



Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Investigation – 200606223

Final

Hydraulic System Event

Sydney Airport, NSW

4 October 2006

Bombardier de Havilland DHC-8-315

VH-TQY



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Abstract

On 4 October 2006, at approximately 1045 EST, while on a scheduled flight from Canberra, ACT to Sydney, NSW, a Bombardier de Havilland DHC-8-315 (Dash 8) aircraft, registered VH-TQY, experienced a hydraulic system failure while on approach to land at Sydney Airport.

The flight crew became aware of the system failure when they selected the landing gear to extend during the approach sequence. Shortly after, the low oil pressure caution light for the number-two hydraulic engine pump illuminated. The crew established that the nose and right main landing gear doors had remained open and the left gear door had closed after all the gears had been extended.

The flight crew issued a radio alert to air traffic services and the aircraft commenced a missed approach. The crew then carried out the relevant quick-reference handbook (QRH) checks and landed at Sydney Airport on runway 16L without further incident.

The investigation determined that a solenoid-sequence valve failed, which resulted in the loss of pressure and quantity of hydraulic fluid from the aircraft's number-two hydraulic system. Failure of the solenoid-sequence valve was due to the fracture of three of the four bolts that had clamped the two halves of the component together. Each of the fractured bolts had failed due to metal fatigue from exposure to in-service cyclic stresses that had developed during the operation of the aircraft's hydraulic system.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

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

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

History of the flight

On 4 October 2006, at approximately 1045 EST¹, while on a scheduled flight from Canberra, ACT to Sydney, NSW, a Bombardier de Havilland DHC-8-315 (Dash 8) aircraft, registered VH-TQY, experienced a hydraulic system failure while on approach to land at Sydney Airport.

The flight crew became aware of the system failure when the crew selected the landing gear to extend during the approach sequence. Shortly after the gear selection, the caution light for the number-two hydraulic engine pump illuminated, which indicated low oil pressure in that system. The crew established that the nose and right main landing gear doors had remained open and the left gear door had closed after all the landing gears had been extended².

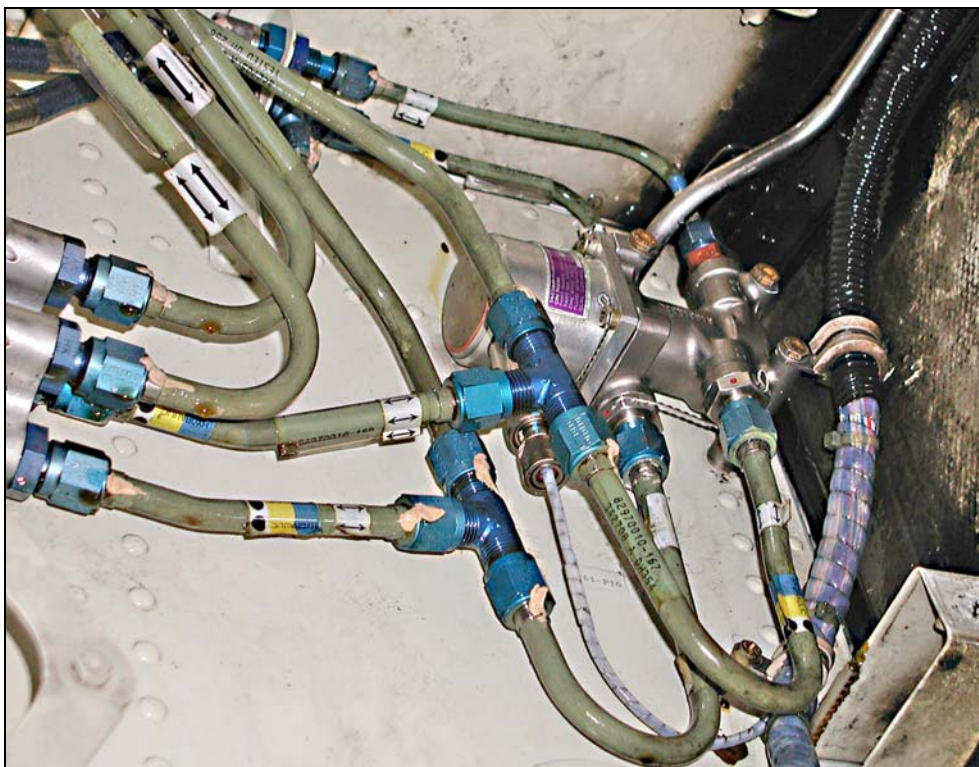
The flight crew issued a PAN³ radio alert to air traffic services and the aircraft commenced a missed approach. The crew then carried out the relevant quick-reference handbook (QRH) checks and landed at Sydney Airport on runway 16L without further incident. After touchdown, the aircraft was taxied to the arrivals bay using asymmetric engine power and braking. This was due to the nose wheel steering being inoperative from the hydraulic power loss.

