertical speed indications appeared to be reading correctly.

The crew then disengaged the autopilot to fly the aircraft manually. The pilot in command maintained a climb attitude of approximately 5° nose up, and climb power settings.

The crew checked all panels and system switching to confirm appropriate selection for the phase of flight. Quick reference handbook (QRH) checklist items were also carried out. Both alternate static systems were selected ON, but the crew's actions failed to restore normal airspeed indications. Examination of the QRH did not provide any procedures for fault finding a combined failure of the autopilot, yaw damper, DADC and both airspeed indicators.

Air traffic control was alerted and advised that the aircraft would be returning to Brisbane. The airspeed correlation checks continued and as the aircraft descended

3 IAS Mode is the use of the autopilot system to maintain a selected indicated airspeed as the reference parameter for vertical navigation, for example, 160 kts when an aircraft is climbing.

4 LNAV Mode is the use of the autopilot system to maintain a desired direction to a destination by using an electronic navigation aid as a reference for lateral navigation, for example, tracking toward a global positioning system (GPS) waypoint.

through about 2,000 ft, the pilot in command was able to confirm a correct airspeed indicator reading. A normal approach and landing was made.

Meteorological Information

Weather conditions forecast by the Bureau of Meteorology consisted of extensive mid-level cloud with patchy rain, freezing level between 7,000 to 9000 ft, and moderate icing present in cloud.

Heavy rain showers were observed by staff at Brisbane Airport when VH-SBJ departed.

1.1.2 Flight Recorder Information

VH-SBJ was fitted with a cockpit voice recorder (CVR) and a flight data recorder (FDR). The data from both recorders was downloaded by the ATSB. However, the CVR, which was capable of two hours recording, had been overwritten.

The flight data recorder installation was capable of recording 42 analogue parameters, such as airspeed, heading and altitude, and 52 discrete (on / off) parameters such as radio press-to-talk, autopilot and yaw damper status. A visual representation of the recorded data was plotted and included as figure 1 and 2. The x-axis indicates elapsed time in seconds and the y-axis indicates the recorded value of the displayed parameters.

Figure 1, a plot of the incident flight, shows that VH-SBJ became airborne at an elapsed time of 544 seconds and landed at 2,605 seconds giving a flight time of 34 minutes 21 seconds. The recorded data shows the coincident disengaging of the autopilot and yaw damper systems when the airspeed information was lost. The step change in recorded static air temperature was due to the loss of airspeed information.

The crew commented that as they had lost airspeed indications from both crew positions, control of the aircraft was assured by maintaining a climb attitude and climb power settings.

Figure 2 is a plot of the incident showing a reduced number of parameters and an expanded time scale. Figure 2 shows that between an elapsed time of 1,100 and 1,900, the computed airspeed trace can be seen to drop to zero for a short period then, as the aircraft continues to climb, increases until the aircraft begins to descend. As the aircraft descends, the computed airspeed value also decreases, reaching zero for a short period before rising rapidly to a normal value.

Figure 1: Plot of FDR data showing the incident flight

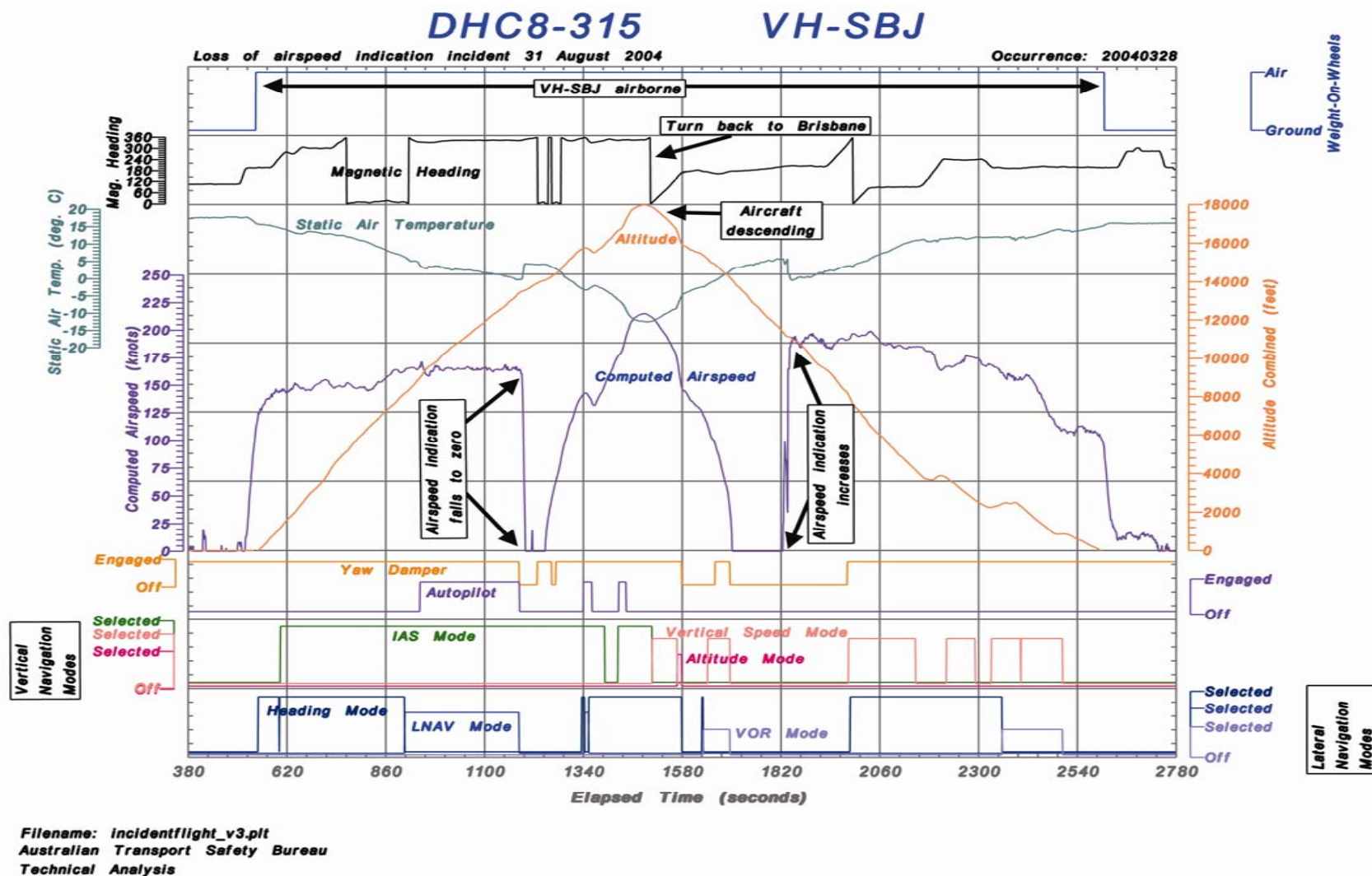
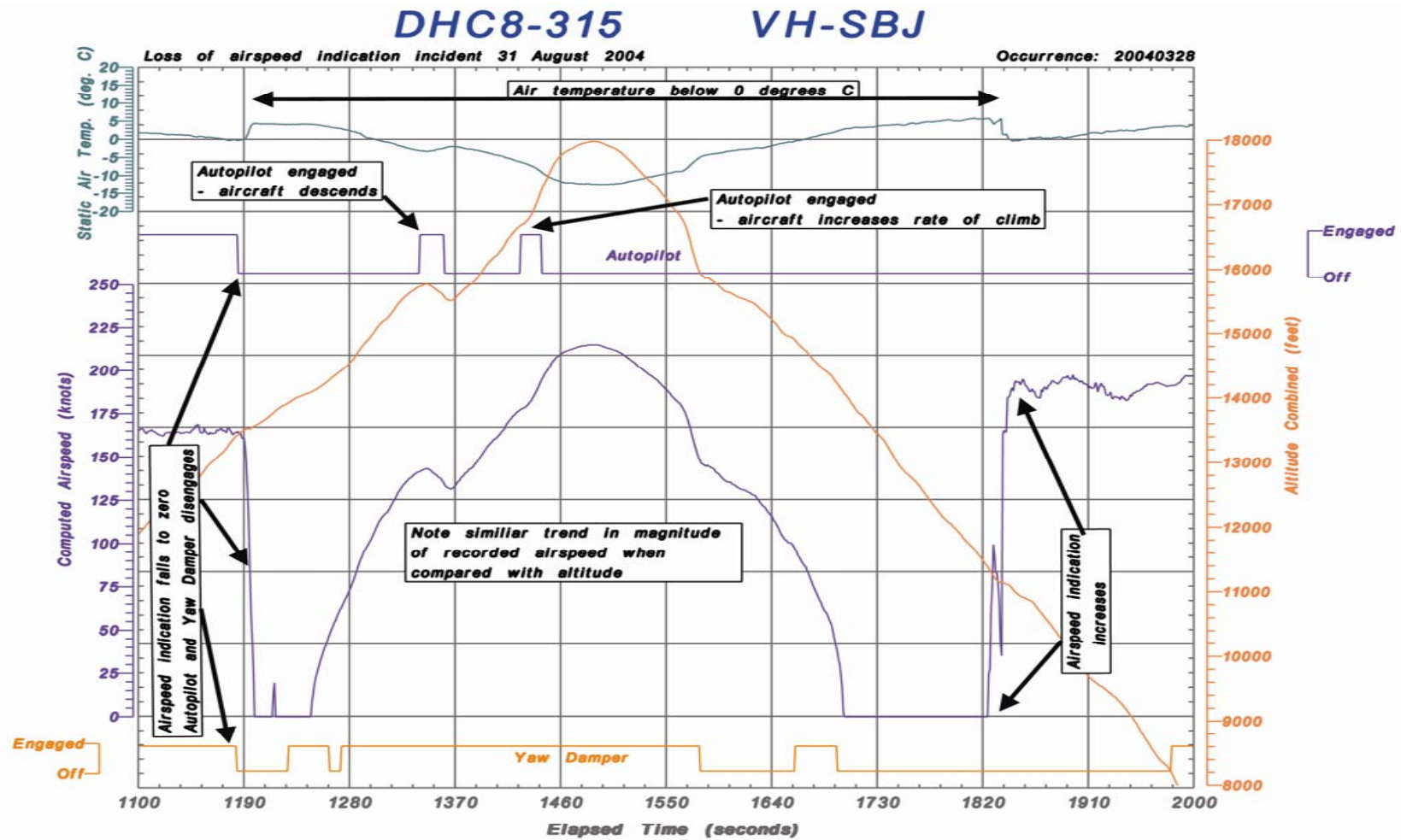


