

# De Havilland Canada DHC-8 Series 311, G-BRYP

## AAIB Bulletin No: 2/98 Ref: EW/C97/2/3 Category: 1.1

<b>Aircraft Type and Registration:</b>	De Havilland Canada DHC-8 Series 311, G-BRYP
<b>No &amp; Type of Engines:</b>	2 Pratt and Whitney Canada PW-123 turboprop engines
<b>Year of Manufacture:</b>	1992
<b>Date &amp; Time (UTC):</b>	10 February 1997 at about 1750 hrs
<b>Location:</b>	South of Aberdeen
<b>Type of Flight:</b>	Public Transport
<b>Persons on Board:</b>	Crew - 4 - Passengers - 26
<b>Injuries:</b>	Crew - None - Passengers - None
<b>Nature of Damage:</b>	Overtorque of both propellers; damage to ball race of one blade of No 2 engine propeller
<b>Commander's Licence:</b>	Airline Transport Pilot's Licence
<b>Commander's Age:</b>	51 years
<b>Commander's Flying Experience:</b>	7,140 hours (of which 484 were on type) Last 90 days - 138 hours Last 28 days - 28 hours
<b>Information Source:</b>	AAIB Field Investigation

## History of flight

The crew reported for duty at 1405 hrs to operate a scheduled service Bristol, Newcastle, Aberdeen, Newcastle, Bristol. The first two sectors were uneventful and the aircraft left the stand at Aberdeen for the sector to Newcastle with the commander as handling pilot. The history of the flight was reconstructed from the account provided by the crew and from the FDR.

The anti ice systems were selected 'ON' when the aircraft took off from Aberdeen at 1748 hrs; there was a strong gusting crosswind and it was raining. The initial climb was normal and the landing gear and flaps were retracted. The Standard Operating Procedure is then to deselect the autofeather system and select climb power, however the commander decided to retain take off power in order to expedite the climb through the layer of moderate to severe turbulence they were experiencing; he

informed the first officer of his intention and asked for the bleed air to be switched on. The first officer actioned the after take off check from memory, however he did not deselect the autofeather system because climb power had not yet been requested.

The commander selected climb power at about 2,100 feet amsl and asked the first officer to reduce the propellers to the climb setting. Both propellers were reduced to 900 propeller RPM (Np) and the torques increased momentarily to 100% before being reselected to 80%. The autofeather system was not deselected. No 1 engine torque increased slowly from 80% until stabilising at around 90%. However, No 2 engine torque increased rapidly to 111% and then returned to 80% over a period of 12 seconds. This was the first of many excursions of No 2 engine torque; most were in the range 10% to 20% and continued for a further 100 seconds until the commander retarded No 2 power lever to about 62%. These excursions in Np and torque are shown in Figure 1. ATC was told of the problem and the climb was continued with No 1 engine torque at 90%, and No 2 engine torque still at 62%; both propellers were at 900 Np.

When the aircraft climbed out of icing conditions the commander selected the No 2 engine intake bypass doors to closed. Shortly afterwards, as the aircraft climbed through about 7,400 feet amsl, No 1 propeller suddenly feathered, reducing to 400 Np and the torque on No 2 engine rose by about 15%. In this installation it is possible to feather the propeller blades without stopping the engine. Because the engine had not actually failed, fuel was still being scheduled to maintain the level demanded by the power lever and consequently No 1 engine torque increased rapidly to a peak value of 120% before being reduced to below 100%. About 100 seconds later No 1 engine torque was further reduced to 38%, the flight idle value, and No 2 engine torque was increased slightly to 85%.

The UNSCHEDULED PROPELLER FEATHERING drill was consulted; the drill calls for the shutdown of the engine associated with the feathered propeller. The flight deck indications were that No 1 engine parameters were normal. Because he now thought they had two, apparently unrelated, problems the commander decided not to shut down No 1 engine. An emergency was declared and the aircraft diverted to RAF Leuchars.