Post-incident examination

Subsequent examination of the aircraft by maintenance engineers identified that a landing gear solenoid sequence valve had failed, resulting in a leak that led to the loss of the number-two hydraulic system quantity and pressure (Figure 1). The defective unit was replaced and the aircraft was returned to service.

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- ¹ The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST), as particular events occurred was Coordinated Universal Time (UTC) +10 hours.
 - ² Normal operation of the gear doors is for them to close after the landing gear is in the down and locked position.
 - ³ Urgency call by a pilot to alert all listening parties of a special handling condition which will receive Air Traffic Control priority for issuance of a clearance or assistance. Normal broadcast by the pilot is PAN PAN PAN.

Figure 1: Image of the failed solenoid-sequence valve and associated high pressure plumbing from the number two hydraulic system; shown in-situ within the right nacelle area.



Aircraft information

The Dash 8, serial number 552, was first registered in Australia October 2000. At the time of the occurrence it had completed 13,093.35 airframe hours and 16,458 flight cycles⁴. The aircraft was equipped with two Pratt and Whitney Canada PW123E turbine engines. Each engine was fitted with a four-blade Hamilton Sundstrand propeller. Two independent hydraulic systems were installed within the aircraft that controlled a number of critical aircraft system services.

Dash 8 hydraulic system

Both the number-one and -two hydraulic systems were powered by the left and right aircraft engines respectively. Each system was pressurised by a pump which was driven by the reduction gearbox of each engine.

The number-one hydraulic system provided primary power for the following aircraft systems; inboard roll spoilers, wing flaps, main wheel brakes, wheel anti-skid control valve, and the lower rudder actuator.

The number-two hydraulic system that normally functioned in parallel with the number-one hydraulic system, provided primary power for the outboard roll

⁴ One cycle is considered a ground-air-ground flight profile usually involving takeoff, climb, cruise, descent and landing. For a landing gear item, one cycle involves retraction and extension.

spoilers, ground spoilers, nose wheel steering, landing gear extension, parking brakes, and the upper rudder actuator.

Solenoid-sequence valve

The failed landing gear solenoid-sequence valve controlled the flow of hydraulic fluid from the number-two system to the landing gear and landing gear doors. The valve was located in the upper left corner of the right wheel well. The component comprised of two main items; the sequence valve and the solenoid. Electrical operation of the solenoid displaced an internal plunger into the body of the sequence valve. The flow of hydraulic fluid through the sequence valve was dependant on the position of the sequence valve plunger.