Figure 2: Plot of FDR data zoomed to show the airspeed anomaly



Filename: incidentflight_1_v3.plt
 Australian Transport Safety Bureau
 Technical Analysis

Sequence of events

Table 1: Recorded flight data from VH-SBJ relating to pertinent events

Elapsed Time (mm:ss after take off)	FDR Elapsed Time (seconds)	Event
00:00	544	VH-SBJ takes off from Brisbane Airport.
06:02	906	LH HSI selected, Autopilot engaged, vertical mode IAS, lateral mode LNAV, aircraft climbing through 9,000 ft
10:40	1184	Yaw Damper and Autopilot disengages, static air temperature (SAT) zero. Aircraft climbing through about 13,500 ft
10:56	1200	Computed Airspeed (CAS) indicates zero and SAT increases by 4°. Aircraft climb continues passing 13,572 ft
11:02	1216	CAS increased to 20 kts, altitude 13,778 ft , SAT 4.18 degrees
11:24	1228	Yaw Damper engaged
11:44	1248	CAS begins to increase from zero, Altitude 14,104 ft, SAT begins to decrease
11:59	1263	Yaw Damper disengages and is re-engaged after 10 sec
13:16	1340	Autopilot engaged, aircraft pitches down and begins to descend, CAS also reduces
13:36	1360	Autopilot disengages and climb is established
14:42	1426	Autopilot engaged aircraft pitches up and rate of climb increases, CAS also increases
15:00	1444	Autopilot disengages and remains off for the remainder of the flight
15:43	1487	Turn back to Brisbane initiated and descent from FL180 begins, propeller torque reduced to about 57%
17:15	1579	Yaw Damper disengages aircraft descending through about 15,900 ft, CAS also reducing
18:36	1660	Yaw Damper engaged
19:12	1696	Yaw Damper disengages
19:18	1702	CAS drops to zero, altitude 14,050 ft, SAT 2.9°
21:21	1825	CAS increases from zero, altitude about 11,300 ft
21:41	1845	CAS returns to normal 190 kts, altitude about 11,000 ft, SAT drops by about four degrees and begins to increase
23:58	1982	Yaw Damper engaged
34:21	2605	VH-SBJ touches down at Brisbane Airport

1.2 Bombardier DHC8-315 VH-SBW

1.2.1 History of the flight

On the 9 November 2004, Bombardier DHC8-315, VH-SBW, was being operated on a scheduled passenger service from Williamtown, NSW, to Brisbane, Qld, when an anomaly in the aircraft airspeed sensing equipment was experienced. The anomaly led to the disruption of other aircraft control systems, such as the yaw damper and autopilot.

The crew reported that during cruise at FL250, the copilot's airspeed indication fell to zero. The pilot in command's airspeed indications remained normal. Aircraft control was transferred to the pilot in command and the copilot consulted the QRH for information to restore a functioning system.

In accordance with QRH instructions, an alternate static source was selected. No improvement in system function occurred. The flight crew then initiated a precautionary descent to FL130. When established in the cruise, the copilot's airspeed indications slowly returned to normal. The flight continued to Brisbane without any further problems.

Meteorological Information

Conditions reported by flight crew included:

- 25,000 ft - air temperature -30°C, overcast cloud, light airframe icing
- 13,000 ft - air temperature -5 degrees C.

1.2.2 Flight Recorder Information

VH-SBW was also fitted with a CVR and an FDR. As the elapsed time following the incident was similar to the recorder capacity, the cockpit voice recorder was not examined for this occurrence.

Plots of FDR parameters relating to the incident are included as figures 3 and 4.

The recorded FDR information closely correlated with the flight crew report. The comment by the crew that the copilot's airspeed fell to zero, was confirmed by the FDR information. Airspeed values appeared normal after the left horizontal situation indicator (HSI) source was selected; control of the aircraft and systems being transferred to the pilot in command. The selection of the HSI also transfers the source of DADC information that is recorded by the FDR.

Figure 3: FDR information relating to flight from Williamtown NSW to Brisbane Qld

