Australian Government

Australian Transport Safety Bureau

**ATSB TRANSPORT SAFETY INVESTIGATION REPORT**

Aviation Occurrence Report – 200605307

Final

# Erratic Airspeed Indications
# 241 km NNE Perth Airport
# 7 September 2006
# VH-NXI
# Boeing 717-200

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**Abstract**

On 7 September 2006, a Boeing 717-200 aircraft, registered VH-NXI, was being operated on a scheduled service from Perth to Port Hedland, WA. Approximately 10 minutes after takeoff, the crew became aware that both the pilot in command's and copilot's computed airspeed displays had become erratic. The pilot in command's computed airspeed rapidly dropped, while the copilot's airspeed gradually increased. During the event, the pilot in command's displayed airspeed dropped as low as 115 kts, while the copilot's computed airspeed reached a maximum of 348 kts. Both the stall warning and overspeed warning sounded. The crew assessed the accuracy of the Integrated Standby Instrument System (ISIS) and used it for air data information.

The crew carried out the non-normal checklist from the Quick Reference Handbook. As part of the checklist, the crew cycled the air data heat switch. Approximately 15 minutes after the first signs of irregularities, both the pilot in command's and copilot's airspeed displays returned to normal and both airspeeds matched. The aircraft returned to Perth and conducted a normal approach and landing.

Analysis of the recorded data indicated that both the pilot in command's and copilot's pitot probes had iced up, which resulted in erratic airspeed indications and erroneous altitude and Mach numbers. The accuracy of the ISIS could not be determined from the recorded data.

The air data heat switch was removed from the aircraft and examined by the switch manufacturer. The switch manufacturer concluded that the latching mechanism in the switch was damaged, when the lamp capsule was forcibly opened while the switch was in the latched position.

It is possible that a piece of the broken latching mechanism jammed the switch in the OFF position, which resulted in no heat being supplied to the air data sensors, including the pitot probes.

# 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.

**Developing safety action**

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.

# FACTUAL INFORMATION

## Sequence of events

At 1818 Western Standard Time[1] on 7 September 2006, a Boeing 717-200 aircraft, registered VH-NXI, with six crew and 83 passengers onboard, departed Perth Airport, WA on a scheduled passenger service to Port Hedland, WA.

At 1828, at a recorded altitude of 21,536 ft, while flying through cloud, the autopilot system disconnected. An error message on the Primary Flight Display (PFD) indicated that the pilot in command's PFD had failed. Recorded data showed that over the next 9 seconds, the pilot in command's displayed airspeed reduced from 322 kts to 184 kts. At the same time, the pilot in command's displayed Mach number reduced and his displayed altitude increased. The pilot in command confirmed that his airspeed data was erroneous and switched over to the copilot's air data.

After a short time, the copilot, who was the pilot flying, noted that his airspeed had become excessive and that increasing the rate of climb did not reduce the airspeed. The crew decided that the copilot's information was also unreliable, so the crew used the Integrated Standby Instrument System (ISIS). When the pilot in command's displayed airspeed initially dropped, the copilot's displayed airspeed remained relatively constant. A short time later, the copilot's displayed airspeed began to increase gradually.

The pilot in command and copilot carried out the 'Airspeed: Lost, Suspect or Erratic' checklist in the Quick Reference Handbook (QRH). The crew confirmed the accuracy of the ISIS by comparing it with power/pitch information in the QRH. The flight crew continued their climb to 33,000 ft.

During that time, the crew reported that both the stall warning and the overspeed warning sounded. During the incident, the copilot's displayed airspeed increased to a maximum of 348 kts, while the pilot in command's computed airspeed was recorded to drop as low as 115 kts.

The copilot reported that whilst working through the QRH checklist, the air data heat switch was cycled[2]. The crew subsequently noticed that the air data systems began to be restored (approximately 15 minutes after the first signs of irregularities). A rapid increase in both the pilot in command's and the copilot's computed airspeed occurred after which both airspeeds matched.

The aircraft returned to Perth and conducted a normal approach and landing with all air data systems operating.