The first officer tried to unfeather No 1 propeller using the alternate system but was unsuccessful. As the aircraft passed about 7,000 feet amsl during descent to Leuchars, the commander selected the No 1 engine bypass door to closed and reduced No 2 engine torque to about 58%. This disarmed the autofeather system and No 1 propeller suddenly unfeathered; Np increased rapidly to 1,200 and the torque fell to zero. There was a yaw to the right of around 2 to 2.5° as the propeller unfeathered and it appears that the commander interpreted this as a failure of the No 2 engine because, about 10 seconds later, he retarded No 2 condition lever to the START/FEATHER detent which caused the propeller blade angle to coarsen towards the feather position. The power lever remained as selected and No 2 engine torque increased rapidly to 100% before reducing to 55% as the lever was subsequently retarded to FLIGHT IDLE. After 5 seconds No 2 engine torque reduced to zero in response to the condition lever being moved fully back to FUEL OFF. Figure 2 shows the engine torque, Np and fuel flow.

The first officer immediately told the commander that he thought he had taken the wrong action and the latter quickly moved the condition lever fully forward to the MAX GOVERNING position. The Np immediately increased to 1,200 and, because the igniters were still selected ON, the engine relit. The propeller was reduced to 900 Np but because the torque gauge pointer was at zero and the digital readout showed four dashes the crew assumed that the engine had indeed flamed out. The FDR was also sensing a zero torque output at this stage but other parameters such as fuel flow and

gas generator RPM (Ng) showed that the engine was still running with the power lever at a moderate setting. The first officer attempted to relight the engine by first retarding the condition lever to START/FEATHER. The Np reduced to 300 but the start switch would not engage as the engine was already running. After 17 seconds the power lever was retarded to FLIGHT IDLE, resulting in a Np of 100.

The approach was flown with both engines running normally but with the No 2 propeller feathered and the power lever at FLIGHT IDLE; No 1 engine condition lever remained at MAX GOVERNING. An uneventful landing was made at Leuchars at about 1814hrs.

## **Meteorology**

An aftercast prepared by the Meteorological Office at Bracknell indicated that there was a deep depression, 971 mb, centred to the north of the Shetland Isles which was moving slowly north-east. A trough of low pressure embedded in the unstable westerly airstream gave strong to gale force winds in the vicinity of the incident. There were occasional showers of rain, hail or snow in which the visibility reduced to 5 km. The main cloud base was 4,000 feet, although there were small amounts with base at 1,000 and 1,500 feet. The wind/temperature profile was as follows:

Surface 230°/30 kt gusts to 45 kt veering to +4°C/0°C

250°/25 kt gusts to 35 kt

2,000 feet 300°/70 kt 0°C/-5°C

5,000 feet 270°/60 kt -5°C/-8°C

10,000 feet 270°/52 kt -15°C/-30°C

The 1750 hrs METAR for Aberdeen was:

EGPD 25023G33KT 200V280 9999 SHRA FEW12CB SCT015 04/M00 Q0982 TEMPO 5000 BKN012

## **Crew's flying experience**

The commander started flying in 1979 and gained an AFI and then FI rating which is still current. He gained a CPL in 1985 and flew air taxi, night mail and air ambulance flights in PA31/34 type aircraft. In 1988 he became a first officer on DHC-7 aircraft and was later promoted to Captain. From 1990 to 1991, he was a first officer on the Shorts Belfast, before returning to the DHC-7 as a Captain in June 1991. He converted to the DHC-8 in June 1996. His initial technical examination was based on the 100 series aircraft which has a different torque sensing system.

The first officer started flying in 1984. He completed the PPL then BCPL courses, gained an AFI rating and started work part time as a flying instructor in May 1993. He passed his ATPL exams and Instrument rating and flew as a first officer on Kingair aircraft from May 1995. The following May he joined the company as a first officer. At the time of the incident he had a total of 1750 hours of which 386 were on type. His initial technical examination was also based on the 100 series aircraft.

## **The autofeather system**

The autofeather system is selected by a single switchlight on the lower right engine instrument panel; it is used only for takeoff. When the switchlight is pressed a green SELECT caption illuminates to indicate that the system is selected. The system is armed when the power levers are advanced and both engine torques are above about 38%; an amber ARM caption illuminates in the bottom half of the switchlight.