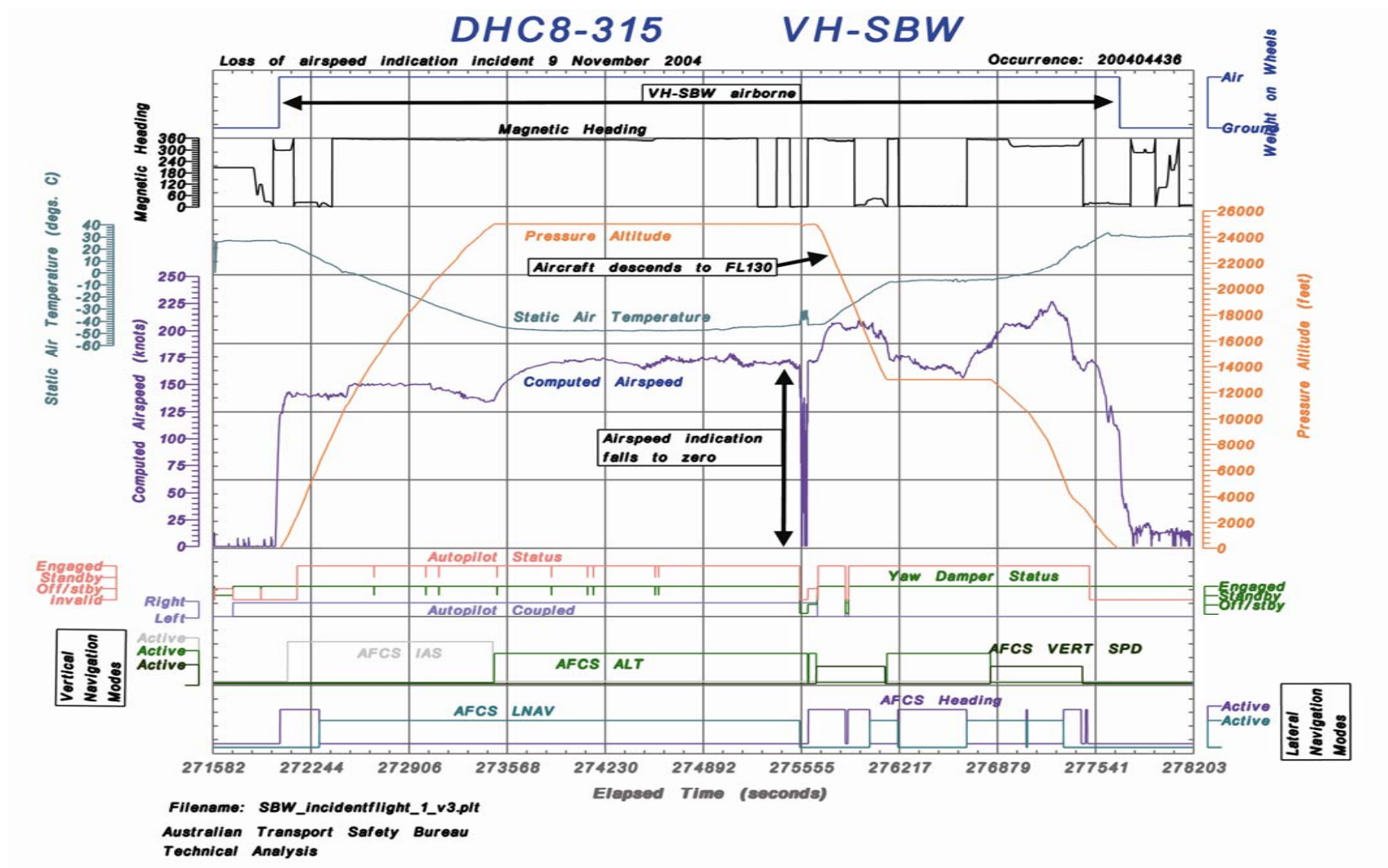
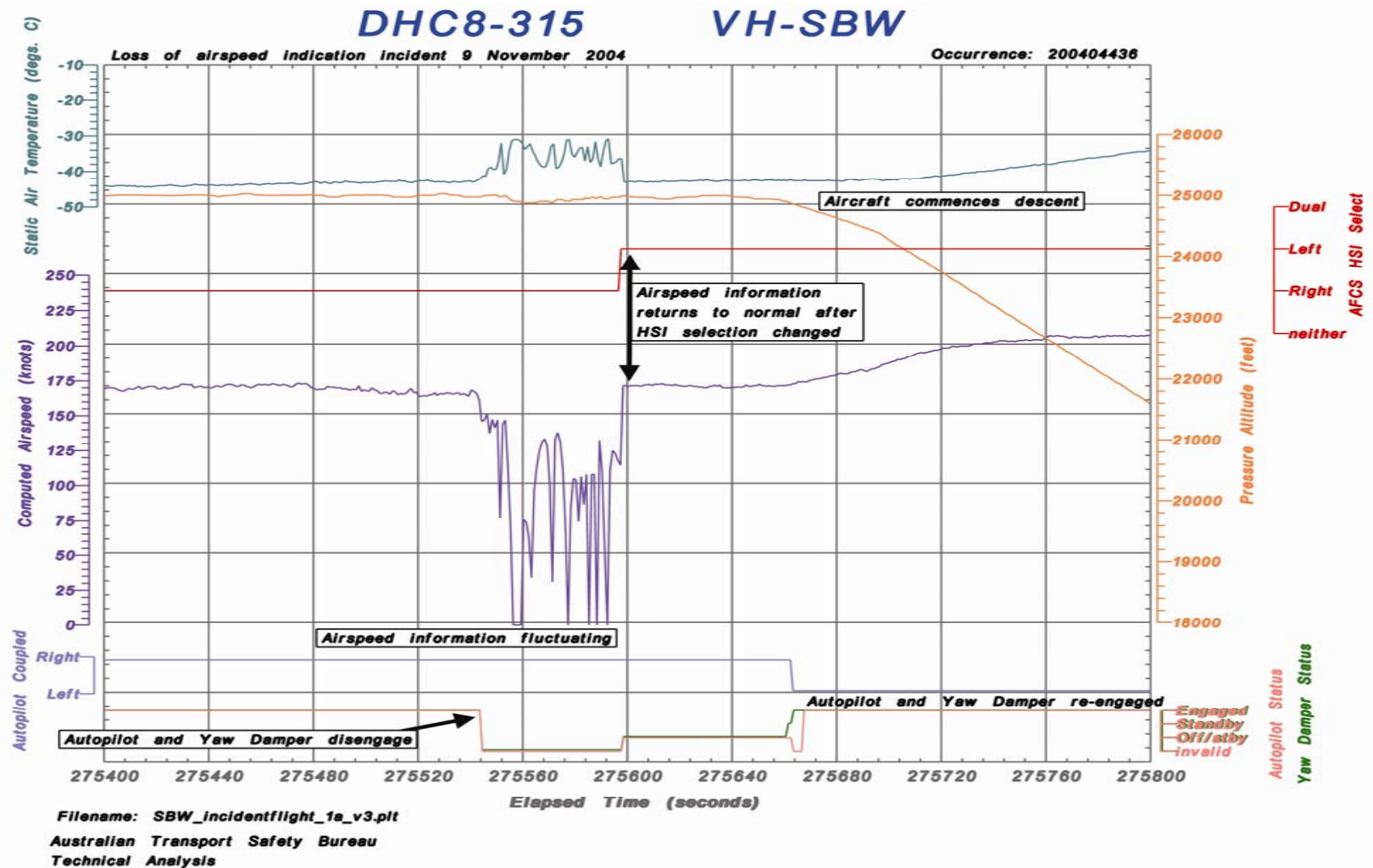


Figure 4: FDR information relating to incident



Sequence of events

Table 2: Recorded flight data from VH-SBW relating to pertinent events

Elapsed Time (mm:ss after take off)	FDR Elapsed Time (seconds)	Event
00:00	272028	VH-SBW takes off from Williamtown Airport.
06:02	272150	Right Autopilot engaged, DADC 2 selected, vertical mode IAS, lateral mode HDG, aircraft climbing through 2,500 ft
10:40	273471	Aircraft reaches top of climb and levels at FL250, Autopilot engaged, vertical mode ALT, lateral mode LNAV
10:56	275478	Cruise at FL250, CAS about 170 kts, SAT varies from -47 to -43 degrees, vertical mode ALT, lateral mode LNAV
11:24	275544	Computed Airspeed (CAS) begins to drop, Yaw Damper and Autopilot disengages and records invalid status
11:42	275556 to 275597	Computed Airspeed (CAS) indicates zero then fluctuates from 0 to 138 kts, SAT fluctuates between -31 to -39 degrees
11:59	275598	DADC switched to DADC 1, CAS and SAT records normal values
	275655	AFCS vertical mode IAS
12:09	275661	Aircraft begins descent , Yaw Damper standby
13:16	275663	Yaw Damper engaged, Autopilot invalid, left Autopilot coupled
13:36	275667	Aircraft on descent passing FL248 ft, Autopilot engaged, lateral mode HDG
14:42	275851	Aircraft on descent passing FL270 Master Caution warning, Yaw Damper and Autopilot invalid, right Autopilot coupled
15:00	275854	Master Caution warning ceases
15:46	273873	Aircraft on descent passing FL197, left Autopilot coupled, Yaw Damper engaged Autopilot invalid
17:15	275874	Autopilot engaged
18:36	276132	Aircraft established at FL130
19:12	276838	Aircraft begins descent from FL130
34:21	277704	VH-SBW touches down at Brisbane Airport

1.3 DHC8-300 Airplane Flight (Operations) Manual and Quick Reference Handbook procedures

1.3.1 Operation of the pitot static heat system

Section 3.16 of the Operations Manual, relating to operation in icing conditions, states that:

Conditions for icing exist when the static air temperature (SAT) on the ground and for takeoff is +10°C or below, or SAT in flight is +5°C or below, and visible moisture in any form is present (such as clouds, fog with visibility of 2km or less, rain, snow, sleet, or ice crystals).

Bombardier QRH checklist items required the pitot heat to be selected ON prior to the aircraft commencing taxi, irrespective of icing conditions being present or not. However, the Bombardier Aircraft Flight Manual (AFM) required the pitot heat to be selected ON prior to the aircraft commencing taxi, if the taxiways were covered with slush or wet snow.

The operator's checklist items differ from the manufacturer's in that it only requires the pitot heat to be selected ON during line-up checks in conditions where the SAT is less than +10°C. The purpose of this requirement is to try to minimise stress to the pitot heating element due to the high temperatures that can be experienced on the tarmac when no cooling airflow is available. Correct operation of the pitot heat system is verified by the pre take-off checklist requiring the caution panel be visually checked clear of abnormal indications. This action checks that the caution light for each pitot head is not illuminated. The caution light illuminates when pitot heat is selected OFF, or if the current drawn by the respective pitot head falls below a certain value which provides an indication of the heater element integrity.