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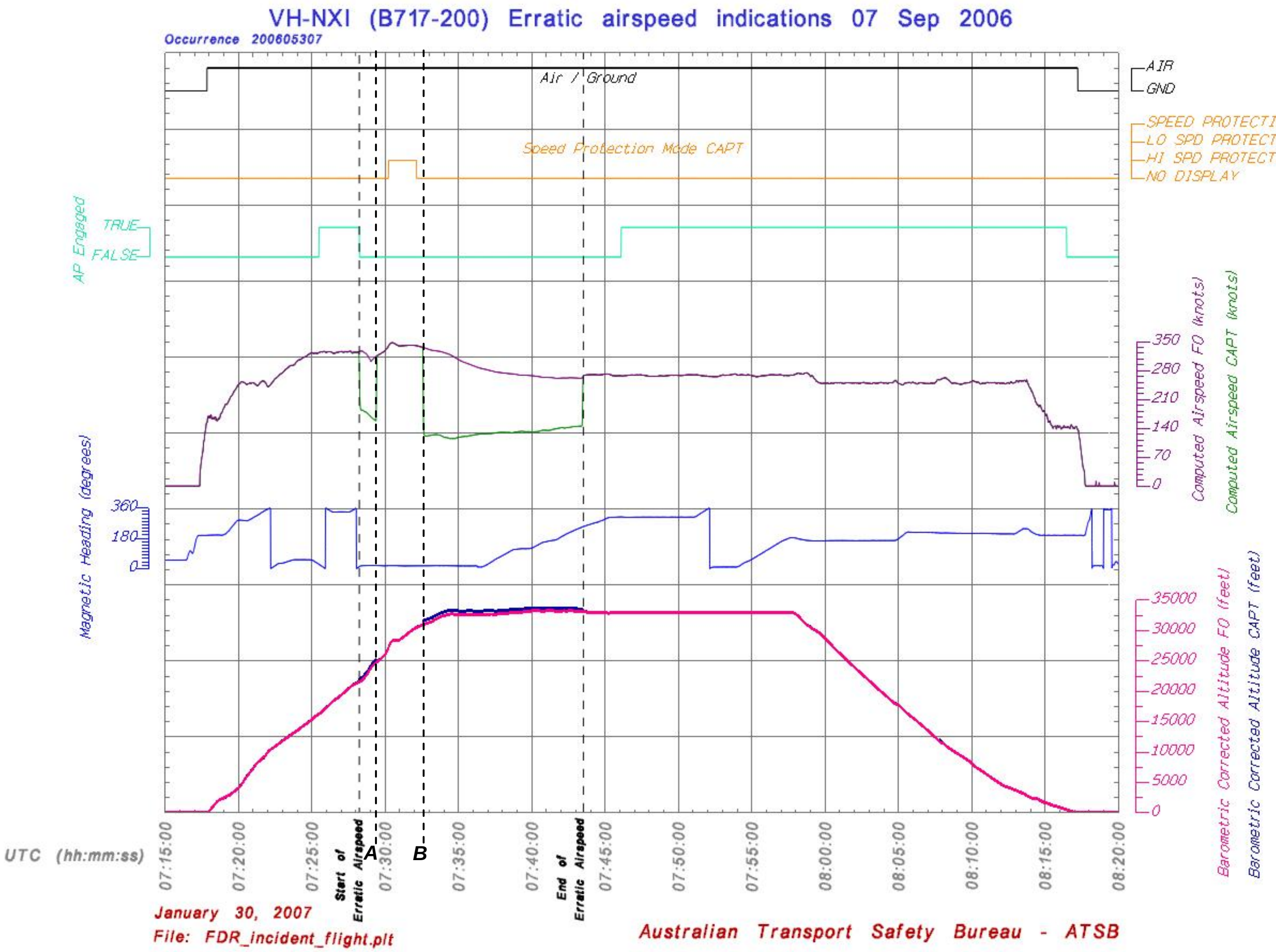
1 The 24-hour clock is used in this report to describe the local time of day, Western Standard Time (WST) as particular events occurred. Western Standard Time was Coordinated Universal Time (UTC) + 8 hours.