The Autofeather Controller receives inputs from potentiometers on the power levers which provide Power Lever Angle (PLA) information and also Outside Air Temperature values from the Digital Air Data Computer. From this a discrete PLA 'HI' or 'LO' signal is output to a Torque Signal Condition Unit (TSCU) associated with each engine (PLA 'HI' equivalent to a torque demand of 60% or greater for a correctly rigged system). When the crew select Autofeather, each TSCU becomes enabled when it is in receipt of its own (local) PLA 'HI'.

Each TSCU also receives actual local torque information from one of two sensing coils on its associated engine. Values of torque greater than 38% result in a local torque 'HI' discrete being generated. This is also fed to the remote TSCU and when a TSCU is in receipt of both local and remote torque 'HI' signals, its autofeather status changes from 'enabled' to 'armed'.

Transition to 'armed and failed' occurs when local torque drops below 22% on the correct standard of TSCU applicable to G-BRYP (see later paragraph). The affected TSCU will immediately send an uptrim signal to the remote engine Electronic Engine Control (EEC) to uptrim its torque by about 10% and a green UPTRIM advisory light will illuminate on the engine control panel. If this condition lasts uninterrupted for 3 seconds, the TSCU transitions again to 'not armed and feather' and the propeller is feathered. The TSCU is latched in this condition unless the Autofeather selector is switched OFF, or both PLA 'HI' discreets are removed, or the remote torque 'HI' is removed.

Whilst one coil in each torque sensor provides information to the TSCU for Autofeather purposes, the other is effectively a separate channel supplying torque data to the ARINC 429 data bus, where it is used by the cockpit instrument display and by the DFDR. In addition, it is used by the EEC for closed-loop power calculations for 60 seconds after uptrim occurs.

Under normal operation, the EEC propeller speed governing logic would adjust the engine fuel schedule to prevent propeller operation below the minimum speed of 785 RPM. When a propeller feathers a cancel signal from the TSCU overrides this governor to prevent the possibility of propeller/engine overtorque as the propeller slows to below the minimum speed. However, should the propeller feather with the engine operating and the power lever at a high-power setting, an overtorque situation will still occur. Should the TSCU cancel signal fail, a back up signal from the torque gauge is initiated when the overtorque limit of 115% is reached.

An auxiliary feathering pump is energised and provides supplementary oil pressure for 18 seconds before automatically shutting off. Once the autofeather sequence has been initiated on one propeller, an interlock prevents autofeather of the other propeller.

The alternate feathering system provides a back up means of manually feathering/unfeathering a propeller if movement of the condition lever fails to achieve full propeller feathering/unfeathering. Provided the power lever is at or above flight idle and the condition lever in START/FEATHER, the alternate system can be used regardless of whether or not the engine is running. If the autofeather system is armed the alternate system will also initiate an uptrim.

### **Pertinent flight crew notices**

The Operations Manual Vol 3 - Supplementary, copy supplied to the AAIB dated 2 March 1995, contained, in part, the following:

"TORQUE SIGNAL CONDITION UNIT

Bombardier have advised ----- of an unusual set of circumstances which have occurred on rare occasions to other operators, namely a false sensing of low torque by the Torque Signal Condition Unit (TSCU) which causes automatic uptrim and autofeather with cockpit indications which are not obvious unless pre-warned:

In series 100 Aircraft TSCU failure results in:

1. Torque Gauge reads ZERO (despite high over-torque)
2. Uptrim light illuminates with simultaneous uptrim of other engine
3. Np decreases to approximately 600 RPM
4. Autofeather ARM light extinguishes
5. Aircraft yaws away from uptrimmed engine

In series 300 Aircraft TSCU failure results in:

1. Torque gauge reads approximately 140%
- 2, 3, 4 and 5 as for 100 Series Aircraft above

In both cases, all other engine parameters remain the same as before the failure."

and:

"To minimise exposure to this serious situation, and to fit in with the requirement to switch OFF the AUTOFEATHER at once should ECU failure occur on take-off, the after take-off SOPs are changed with immediate effect so that the RHS switches OFF the AUTOFEATHER just prior to reducing power to MCP."