The flight crew involved in each incident reported there was no indication that the pitot static heat system was not functioning normally.

1.3.2 QRH actions regarding abnormal system operation

Operator's QRH

Note: The following extracts from the QRH are formatted similar to those in the QRH.

Section 4 contained guidance material relating to *Autoflight, Flight Instruments and Navigation systems*. Page 4.06 contained the following guidance:

ABNORMAL INDICATIONS OF AIRSPEED, ALTITUDE AND	
STATIC SOURCE SELECTOR (affected side)	ALTERNATE

Section 11 contained guidance material relating to *Ice and Rain Protection*. Page 11.06 contained the following guidance:

ABNORMAL INDICATIONS OF AIRSPEED, ALTITUDE AND VERTICAL SPEED
STATIC SOURCE SELECTOR (affected side) ALTERNATE IF switching the STATIC SOURCE selector to ALTERNATE does not correct the abnormal indications, rely on the instruments on the opposite side

Bombardier QRH

Section 6 contained guidance material relating to *Autoflight, Flight Instruments and Navigation systems*. Page 6.5 contained the following guidance:

ABNORMAL INDICATIONS OF AIRSPEED, ALTITUDE AND VERTICAL SPEED
• Static Source Selector (affected side) Alternate IF switching the Static Source selector to Alternate does not correct the abnormal indications: -Rely on the flight instruments on the opposite side

Section 13 contained guidance material relating to *Ice and Rain Protection*. Page 6.5 contained the following guidance:

ABNORMAL INDICATIONS OF AIRSPEED, ALTITUDE AND VERTICAL SPEED
• Static Source Selector (affected side) Alternate IF switching the Static Source selector to Alternate does not correct the abnormal indications: -Rely on the flight instruments on the opposite side

In both incidents, the flight crew reported referring to the operator's QRH for guidance and actioned the checklist items. However, the checklist actions did not resolve the problems that the crew encountered.

1.4 DHC8-300 pitot static systems

Pitot static system operation

To provide for safe operation of an aircraft, flight crew need to be provided information relating to altitude and airspeed. Altitude is useful to accurately

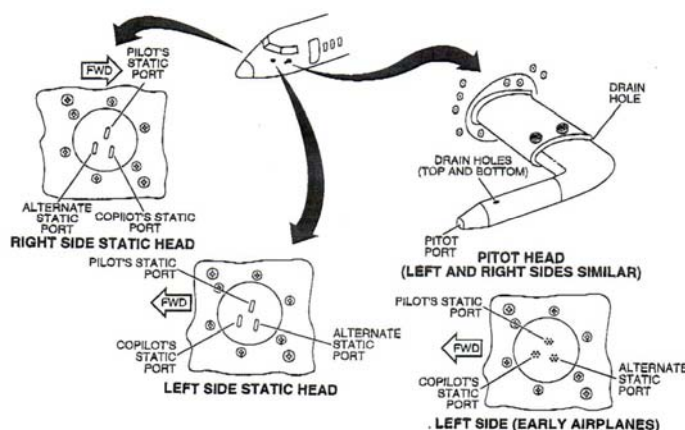
determine distance from the ground and vertical separation from obstacles. Altitude is directly proportional to the local pressure of the air mass an aircraft is travelling through, known as the static pressure. Airspeed is useful to determine an aircraft's ability to maintain flight. By providing the crew with information relating to the speed the wing is passing through the air, the amount of lift generated by the wing can be determined and hence the aircraft's ability to remain airborne. Airspeed is sensed through a pitot head aligned in the direction of flight and is proportional to the pressure of the aircraft's motion through the air, impact pressure plus static pressure. When an aircraft is parked or motionless the airspeed will be zero as the pitot and static pressures are equal.

Pitot and static head location and connection

The static head consists of a plate, flush mounted to the aircraft skin, with ports (or holes) that allow instruments access to the ambient air pressure. Two static heads are fitted to the DHC-8, one located each side of the aircraft nose, see figure 5. Each head has three ports⁵ which are connected to the pilot's and copilot's instruments, figure 6 shows the connections.

The pitot head is a tube with a knife edge orifice facing in the direction of flight. Two pitot heads are fitted to the DHC-8, one for each pilot's instruments, and are located each side of the aircraft nose, see figure 5. Each pitot head is connected to the respective pilot's instruments and cannot be switched between pilot in command and copilot. Figure 6 shows the connections.

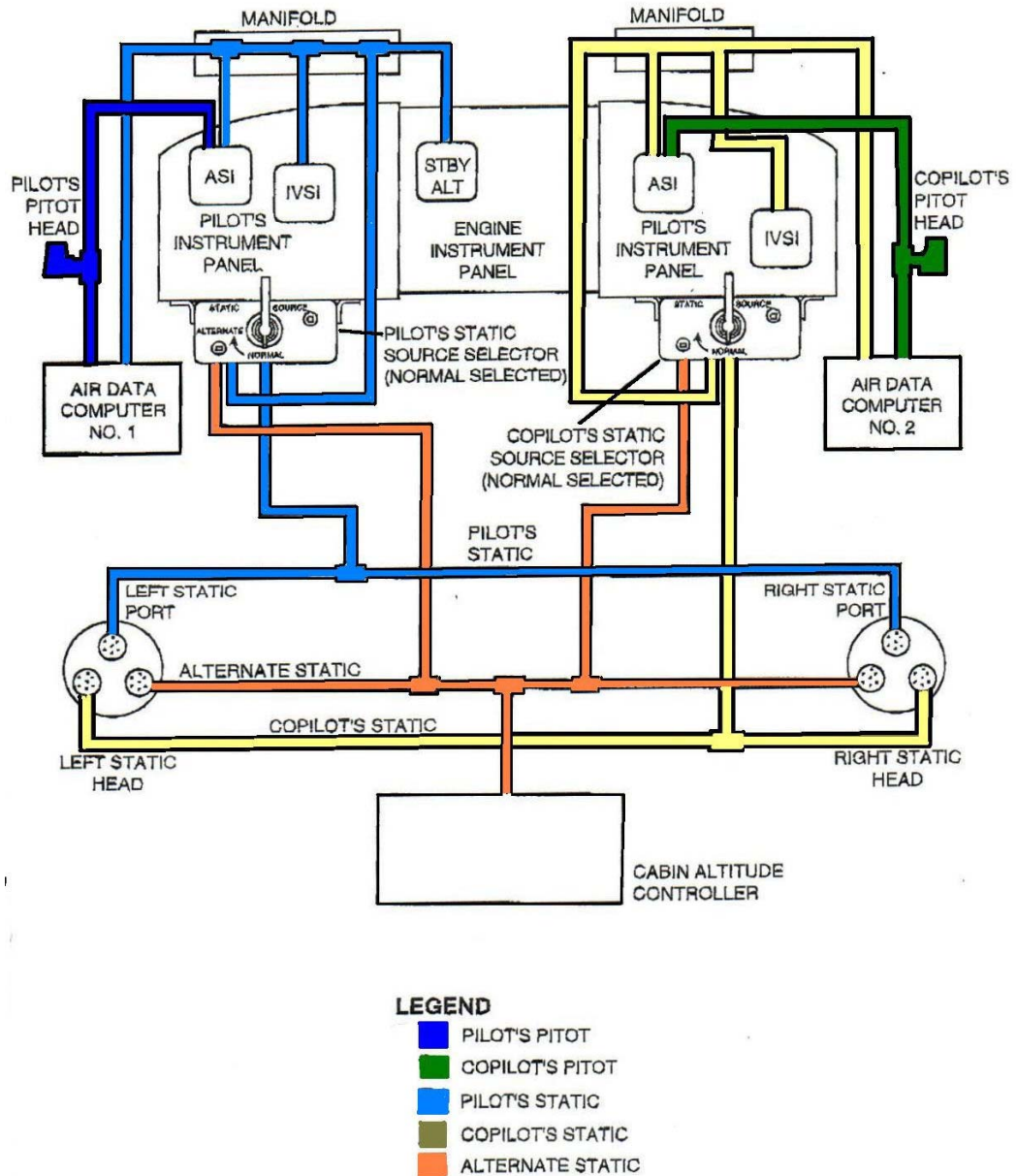
Figure 5: Location of pitot and static heads



⁵ The three individual ports on the left and right static heads are connected together, making three static sources available. One static source is dedicated to each respective pilot's normal static system. Should a problem occur with a pilot's normal static source, a third or alternate, static source can be selected.