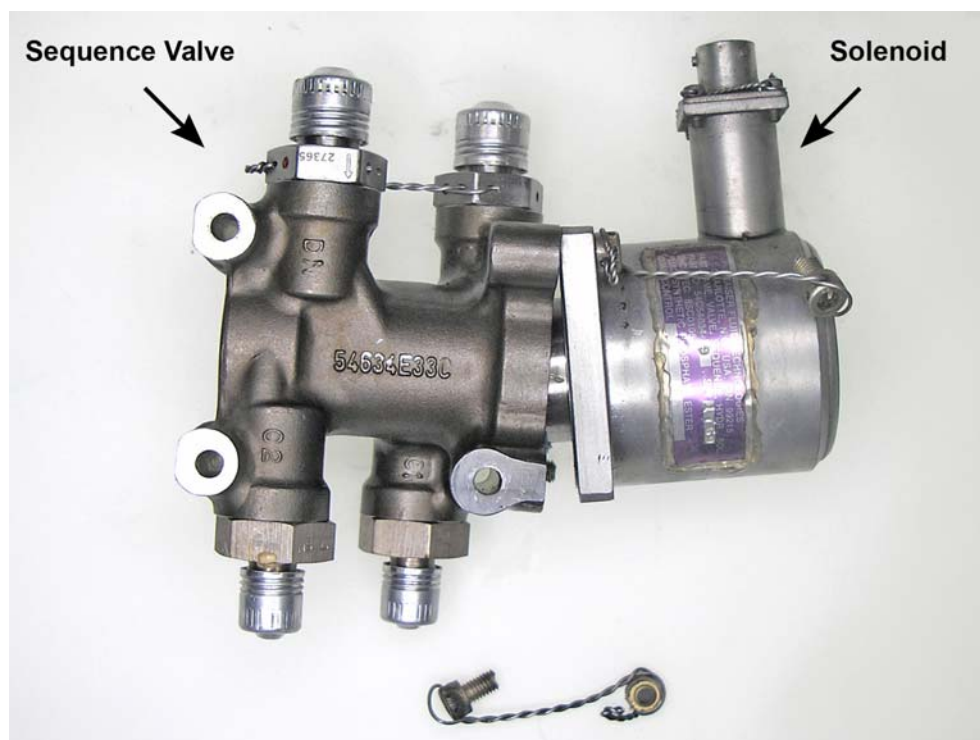
Solenoid-sequence valve examination

In order to establish the factors contributing to the solenoid-sequence valve failure, the aircraft operator forwarded the failed component from the aircraft to the Australian Transport Safety Bureau (ATSB).

Visual examination

The solenoid-sequence valve is shown assembled as-recovered from the number-two hydraulic system of the aircraft in Figure 2.

Figure 2: The failed component assembly showing the solenoid (right) and the sequence valve (left) as-received by the ATSB.



Visual examination showed that three of the four small steel socket head bolts that had clamped the solenoid and sequence valve together as an assembly, had fractured (Figure 3). Two of the bolts had fractured midway through the threaded region; the other bolt had fractured in the head-to-shank transition.

Examination of the fracture surfaces revealed characteristic features that indicated fatigue cracking had initiated and then propagated through each bolt. The origins of cracking were evident by the presence of many small 'ratchet mark' type features on each fracture (Figure 4). In each case, fatigue cracking was found to have started from the fastener thread root, and then propagated through the majority of the component cross-section. Final fracture of each socket head bolt was by overload as a consequence of the reduced cross-sectional area.

Blackening and staining from fretting damage was found on both the sequence valve and solenoid flange surfaces. Fretting is a wear process when small amplitude oscillatory movement takes place between tightly fitted metal-to-metal surfaces. In this event, the presence of fretting damage indicated that the component flange surfaces had been able to move against one another during service (Figure 5).

It was noted that the lock-wire which had been used to prevent each of the small socket bolts from loosening and backing off in service, was still attached through the head of each bolt.

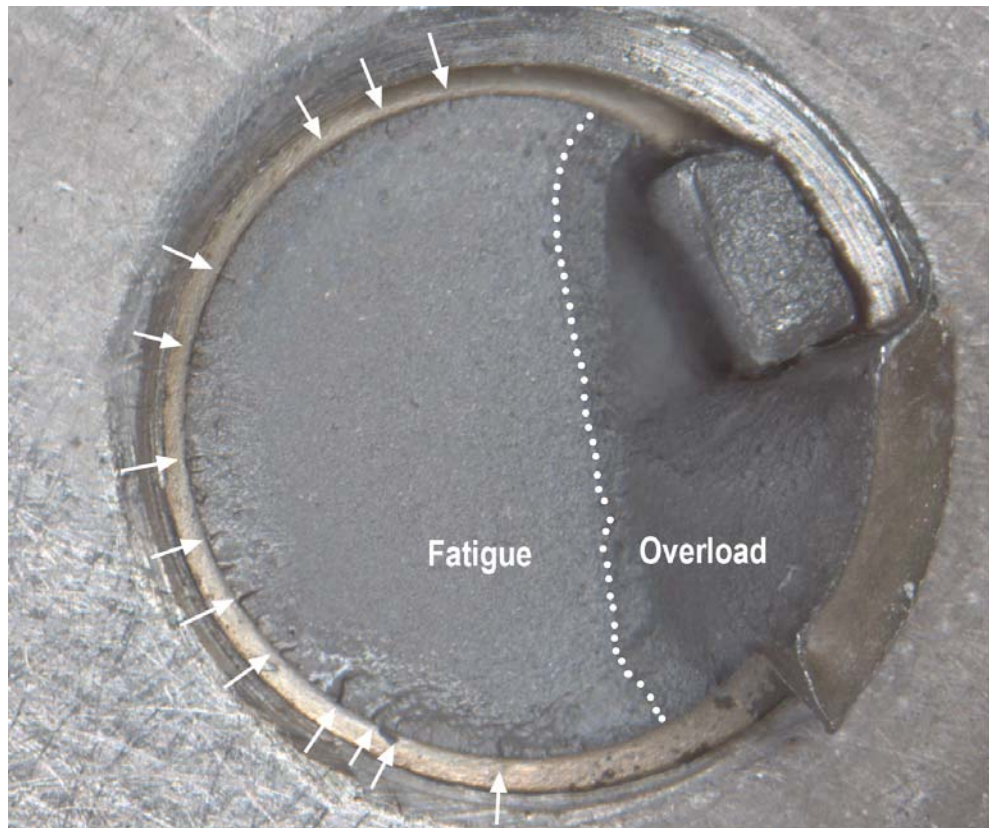
Although no specifications for the fractured bolts were available, measurements indicated that each bolt was a metric M5 x 0.80 size, made from medium-carbon alloy steel, quenched and tempered to a hardness of 433 HV. No imperfections were identified in the manufacture of the fractured bolts that could have contributed to the failure.