Flight Crew Notice: 37/96 was issued on 25 June 1996 by the Operator; it contained, in part, the following:

"In a recent incident with another Dash 8 operator, a selection of an engine intake door open resulted in the engine flaming out and feathering. The cause was traced to a chafed wiring loom in the fuselage, which had resulted in a signal for the emergency fuel valve to close."

**Previous incidents of a similar nature**

The operator was in possession of two notifications from Bombardier concerning uncommanded autofeather and opposite engine uptrim events. The first of these was dated 19 December 1990 and was an In-Service Activity Report (ISAR) No 90-12-6120-00 and mentioned that four cases of uncommanded Autofeather were being investigated by the manufacturer. In three of the four cases

there had been a loss of torque indication similar to that experienced on G-BRYP (but on the Autofeathered engine itself), with the display showing zero analogue and dashed digital display. This was explained as being due to an overtorque condition which, when it reached 135% would be interpreted as an out-of-range situation by the indications system.

The second notification, also an ISAR, was dated 15 February 1995 and numbered 95-02-6100. This reported a case whereby an apparently faulty torque probe led to intermittent low torque signals to the TSCU and caused associated uptrims of the opposite engine. The ISAR presented information on the symptoms to assist troubleshooting on both series 100 and 300 aircraft, again pointing out that a zero/dashes torque indication could result if the propeller actually does feather on engines programmed with early-standard EEC software. For later standards of software, the indication was said to read Maximum on the analogue and 199% on the digital display. Also mentioned was the fact that provision of separate torque channels on the series 300 aircraft could result in a normal torque indication to the crew on an engine which is experiencing a varying torque signal on the control channel.

The extract from the Operations Manual quoted in the paragraph above seems to imply that this operator's series 300 aircraft were fitted with EEC's programmed with the later standard of software which does not indicate zero/dashes when receiving high overtorque signals from the torque sensors. However, the figure quoted of 140% does not relate to either of the two software standards mentioned in the Bombardier ISAR.

When queried about the precise origin of the information behind the Operations Manual Supplement, the operator said they recalled that it had been gathered during a personal visit from a Bombardier design specialist.

### **Engineering investigation and analysis**

From the information provided by the crew and analysis of the FDR data, it was clear that the fluctuations in torque of No 2 engine which precipitated the subsequent events were caused by uptrim commands due to erroneous low engine No 1 torque signals being received by its EEC. These signals were not reflected either in the cockpit instruments or the data recorded on the FDR which are fed by a separate channel which did not receive the erroneous signals. It was also clear that the spurious signals were intermittent, since they did not initially result in a feather command to No 1 propeller which requires the signal to be present for a minimum of 3 seconds. However, the uptrim command to No 2 engine EEC was received immediately each time the low torque signal was sensed. It is for this reason that the first uptrim command exceeded the intended nominal 10% increase by a factor of about three, since the first intermittent signals were received in such quick succession that the EEC 'ramped' up the command each time until the limit of 107% torque was reached. According to Pratt and Whitney Canada (PWC) the peak figure of 111% recorded was due to overshoot. The subsequent excursions in torque were more in line with the nominal uptrim schedule.

The No 1 and No 2 torque sensing probes, and No 1 TSCU were despatched to PWC for testing and examination. No significant defects were discovered but the TSCU was found to be of an inappropriate type for use on the PW123 engines fitted to G-BRYP, having the part number 30005-0000-46 and intended for use on PW120 and PW121 engines but repeated testing did not reveal any faults or anomalies with the unit. According to PWC, fitment of this incorrect model of TSCU to the particular modification standard was probably not significant in this incident since the principal difference in performance of the unit lay in the trigger torque for Autofeather of a 'failed' engine

being increased from 22% to 29%. Since the reason for the erroneous triggering signal probably lay in an intermittent open or degraded circuit (as discussed in the next paragraph), the TSCU may have been sensing effectively zero or very low torque and the variation in trigger point therefore was probably of minimal significance.