Figure 6 shows the interconnection of the pitot and static system fitted to the DHC-8. It can be seen that the pitot head is dedicated to the instruments utilised at a flight crew position and cannot be switched. The static system has two ports available to each flight crew and is controlled via selection of a *normal* port or an *alternate* port.

Figure 6: Pitot and static system configuration

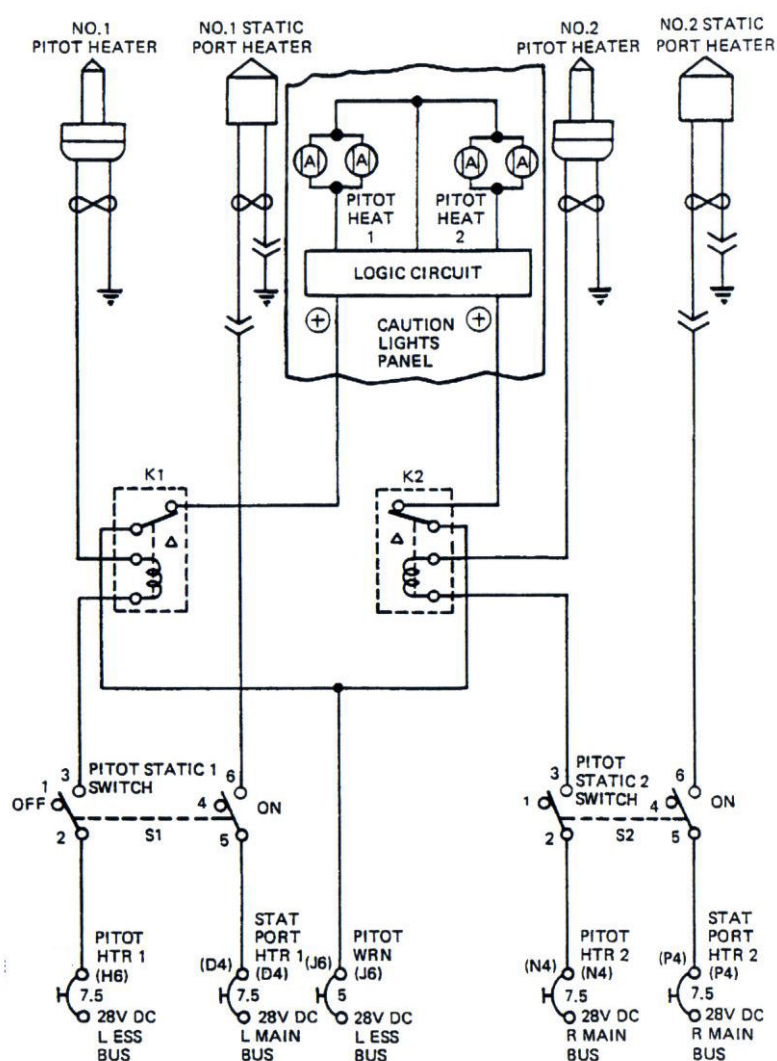


Pitot and static head heating system

Both the pitot and static heads are fitted with an electrically powered heating element to minimise the effect of ice build up that may block the ports when the aircraft is being operated in moist cold conditions. Each pitot and static head heater is powered by 28V direct current (d.c.) with the pilot's pitot and static head being powered from the left essential buss and the copilot's powered from the right essential buss, see figure 7.

The crew is alerted to the heaters being turned off with a light for each respective system being illuminated. If the pitot heating system is turned on and a heating element fails, the corresponding warning light will also illuminate.

Figure 7: Pitot Static heating system schematic



1.5 Operator's engineering Investigation

Following the incidents involving abnormal airspeed indications, the operator examined and conducted tests of the pitot heat system fitted to the aircraft in accordance with the manufacturer's instructions.

Engineering examination of VH-SBJ, DHC8-315 c/n 578

No fault in the pitot heat system could be identified during examination and tests of the aircraft following the incident. Inspections were carried out in accordance with the aircraft maintenance instructions. However, both pitot heads were replaced as a precaution and the aircraft was returned to service following a satisfactory test flight.

Engineering examination of VH-SBW, DHC8-315 c/n 599

The copilot's pitot head was checked and a loose pin in the heater element connector was found. When the heater plug was dismantled, the connecting pins were found to be a loose fit to the heater pins. The heater pins were tightened and the plug was reassembled. The pitot head was changed and checked for leaks before being return to service. The pilot in command's pitot system was serviced in accordance with DHC8 maintenance manual, section 34-11.

Engineering examination of VH-SBI, DHC8-315 c/n 605

On 8 November 2004, DHC8-315, VH-SBI, which had been recently delivered to the operator, developed abnormal indications of the pitot heat system. Evidence was found that solder had been melting and re-solidifying in the solder joint between the wiring and the heater element electrical sockets, see figure 8 and 9.

Figure 8: Photograph of electrical sockets fitted to VH-SBI (note - globule of solder and discolouration seen on socket attached to blue wire)

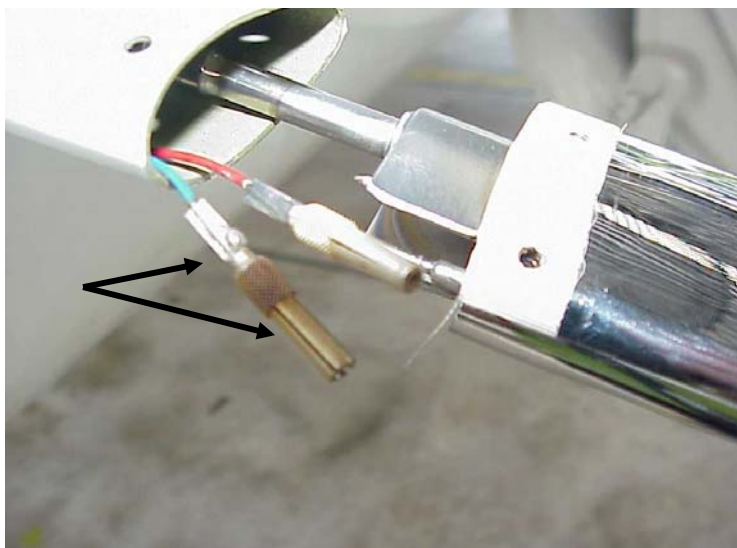
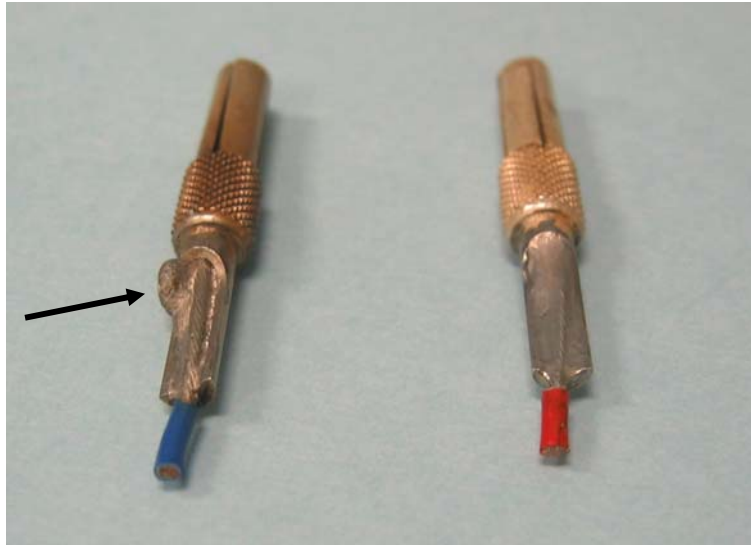


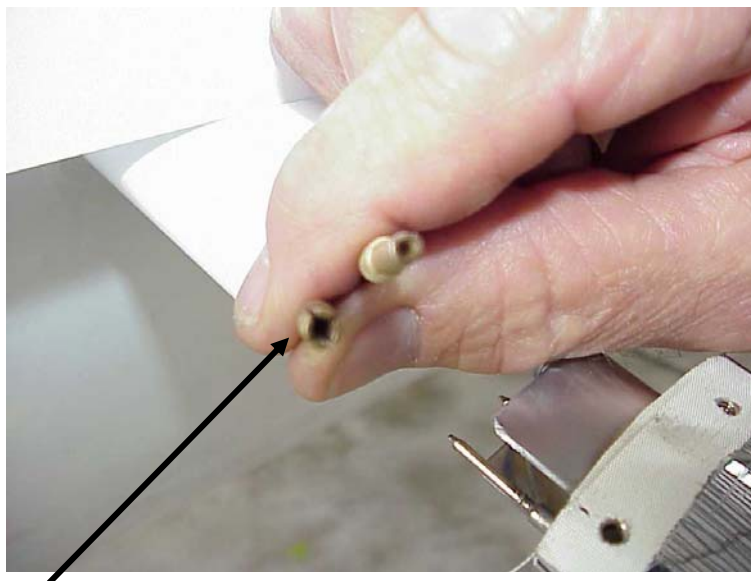
Figure 9 **Photograph of connector pins solder joint**



An examination of the solder present on the electrical sockets showed that it was a tin-lead alloy with no silver present.