2 Interim Operating Procedure 1-29, incorporated into the 'Airspeed: Lost, Suspect or Erratic' checklist, on 23 March 2006, advised crew to cycle the air data heat switch to verify that it was ON.

**Figure 1: Information from the Flight Data Recorder for the incident flight**




***A*** – Pilot in command switched to the copilot's air data.
***B*** – Pilot in command switched back to his own air data.

## Recorded data

A number of devices, including the Flight Data Recorder (FDR), Quick Access Recorder (QAR), and the Flight Control Computer (FCC), recorded flight information and parameters. The operator provided the recorded data to the Australian Transport Safety Bureau (ATSB).

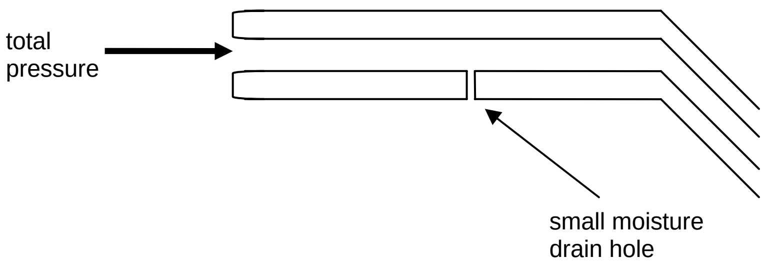
The airspeed and altitude that was displayed on the PFD was recorded by the FDR. The FDR did not record the air data that was displayed on the ISIS. When the pilot in command noted that his airspeed was erroneous, he switched to the copilot's air data information. That action was shown on the FDR information (Figure 1).

The BITE[3] data downloaded from the aircraft's FCC was sent to the equipment manufacturer for decoding and analysis. The information showed data failures at the time of the incident, consistent with failure of both the pilot in command's and copilot's air data systems. The specific recorded faults included the airspeed, altitude, and Mach number. The equipment manufacturer reported that invalid total pressure (pitot)[4] was one of the possible failures that could result in the recorded faults. The manufacturer was unable to determine the exact source of the failure from the FCC BITE data.

## Pitot icing effects

The Boeing 717 aircraft had three pitot probes located below the cockpit windscreen: one for each of the pilot in command, copilot, and the auxiliary[5] flight data systems. These pitot probes sensed the outside air total pressure through an opening at the front of the probes. A moisture drain hole was located on the lower side of the pitot probes (Figure 2).

**Figure 2: Cross-sectional representation of a pitot probe**




The total pressure measured by the pitot probes was used in the calculation of a number of the flight information variables displayed on the Primary Flight Display.

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3 BITE: Built In Test Equipment is integrated into a system, finding and recording failures in the system (Cambridge Aerospace Dictionary, 2004).

4 Total pressure is the sum of the static air pressure and the pressure due to the velocity of the aircraft (Cambridge Aerospace Dictionary, 2004).

5 The auxiliary flight data system provided information for the ISIS (Boeing 717 Aircraft Maintenance Manual).

These included airspeed, Mach number, and altitude[6]. The air data was also used by the FCC.

Airspeed was calculated from the difference in the total air pressure and the static air pressure. Total pressure was measured from the pitot probe, while static pressure was measured from the sensors in the static plate[7].

Previous analysis by the aircraft manufacturer has shown that if the opening at the front of the pitot probe was blocked, the pressure sensed would be much lower than the actual total pressure because air would exit the probe through the drain hole. However, the pressure in the pitot probe would not drop to static pressure because of the airflow over the nose of the aircraft. Consequently, there would be a drop in the computed airspeed, but the computed airspeed would not drop to zero.

If the pitot probe, including the drain hole were covered with ice, the air would be trapped inside the probe at the pressure when the ice formed. If the aircraft climbed, the static pressure would reduce, increasing the difference between it and the trapped pressure in the pitot probe, thereby increasing the computed airspeed.