Figure 3: The solenoid-sequence valve after preliminary disassembly.



Note the three fractured bolts.

Figure 4: Close-up of the fastener fracture surface from Figure 3.



'Ratchet marks' (arrowed) at the thread root indicates multiple fatigue crack origins. The fracture regions of fatigue cracking and overload are labelled.

Figure 5: Fretting damage was found on the sequence valve flange surface, close to each of the broken fastener locations.



History of related failures

At the time of the failure, the valve had accumulated 13,093.35 hours service and 16,458 flight cycles since new.

As part of this investigation, a search of the Australian Civil Aviation Safety Authority (CASA) and other international databases showed that a number of other similar events had occurred within the Dash 8 fleet. Of the databases that were reviewed, the records indicated that from 1996 to 2006, 24 events involving the failure of solenoid-sequence valves of the same part number had occurred. Examination of the available data revealed that the average time to failure was approximately 15,700 hours service.

The service life for the failed components varied considerably, with respective maxima and minima service lives of 31,500 hours and 667 hours reported. Due to the limited information contained in the records, any similarity between the type and nature of the 24 other reported failures and that which occurred on VH-TQY, could not be fully determined.

ANALYSIS

While on approach to Sydney Airport, the number-two hydraulic engine pump caution light illuminated when the landing gear was selected down. The nose and right main gear doors remained open, while the left main gear door closed. Normal operation of the gear doors is for them to close after the landing gear is in the down and locked position. The actions by the flight crew to commence a missed approach were appropriate for the circumstances and gave them time to isolate the problem and apply corrective measures for a successful landing at Sydney airport.

System failure

The ATSB examination revealed that the rapid loss of hydraulic fluid from the Dash 8's number-two hydraulic system prevented the nose and right main gear door from properly closing after extending the gear during the landing approach. The fluid loss was due to the failure of a number-two hydraulic system solenoid-sequence valve. Three of the four bolts that had clamped both halves of the component together had fractured, resulting in the uncontained release of pressurised hydraulic fluid from the number-two hydraulic system.

The examination revealed that fatigue cracking had initiated and propagated through each bolt, until overload fracture occurred as a consequence of the reduced cross-sectional area. The fatigue cracking had initiated at multiple locations in the thread root of each bolt, and had propagated slowly under high-cycle low-stress conditions.

Bolt failures

While the reason for the bolt failures could not be conclusively established, one possibility that may explain the failures is insufficient application of preload when the bolts were initially tightened during assembly. The ability of a bolted assembly to adequately resist cyclic stresses is dependant on the torque (or bolt tension) applied to the bolts as they are tightened. This inadequacy may have allowed the bolts to flex during service and subsequently fail from fatigue cracking.

Another possibility to explain the bolt failures lies in the magnitude of the stresses experienced by the bolted solenoid-sequence valve assembly during service. If the peak stresses generated from pressurising the fluid within the number-two hydraulic system were excessive, a progressive loss of bolt preload would have occurred. This would have resulted in joint movement, bolt flexing and eventual fatigue failure.

FINDINGS

Context

From the evidence available, the following findings are made with respect to the failure of the number-two hydraulic system on a Bombardier de Havilland DHC-8-315 (Dash 8) aircraft, and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- A solenoid-sequence valve failed, which resulted in the loss of pressure and quantity of hydraulic fluid from the aircraft's number-two hydraulic system.
- Failure of the solenoid-sequence valve was due to the fracture of three of the four bolts that had clamped the two halves of the component together. Each of the fractured bolts had failed due to metal fatigue from exposure to in-service cyclic stresses that had developed during operation of the aircraft's hydraulic system.