The tines on the electrical heater element socket connected to the blue wire had become discoloured and splayed, preventing them from gripping the mating pin firmly, see figure 10.

Figure 10: Photograph of tines of electrical socket fitted to VH-SBI.



Note: Figure 11 includes further detail regarding the electrical socket.

DHC8 pitot electrical system tests by operator

Subsequent to the return-to-service of the affected aircraft, the operator conducted further tests of the pitot heat system. The tests were intended to ascertain if the aircraft wiring was capable of carrying sufficient electrical energy to allow the pitot head heater element to develop the specified rated power.

Three aircraft from the operator's fleet, VH-TNU, VH-SDA and VH-SBJ, were tested by substituting a 150 watt (W) taxi lamp as a substitute for the pitot heater. The open circuit voltage at the connections to the heater element was measured. The taxi lamp was turned on and left for 30 minutes to allow the wiring system to attain a stable operating state, and the voltage at the connections were measured again. A check of the 'firm fit' of pin-to-socket connection of the pitot heater connections was carried out prior to the test. The electrical supply was provided by a regulated ground power source that maintained a constant voltage and current to the aircraft systems throughout the test.

The results from the tests showed the three aircraft exhibited similar characteristics. The measured open circuit voltage averaged about 27V and the voltage when the lamp had been on, drawing about 5A, averaged about 23V. This resulted in the power available to the pitot heater element averaging about 115W. The pitot head heater is specified as having a rated power consumption of 125W at 28V direct current (d.c.), a calculated current draw of about 4.5A.

It was reported that the wiring fitted to the DHC8-100/200/300 series aircraft for the pitot heater element is 20 American wire gauge, (AWG), and the length of the conductor is about 40 ft long.

FAA guidance material relating to aircraft electrical systems is contained in maintenance advisory circular AC 43-13, Acceptable Methods, Techniques, and Practices – aircraft inspection and repair. AC43-13 chapter 11 relates to aircraft electrical systems and contains guidance material relating to the maximum voltage drop and wire gauge versus current carrying capacity. Table 11-6 of chapter 11 indicates that the allowable voltage drop, between bus and utilization equipment ground, for continuous operation at 28V d.c. is 1V. Figure 11-2 is a chart showing the relationship between wire gauge, conductor length, allowable voltage drop and current carrying capacity for continuous operation at 20°C for tin plated MIL-W-22759 wire. A direct interpolation of 20AWG conductor with a length of 40 ft provides a recommended maximum operating current of about 2.5A.

The pitot head manufacturer recommends MIL-W-22759/1 wire and indicates the PH1100-1-DH heater will draw approximately 5A. Figure 11-2 indicates that 20AWG, MIL-W-22759/1, wire drawing a constant current of 5A could be about 23 ft long and meet the allowable voltage drop.

Pitot head manufacturers installation and maintenance instructions

During the investigation, the ATSB requested a datasheet for the model PH-1100-1-DH pitot head from Aero Instruments, the manufacturer of the pitot head. In particular, details relating to the anti-ice heating elements and provisions for the venting of water vapour or draining of moisture were requested. Aero Instruments provided data sheets which showed the physical construction of the head, including detail of moisture drain holes.

Aero Instruments also provided instructions relating to the installation and operation of the pitot head. Included were instructions regarding the installation of the pitot head heater connections using lead-silver solder to join the wires to the connector sockets and a note to make sure the electrical receptacle is securely in place when fitted to the pitot head. Also recommended was the use of a 10 ampere (A) circuit breaker or 'slow-blow' fuse to allow for power to draw under icing conditions.

The heater element has a positive temperature co-efficient, that is, the electrical resistance increases as the temperature of the element increases. Tests carried out by the manufacturer would indicate that the heater element requires about 3.9A at 28V d.c. (109W) to operate at about 500°C, after being turned on for about 20 minutes in air with an ambient temperature of 26°C. However, if the head was being subjected to a cooling environment that limited the temperature to about 400°C, then the heater would require about 4.5A (126W). The greater the cooling of the pitot head, the higher the current demand.

Detailed instructions regarding periodic maintenance included physical examination of the pitot tube for mechanical damage, ensuring that the drain holes are not blocked or enlarged beyond 0.050 inches, ensuring that the intake opening is round with the intake lip dimension to be between 0.020 inches and 0.030 inches, and cleaning the pitot tube with air pressure (after disconnecting from instrument lines). A thorough cleaning of the spigot from which the pressure tube and electrical connections protrude was also recommended. A note was made to remove any corrosion, dirt or moisture to prevent short circuiting of the heating element. It was also noted by the manufacturer that the pitot tubes can break down due to high heat and salt air corrosion.

The silver-lead solder specified was an alloy consisting of 63% silver and 37% lead which has a solidus temperature of 304°C and a liquidus temperature of 380°C⁶. Whereas a tin-lead solder alloy consisting of 60% tin and 40% lead, commonly called 60/40 solder, has a solidus temperature of 183°C and a liquidus temperature of 191°C.

A test by Aero Instruments to document the power consumption and temperatures generated by the pitot heater, was made in an environmental chamber to simulate freezing conditions and then moved into a room to simulate general ambient conditions. The temperature probes attached to the pitot head indicated that the

⁶ The solidus temperature is the temperature where the alloy freezes or becomes completely solid. The liquidus temperature is the temperature where the alloy is completely liquid. The alloy is partially molten, or pasty, over the temperature range from solidus to liquidus. Mechanical movement while the solder alloy is partially molten, and exposed to air, can result in high resistance joints. (Metals Handbook, Volume 6, Welding, Brazing and Soldering)

electrical connectors could experience temperatures greater than 150°C when the pitot head was operated at temperatures of around 27°C.

Subsequent discussions with the operator regarding their electrical testing, indicated that Aero Instruments' maintenance instructions were not reflected in the aircraft manufacturer's instructions. The pitot head manufacturer's instructions were passed to the operator on 22 October 2004.

1.6 Bombardier experience and advice

Pitot heat anomalies due to electrical arcing at connector

In September 2004, Bombardier advised that they were aware of two similar events where dual abnormal airspeed indicator fluctuations occurred.

These events were reported to have occurred in 1998. The affected aircraft flew through severe weather within minutes of each other. After investigation by the manufacturer, findings were made detailing a number of circumstances in which the pitot heater electrical pins may have been shorted to ground, therefore compromising the performance of the heating element. Bombardier stated:

Primarily, the investigation, by Bombardier, revealed that water ingress [had occurred] into the pitot heater electrical connector. This moisture ingress most likely occurred through the pitot mast section, due to the absence of weather sealing around the pitot head to aircraft mast joint.

In addition, an intermittent short circuit to the heating element may have been induced during the installation of the pitot head into the aircraft mast. It was found that, if installed without the lock washers, there was a possibility that the forward mounting screws could come in close proximity to the forward heating element electrical contact. The close proximity in conjunction with ingress of water, could lead to intermittent shorting of the heater element connections. This would cause the heater to become ineffective, until the water was displaced.

The same scenario could occur if the pitot was not installed in accordance with aircraft maintenance manual (AMM) 34-11-11 where it states; wrap glass cloth insulating tape around the pitot head at entry to mast as necessary to give snug fit. If the glass cloth was absent it would also cause the mounting screw to come into close proximity to the heater electrical connection, and allow a much greater amount of water ingress into the area where the connector and screw are located.

Bombardier also offered the following:

In consideration of the issues as described above Sunstate may wish to consider the following for compliance:

Ensure that all pitot tube installations use the proper glass cloth insulating tape (as per AMM 34-11-11) so that the tube is properly sealed and minimizes water ingress.

Ensure that the pitot tubes are installed in the mast using the correct hardware, and that the weather sealant specification DSC233-1 has been applied to the joint between the tube and the mast.