## Air data heat switch

Air data sensors were electrically heated during flight to prevent ice formation. The air data heat switch controlled the heating of the sensors, including the pitot probes, static plates, Ram Air Temperature (RAT)[8] sensor, and angle of attack transducers (Figure 3).The single air data heat switch operated all the air data senor heaters[9]. As part of the pre-flight checklist, the crew was required to turn the air data heat switch ON.

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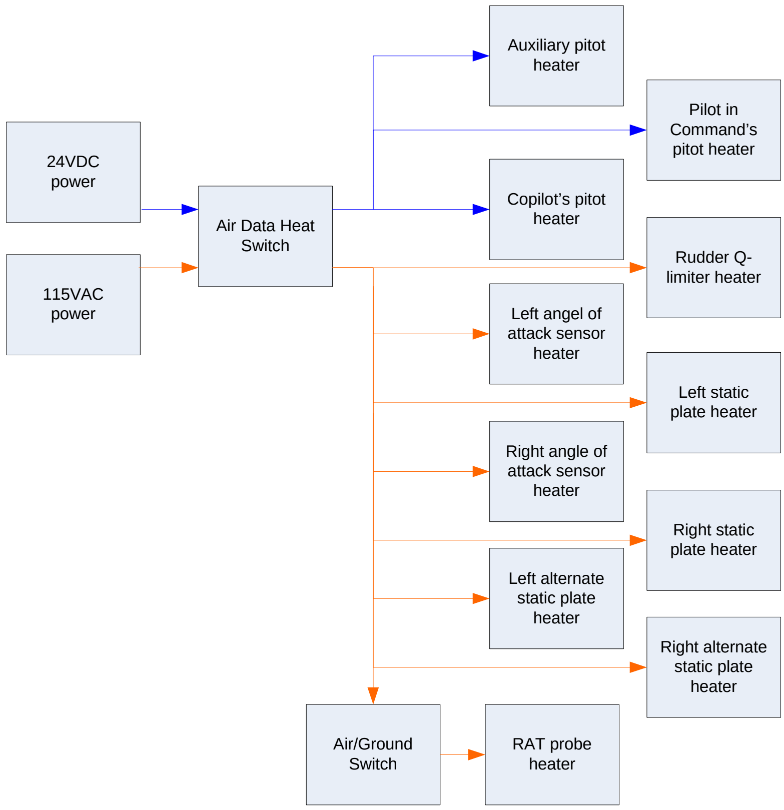
6 The altitude is calculated from the static pressure after the application of a correction factor, which is a function of Mach number (aircraft manufacturer, personal communication, October 27, 2006).

7 The Boeing 717 aircraft had two static plates located on either side of the fuselage. Each plate contained three static ports, one for each of the pilot in command, copilot, and auxiliary air data systems (Boeing 717 Aircraft Maintenance Manual).

8 The RAT sensor measured the stagnation temperature (Cambridge Aerospace Dictionary, 2004).

9 The RAT sensor was also linked to the ground/air switch. The air data heat switch must be ON and the aircraft must be in the air for the RAT probe to be heated (Boeing 717 Flight Crew Operating Manual).

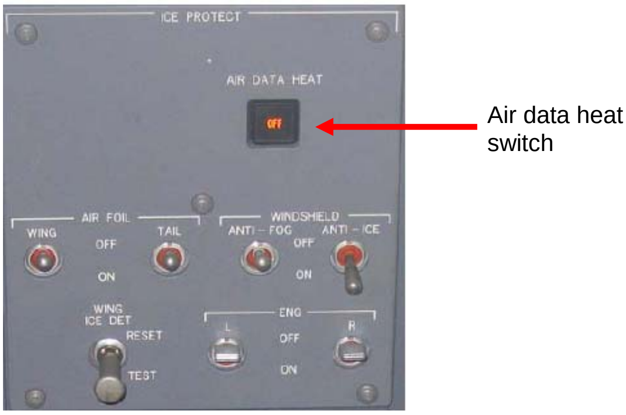
**Figure 3: Air data heating system**




The air data heat switch was located in the forward overhead panel, as part of the ice protection control panel. The air data heat switch was the only push button switch on the ice protection control panel (Figure 4) and the only push button switch in the vicinity.

The switch was an alternate action type switch, containing a latching mechanism. The aircraft manufacturer configured the switch so that when the button was latched (OFF), the probe heaters were off and the switch was illuminated. In that mode, the button would have protruded about 5.5 mm from the panel. When the switch was unlatched (ON), the probe heaters were on and the switch was not illuminated. In that mode, the button would have protruded about 7.6 mm from the panel. No information was found in the maintenance procedures describing how to open the lamp capsule.

**Figure 4: Air data heat switch in situ showing the position of the switch in the OFF mode.**




Courtesy of the US National Transportation Safety Board

## Testing of the air data heat switch

The air data heat switch was removed from the aircraft and sent to the ATSB for examination and testing. Preliminary testing found that the switch acted as a momentary type switch; that is, the switch was always ON, heating the air data components, unless it was depressed and held in. During the ATSB examination, the switch partially jammed in the OFF position on one occasion.

The switch manufacturer, under the supervision of the US, National Transportation Safety Board, carried out further testing. That testing revealed that the latching mechanism within the switch had failed, leading to the switch having a momentary action. The latching mechanism had been torn outwards; abrasions in the fingernail grooves were observed (Figure 5). Previous testing carried out by the switch manufacturer indicated that 17 lbs (7.7 kg) of force would have been required to tear out the latching mechanism. The switch manufacturer concluded that the outward direction of the tear on the latching mechanism, together with the abrasions in the fingernail grooves, indicated that the lamp capsule had been forcibly opened[10] while in the latched (OFF) position.

10 The lamp capsule contained within the button of the switch could be opened for maintenance to check and/or replace the light globe (Manufacturer's Data Sheet).

**Figure 5: Abrasions (arrowed) on the fingernail grooves of the air data heat switch**


Source: Eaton Aerospace

The switch manufacturer found the contact resistance on some of the contacts were beyond their manufacturing limits. Nonetheless, in the context of the air data heat system, the manufacturer found that the performance of the switch was not degraded, apart from the failed latching mechanism. All four lamps in the switch illuminated when tested.

## Boeing 717 crew warning and alerting systems

The air data heat being switched OFF or, failure of the heater element in any of the eleven sensors associated with the air data heat switch, would have resulted in an alert (Table 1). Heater element failures were displayed when the air data heat switch was selected ON.

**Table 1: Air data heating system alerts**

| Reason for alert | Engine and Alert Display message | Other warnings |
|---|---|---|
| Air data heat switch OFF | AIR DATA HEAT OFF (MISC)[11] | Air data heat switch OFF light illuminated |
| Left and/or right Angle of Attack heat fail | AOA HEAT L/R FAIL (MISC) | Master Caution light illuminated |
| Pilot in command's, copilot's, and/or auxiliary pitot heat fail | PITOT CAPT/FO/AUX FAIL (MISC) | Master Caution light illuminated |
| Ram air temperature probe heat fail | RAT PROBE FAIL (MISC) | none |
| Rudder Q-limiter pitot heat failure | RUD PITOT FAIL (MISC) | none |
| Left and/or right static port heat fail | none | STATIC L/R HEAT[12] |

The number-2 autopilot was unserviceable at the time of the incident flight. An inoperative autopilot would have resulted in a warning on the Engine and Alert Display, and the illumination of the MISC button.

Pressing the MISC pushbutton brought up the Miscellaneous Alerts page, which showed all the MISC warnings and removed these warnings from the Engine and Alert Display. A reminder, 'MISC', was left on the Engine and Alert display to show that there were still miscellaneous warnings.

## Federal Aviation Regulations

The Boeing 717-200 was certified to meet Section 25 of the Federal Aviation Regulations. Section 25.1333(b) of the regulations covered the separation of flight instrumentation that was essential to the safety of flight. The regulation stated:

> The equipment, systems, and installations must be designed so that one display of the information essential to the safety of flight which is provided by the instruments including attitude, direction, airspeed, and altitude will remain available to pilots, without additional crew member action, after any single failure or combination of failures that is not shown to be extremely improbable.