Ensure that the tubes are in serviceable condition, and an inspection interval is set up that is compatible with Sunstate's operating environment to preclude the physical degradation of the pitot tube. If there is evidence of loose particles in the heater head (just inside the intake) consideration should be given to changing the pitot tube at the next available opportunity.

Solder used in the wiring connection to the pitot heater

Correspondence from Bombardier in relation to the wiring connection, stated that 'the de Havilland Electrical Shop had used Kester 60/40 tin lead solder for joining the aircraft wiring to the pitot head heater sockets with no reported problems'.

However, Bombardier also added that 'the pitot head vendor specified lead-silver solder would have the advantage of a higher melting point'.

Service Letter regarding new procedures to address loss of airspeed indication

On 6 September 2006, Bombardier published Service Letter, DH8-SL-34-023, applicable to DHC8 series 100, 200, 300 regarding 'Loss of Airspeed Indication'.

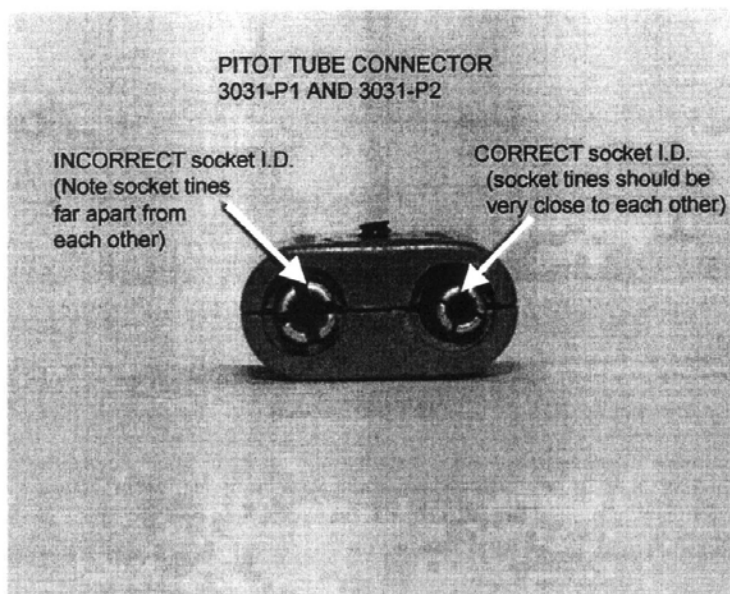
The purpose of the service letter was to inform operators of airspeed loss events and new procedures to address this condition.

A recent incident occurred where the pilot reported a loss of airspeed indication without the illumination of the Pitot tube caution light. Maintenance checks on the copilot's probe revealed a poor electrical connection in the pitot heat circuit at the pitot head. The copilot's connector socket tines were spread open (see figure 1) and not firmly grasping the mating connector pins on the pitot tube. With vibration, the excessive play results in arcing, which further worsens the situation. In severe cases, the arcing can lead to over heating, which results in melted solder at the aircraft wiring connector. When this occurs the solder can melt and re-solidify various times resulting in a "cold solder" joint. A "cold solder" joint is a poor conductor of electricity and can act as a resistor. When this occurs, it will prevent sufficient power from reaching the pitot tube heater, resulting in pitot tube icing.

The figure referred to in the quotation above, and corrective actions, are contained in Figure 11.

Figure 11: Page 2 of Bombardier Service Letter, DH8-SL-34-023

FIG 1



OPERATOR ACTION:

To ensure the integrity of the wiring between the pitot tube and the electrical connector, Operators may wish to consider incorporating the following actions:

1. Ensure all maintenance personnel are aware of the new Pitot Tube Removal and Replacement procedures, AMM ref; Q200 (TR34-030), Q100/300 chp. 34-11-11, The revised procedures includes the following.
 - a. Inspect for the pitot tube connector sockets for any sign of arcing and replace if necessary.
 - b. Inspect the pins for enlarged socket Inside diameter (ID) (Use Fig 1 above as typical example).
2. Remove the pitot tube and check for signs of thermal stress on the electrical connector and pins as described on the revised AMM chapter at the next maintenance opportunity.
3. Inspect the pitot tube for any signs of erosion and deformation due to damage and replace and necessary. Please refer to Q200 (TR34-029), Q100 chp. 34-11-02, Q300 chp 34-11-01 for erosion limits.

2.1 Operation of the pitot heat

In accordance with standard operating procedures, the pitot heat system is selected on prior to takeoff. The status of the pitot heaters are indicated to the flight crew by lights that illuminate if a pitot heater is switched off or becomes an open circuit.

In both occurrences, the crew had not reported any abnormal indication regarding the selection or in-flight operation of the pitot heat system and there was no evidence to suggest that the pitot heat was not selected on and electrical power was not being supplied.

2.2 Airspeed indication anomalies

Flight recorder indications

The flight data recorder (FDR) information for both aircraft showed the recorded airspeed dropping to zero over a short period of time. The characteristic of the airspeed dropping to zero indicates the pitot port was being reduced until becoming completely blocked, while the trapped air under pressure was able to leak down through the drain holes. When the orifice was completely blocked, the pitot head sensed the ambient, or static, pressure via the drain holes located at the top and bottom of the pitot head.

The airspeed information recorded by VH-SBJ showed that, after a period of time at zero, the airspeed began to rise as the aircraft continued to climb. The airspeed indicating system was sensing the difference in pressure between the reducing air pressure, as the aircraft climbed, and a trapped parcel of air in the pitot system. This indicates that the blockage had spread back to cover the pitot head drain holes. It was significant that in the case of VH-SBJ, both airspeed indicating systems were rendered unserviceable and that the crew assured safe flight was maintained by adopting an attitude and engine power setting suitable for climb.

The airspeed information recorded by VH-SBW showed that, after dropping from about 170 kts down to zero, the airspeed began to rise and fluctuated between zero and about 140 kts. During this time, the aircraft was maintaining a steady altitude in cruise. This would indicate that the pitot port was alternating between clearing and blocking. Throughout the event, the pilot in command's airspeed indication remained normal. In this case, the crew opted to descend to a lower altitude which would benefit aircraft flight performance and also provide the possibility of reduced icing conditions.

At all times during the events, recorded altitude information showed normal expected values relating to the reported flight profile of the aircraft. This indicates that the anomaly was related to the pitot pressure sensing systems only.

Sunstate QRH action items relating to abnormal airspeed indication, instructed crews to change selection of the static source to an alternate source for the affected system. This action would only affect the operation of the static pressure sensing system (static source).

The further guidance provided in the section 11 of the Sunstate QRH would have assisted the crew of VH-SBW, however the crew of VH-SBJ were faced with a dual airspeed indication failure.

Aircraft system indications

Both incidents were very similar regarding how the airspeed anomaly affected the aircraft operating systems. The first indication to the crew that a problem was occurring was the simultaneous disengagement of the yaw damper and autopilot systems. It then took over 15 seconds for the airspeed to drop to zero. Although the loss of airspeed information was the root cause of the system anomaly, the aircraft caution panel indications, yaw damper OFF and air data computer FAIL, would have presented the crews with indications of multiple system failures.

Automatic flight guidance modes selected prior to the event were also cancelled by the disengagement of the various aircraft systems.

The QRH checklist relating to abnormal airspeed indication, did not contain any guidance regarding the effect of loss of airspeed indication on other systems.

Quick Reference Handbook (QRH) guidance

The QRH is intended to be a concise reference of standard operating procedures designed to provide detailed guidance for both normal and abnormal operations.

Standard operating procedures (SOP's) are typically defined by the aircraft manufacturers or operators and prescribe much of the work performed on the flight deck. However, actual work performed is an integration of the resources provided by SOP's with the expert decision making of flight crew⁷.

Therefore, the content of a QRH should be a resource that complements flight crew knowledge and aids decision making by providing information that:

- is easily accessed
- is relevant to the situation
- contains warnings to prevent increasing hazards
- contains enough detail to provide a solution
- references other flight crew actions or sections of the QRH that may be relevant.

In this case, the flight crew of both aircraft consulted the QRH extensively and were still unable to resolve the abnormal indications, and apparent multiple systems failures, resulting from the pitot system problem.

⁷ Peter Wright P, Pocock S and Fields B *The prescription and practice of work on the flight deck* University of York 1998

2.3

Installation and maintenance of the pitot heating system

Maintenance of the pitot head

The FDR information showed that the pitot system had become blocked almost coincident with the static air temperature dropping below freezing. The airspeed recovered as the temperature rose above freezing. Post-incident maintenance did not detect any failure of the pitot heater system but highlighted the lack of guidance in the aircraft maintenance manual regarding appropriate maintenance of the pitot head and associated heating system.