11 When the MISC button was pressed the warning would be removed and replaced by the message 'MISC' on the Engine and Alert Display (Boeing 717 Flight Crew Operating Manual).

12 A failure of either the left or right static port heater would result in a warning message on the status page (Boeing 717 Flight Crew Operating Manual).

After a previous icing incident involving a Boeing 717-200 aircraft[13], the aircraft manufacturer found that the air data heat switch did not meet the separation of essential systems requirement as specified in the above regulation. The findings included that the three pitot heaters shared a common switch ground and the three pitot heaters all operated from the air data heat switch.

As a result, the aircraft manufacturer released an Alert Service Bulletin 717-30A0003 in September 2005, with Revision 1[14] released on 2 March 2006. The service bulletin:

- changed the air data heat switch grounds;
- changed the contact on the air data heat switch associated with the copilot's pitot probe heater; and
- linked the pitot probe heat to the air/ground switch as well as the air data heat switch.

The change to the air/ground switch meant that heat would always be supplied to all three pitot probes regardless of the position of the air data heat switch when the aircraft was in the air. On the ground, heat would only be supplied to the pitot probes when the air data heat switch was ON.

The changes provided separation between systems and reduced the probability of all three pitot probes icing up at the same time. The manufacturer recommended that the modification be completed within 24 months after the release of the service bulletin.

At the time of the incident, the service bulletin had not been carried out on VH-NXI.

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13 Federal Aviation Administration Notice of Proposed Rule making, Docket Number FAA-2007-27152, Directorate Identifier 2006-NM-219-AD.

14 Revision 1 changed the kits/parts, the operational test and wire routing installation (Alert Service Bulletin 717-03A0003).

# ANALYSIS

The recorded data indicated that the pilot in command's and copilot's air data became erratic while the aircraft was climbing through cloud. The air data returned to normal approximately 15 minutes later, after the flight crew had cycled the air data heat switch.

Recorded data showed that the pilot in command's computed airspeed rapidly decreased during the incident, leading to the stall warning sounding. That drop in airspeed was consistent with icing of the pilot in command's pitot probe with the drain hole not blocked. The flight crew statements and the recorded data established that the copilot's computed airspeed gradually increased over the event, which lead to the overspeed warning. The increase in the copilot's computed airspeed was consistent with a pitot probe icing event. The icing was consistent with a simultaneous blockage of the pitot tube opening and the moisture drain hole.

Blockages of pitot probes with ice occur when the probes are not heated and the aircraft is in conditions conducive to icing (such as flying in cloud). Possible reasons for the pitot probes not to be heated were, a failure of the associated pitot probe heater, or the air data heat being selected OFF.

A failure of the pitot probe heater would result in a Master Caution warning. However, the flight crew did not report such a warning. It was also unlikely that both the pilot in command and copilot's pitot probe heaters would fail at around the same time and regain operation at exactly the same time. It was therefore considered that the ice blockage of the pitot probes was due to the air data heat switch being selected OFF.

Evidence that the air data heat switch was OFF included the flight crew's report that the air data returned to normal after the air data heat switch was cycled. From the crew's description and the return of the computed airspeed, it was probable that cycling the air data heat switch turned the air data heat ON.

The manufacturer's examination of the air data heat switch revealed that the latching mechanism had failed. The switch had been designed so that a failure in the latching mechanism would result in the switch always being ON, supplying heat to the sensors. It was possible that a broken piece of latching mechanism jammed the switch in the OFF position and was dislodged when the switch was cycled as part of the Quick Reference Handbook (QRH) checklist, during the incident flight.

The latching mechanism in the air data heat switch, was most likely damaged when the lamp capsule was forcibly opened while the switch was in the latched position. No information was found in the maintenance documentation on the correct method for opening the air data heat switch lamp capsule. The 2 mm difference in height between the latched and unlatched positions on the switch made it difficult to differentiate between the ON/OFF modes. In addition, the air data heat switch was not located near any similar switches making it difficult to compare the switch ON/OFF position. Consequently, someone replacing a lamp may not have realised that the switch was latched prior to opening the lamp capsule. Provision of information to maintenance personnel on the correct procedure for opening the lamp capsule may avoid damaging the switch.

The number-2 autopilot had been noted as inoperable prior to the incident flight. Prior to takeoff, the crew may have pushed the MISC press button to remove the autopilot failure from the Engine and Alert Display. That action would have also removed the air data heat OFF warning from the Engine and Alert Display, leaving only the MISC alert on the display. During the flight, the crew may not have checked the Miscellaneous Alerts page since they were aware of the inoperative autopilot alert.

The OFF light on the air data heat switch was probably illuminated. However, the crew may not have noticed it due to its location on the overhead panel.

The US Federal Aviation Regulations, to which the Boeing 717 was certified, required that essential flight instrument systems be separated, so that a failure of one part would not lead to a failure of all the systems. The air data heat wiring on the incident aircraft did not ensure that separation. All three pitot probes relied on the single air data heat switch being ON for heating. That included the auxiliary pitot probe, which supplied flight data to the Integrated Standby Instrument System (ISIS).

The crew reported that based on the power/pitch information in the QRH, the air data displayed on the ISIS was accurate. However, the auxiliary pitot probe was located next to the copilot’s and pilot in command’s pitot probes. Hence, it was likely that the auxiliary probe also iced up when the other two probes had. As a result, it was likely that the indicated airspeed displayed on the ISIS was also inaccurate. The flight data displayed on the ISIS was not recorded on the Flight Data Recorder, so the accuracy of the indicated airspeed could not be verified.

# FINDINGS

## Contributing Safety Factors

- Ice formed on the pitot probes leading to inaccurate air data indications including air speed, Mach number and altitude.
- Icing of the pitot probe probably occurred due to the air data heat system being switched OFF. It is possible that a broken latching mechanism had jammed the switch in the OFF position.
- The latching mechanism in the air data heat switch had failed, resulting from the opening of the lamp capsule while the switch was latched.
- The warning that the air data heat switch was OFF would have been masked by the inoperable number-2 autopilot. The air data heat OFF light was probably illuminated but not noticed by the crew.
- The design of the air data heat system did not ensure separation of the air data heat systems as required by the Federal Aviation Regulations.

# SAFETY ACTION

## Aircraft Manufacturer

The aircraft manufacturer released an Alert Service Bulletin 717-30A0003 in September 2005, the first revision was released on 2 March 2006, with a second revision released on 28 November 2006. The second revision added to the background and reason statements and clarified some information.

The changes included in the service bulletin, provided separation between systems and reduced the probability of all three pitot probes icing up at the same time.

The aircraft manufacturer revised the Flight Crew Operations Manual (FCOM) After Start Checklist via Temporary Revision (TR) 2-185 and TR 2-186, both dated December 11, 2006 and later 717 FCOM revision 22, dated July 15, 2007, requiring the flight crew to verify that the air data heat switch is ON.

## Federal Aviation Administration (US)

The Federal Aviation Administration released an Airworthiness Directive, 2007-13-01 Amdt 39-15105, effective 25 July 2007, mandating the Alert Service Bulletin 717-30A0003, Revision 2. The Airworthiness Directive required operators to carry out the required actions within 24 months of the effective date of the directive.

## Civil Aviation Safety Authority (CASA)

CASA released an Airworthiness Directive, AD/B717/22, effective 30 August 2007, mandating the Alert Service Bulletin 717-30A0003, Revision 2. The Airworthiness Directive required operators to carry out the required actions within 24 months of the effective date of the directive.

## Operator

On 8 June 2006, the operator scheduled the inclusion of the Alert Service Bulletin, 717-30A003, into their fleet. To date, the service bulletin has been incorporated on one aircraft in the operator’s fleet.

The operator has distributed a Notice to Pilots revising the Before Take-Off checklist to verify that the air data heat switch is ON and revising the Engine Alert Display section of the checklist. The revision requires that the Status page be checked if there are any warnings on the Engine and Alert Display, to ensure that miscellaneous alerts are not masked.

The operator has also alerted maintenance personnel to the possibility that the air data heat switch may break during its removal.