Through investigation of several incidents where pitot icing had been identified, Bombardier provided advice regarding the possible failure modes of the pitot heater system. The post-incident maintenance performed on VH-SBJ did not detect evidence of electrical arcing as described in that advice.

Bombardier service letter, DH8-SL-34-023, provides notification of amendments to the aircraft maintenance manual. The amendments incorporated maintenance practices recommended by the pitot head manufacturer.

The maintenance actions described in the service letter address the issues relating to the airspeed anomaly experienced by VH-SBW and the damaged electrical connections found in VH-SBI.

Solder used to join wires to heater element pins

Bombardier Service Letter, DH8-SL-34-023, also appears to address the issues raised by the molten solder discovered in the pitot heater connector installed on VH-SBI.

The lack of reported problems would indicate that the use of tin-lead solder, with a lower solidus / liquidus temperature range than the silver-lead solder recommended by the pitot head manufacturer, performed adequately. However the evidence provided by the pitot head manufacturer of the elevated temperatures experienced at the pitot heater connection and the molten joint in the connector fitted to VH-SBI, would indicate that tin-lead solder has a significantly lower tolerance to elevated ambient temperatures.

3

FINDINGS

3.1 Contributing safety factors

There was inadequate pitot head maintenance guidance regarding the continuing airworthiness of the pitot head and associated electrical system. *[Safety issue]*

Although serviceable and selected on, the electric pitot heating elements were not able to prevent the build up of ice over the pitot head.

DHC8-315, VH-SBJ, suffered a dual airspeed indication failure due to both pitot systems becoming blocked by ice while VH-SBW suffered a single airspeed indication failure due to one pitot system being blocked by ice.

Both the operator's and the manufacturer's QRH for the DHC8-300 did not contain adequate guidance for the flight crew to resolve the abnormal operation of the aircraft systems. *[Safety issue]*

3.2 Other safety factors

The use of solder alloy containing 60% tin and 40% lead, rather than the recommended 63% silver and 37% lead, lowers the tolerance to elevated temperatures by the soldered joint at the pitot head heater connections. *[Safety issue]*

Tests of the pitot heat electrical system carried out by the operator suggest the voltage drop measured on the DHC8-100/200/300 aircraft is higher than recommended. *[Safety issue]*

3.3 Other key findings

Safe flight of the aircraft was assured by the crew maintaining climb attitude and power settings until a decision to return was made.

4.1 Quick Reference Handbook guidance

Safety issue

Both the operator's and the manufacturer's Quick Reference Handbook (QRH) for the DHC8-300 did not contain adequate guidance for the flight crew to resolve the abnormal operation of the aircraft systems.

Response from Bombardier Aerospace

Date received: 24 April 2007

In general, the report makes continual reference to the lack of adequate QRH procedures associated with a complete loss of airspeed information. The basis of certification for the Q300 and other Part 25 aircraft dictates that a loss of all airspeed information must not occur. Therefore, neither QRH nor AFM procedures are provided. Airspeed information failures of this type are extremely improbable events. In addition, it is not possible to provide accurate guidance to flight crews covering the loss of all airspeed information given the numerous configurations and operating scenarios to which an aircraft may be exposed. Accurate information is provided for the loss of a single airspeed indicator, which was demonstrated by the flight crews handling of the event involving aircraft VH-SBW.

ATSB assessment of response

There is clear evidence that a dual loss of airspeed information can occur, despite certification dictating that it must not, and that the aircraft system indications to the flight crew may not clearly identify the failure mode. Therefore, it would be difficult for the flight crew to correctly analyse the problem and perform appropriate corrective actions.

The comment by Bombardier that '*it is not possible to provide accurate guidance to flight crews covering the loss of all airspeed information given the numerous configurations and operating scenarios to which an aircraft may be exposed.*' is not supported by the FDR information available. Analysis of the FDR information shows that the loss of active pitot pressure resulted in indications of systems failures that were common in both events. For example, coincident with the loss of airspeed information, both the autopilot and the yaw damper systems indicated a disengaged condition. In addition, the flight crew reported that the Air Data Computer of the affected pitot system indicated a failed state. Anecdotal evidence provided to the ATSB by Australian and New Zealand operators and flight crew, indicates that loss of airspeed events involving DASH8 S100/200/300 are not rare and that flight crew have developed ad-hoc QRH references to assist them in managing these events in the absence of any guidance promulgated by the manufacturer.

ATSB Safety recommendation R20070012

The ATSB recommends that Bombardier Aerospace address this safety issue.

4.2 Maintenance of pitot head and associated wiring

Safety issue

There was inadequate pitot head maintenance guidance regarding the continuing airworthiness of the pitot head and associated electrical system.

Response from Bombardier Aerospace

Date received: 24 April 2007

This report should emphasize the requirement for sound maintenance practices appropriate to the pitot static system, for which both Bombardier and the operator are responsible. It currently does not.

ATSB assessment of response

Sound maintenance practices have been considered in this report and the ATSB acknowledges the service bulletins and amended maintenance information developed by Bombardier, see section 1.6.

However, the ATSB agrees with Bombardier's response that strong emphasis of sound maintenance practices and the provision of appropriate maintenance instructions should be emphasised. Sound and appropriate maintenance practices are considered essential to providing an adequate operating environment for the DASH8 S100/200/300 pitot heating system.

The importance of optimal pitot heat system integrity is emphasised by Bombardier's agreement that *'the events in this report appear to be a result of inadequate pitot heat'* and *'the voltage drop in the pitot heater circuit exceeds the recommendations found in FAA advisory circular AC43.13'*. However Bombardier considers *'the voltage supplied to the pitot heater is adequate to perform its intended function'* and *'believe that the manufacturers' data is available and provides adequate wire gauge for pitot heating.'*

4.3 Pitot heater connector solder

Safety issue

The use of solder alloy containing 60% tin and 40% lead, rather than the recommended 63% silver and 37% lead, lowers the tolerance to elevated temperatures by the soldered joint at the pitot head heater connections.

Response from Bombardier Aerospace

Date received: 24 April 2007

Bombardier confirms that solder used in the pitot heater sockets is either Sn60Pb40 or SN63Pb37 as per QQ-S-571. These solders have a solidus temperature of approximately 183 C. Test data indicates a connector temperature of up to 150 C. We acknowledge field observations of cold solder joints, which we believe may be caused by abnormally elevated temperatures or temperature cycling at the pitot connector. Despite the generally good in-service experience, we agree that an increased margin should be provided to elevated temperatures and are therefore investigating using a higher temperature solder consistent with our manufacturing processes.

ATSB assessment of response

The ATSB acknowledges Bombardiers intention to address this safety issue.

4.4 Testing of pitot heater electrical system

Safety issue

Tests of the pitot heat electrical system carried out by the operator suggest the voltage drop measured on the DHC8-100/200/300 aircraft is higher than recommended.

Response from Bombardier Aerospace

Date received: 24 April 2007

The heating and de-icing characteristics of the pitot probe, when installed on the DHC8-300, have been tested and demonstrated to satisfy the applicable certification de-icing requirements. This is further supported by a long and successful in-service experience of over 15 million flight hours on the DASH8 S100/200/300, with over 4 million flight hours on the S300 itself. All of these models use the same pitot probe. While the voltage drop in the pitot heater circuit exceeds that of the recommendations found in AC43.13-1, the voltage supplied to the pitot heater is adequate to perform its intended function. Bombardier does not believe the events in question are related to the heating characteristics of the pitot heat system, in an unfailed condition. It is further noted that while AC43.13-1B provides excellent guidance, para 1. of the AC states that it's purpose is for "inspection and repair of nonpressurized areas of civil aircraft, only when there are no manufacturer repair or maintenance instructions." Further, it is to be used only if it is "not contrary to manufacturers data." We believe that the manufacturer's data is available in this case and provides adequate wire gauge for pitot heating.

ATSB assessment of response

The ATSB partially agrees with Bombardiers response in accepting that the DASH 8 has been tested and demonstrated to satisfy the applicable certification de-icing requirements. The ATSB considers that the pitot heater wiring may contribute to the operating performance of the pitot heater system.

It is recognised that any component within a system may limit the performance of other associated components. Therefore, the wiring used to connect the power supply to the pitot heater element may influence the de-icing performance of the pitot head. The effect of the voltage drop present in the DASH 8 pitot heater wiring would become more significant due to the higher current demand of the pitot heater when the pitot head was being cooled, that is, operating in an environment conducive to icing.