It was suspected at an early stage that the reason for the spurious autofeather signals probably lay in intermittent poor contact of the connections within the engine nacelle associated with the Autofeather system. Such poor contacts would be difficult to trouble-shoot on the ground because they could be influenced by vibration and transient moisture contamination. Examination of the TSCU did show signs of light, greasy contamination of connector receptacles J6 and J7, although it was not possible to categorically state that this was responsible for the malfunction. Bombardier have, however, pointed-out that the AFM had been revised to require deselection of autofeather *prior* to reducing power after take off because the reduced propeller RPM results in a reduced voltage output from the torque sensor. Hence a torque signal circuit degraded by, say, contamination of a connector would be more vulnerable to generating a spurious low torque signal at this time. It is for the same reason that Service Bulletin 21456 was introduced to help overcome such problems (see below).

Arising from previous incidents involving spurious low-torque signals, PWC had developed two modifications and a maintenance practice to minimise the problem and has advocated to the operator:-

Service Bulletin (SB) 21456. This modification introduced a revised torque sensor shim which optimises the air gap in the sensor, increasing its signal strength and hence reducing its sensitivity to noise caused by vibration. This modification was not embodied on the operator's fleet.

SB 21463. This modification introduced a new engine wiring harness having improved connector sockets which are less susceptible to fretting damage, have better locking retention and improved sealing against moisture ingress. This modification was also not embodied on the operator's fleet.

In addition, the Dash 8 Maintenance Review Board had required periodic removal and cleaning of connectors and retorquing and re-taping of connectors. Embodiment of SB 21463 obviated the above requirements, which the operator was not performing.

### **Discussion of the incident**

The commander's decision to delay the selection of climb power was the initiating event in the sequence which started with the failure of the first officer to disarm the autofeather system and allowed a train of events to occur which could have had more serious consequences. It is clear that had the standard practice of 'autofeather disarm - select climb power' occurred at the normal point, this incident would not have happened. However, the subsequent problem could have occurred at any time after the autofeather system had armed during the take off roll and it has served to highlight both the engineering problem of erroneous signals in the TSCU system and the difficulty experienced by the crew in their analysis of the situation, exacerbated by the fact that the fault in the operating channel of the torque sensing system was not reflected in the indication channel. Indeed, it is difficult to see the logic in having separate channels in this way since a simplex failure can still result in an uncommanded autofeather. The provision of an independent indication channel in this case served only to confuse the crew.

The crew may have identified the problem as an autofeather if it had initially manifested itself as an increase in No 2 engine torque followed 3 seconds later by No 1 propeller feathering. Even with the normal No 1 engine torque gauge reading, they may have related the higher No 2 engine torque to the feathered No 1 propeller and carried out the UNSCHEDULED FEATHERING DRILL and landed safely without further incident.

The green uptrim light would have been flashing in sympathy with No 2 engine torque fluctuations, indicating to the crew that the engine was uptrimming in response to a signal from the autofeather system. However, it is a small light and is not compelling, being an indicator of activity rather than a warning; given its position and colour, it is not surprising that, during the high workload departure phase, they did not notice it among the many other flightdeck lights. The autofeather switch light would have also been illuminated with either SELECT or ARM depending on the state of the system at the time. The crew did not positively check these lights because they did not at any time suspect that the problem was in the autofeather system.

The commander had come to terms with a No 2 engine problem, of unknown source, which could be contained by a power reduction; there was no concern for the No 1 engine which appeared to be functioning normally. When the No 1 propeller feathered, seemingly as a consequence of the selection of the bypass door to closed, the commander thought that he now had a further problem this time with No 1 engine. He recalled having read about an engine flameout and subsequent propeller feathering associated with the selection of the bypass doors and was convinced that this was the most likely cause. In fact the autofeather system had been triggered by the erroneous low torque signal which had now been present for over 3 seconds. The attempt to unfeather No 1 propeller using the alternate unfeather switch failed because the autofeather system uses the same oil pump and it would have been locked out when the autofeather system had operated. The alternate unfeather switches are adjacent to the autofeather switch light on the lower right side of the central instrument panel but neither pilot noticed that it was illuminated nor that the uptrim light on the left side of the panel was also illuminated.

When, during the descent into RAF Leuchars the commander closed the No 1 bypass door and shortly afterwards No 1 propeller unfeathered, it took him completely by surprise and he misinterpreted the event as a failure of the No 2 engine. The commander over-reacted to the situation and failed either to consult the first officer or to get him to confirm his subsequent actions. The first officer reacted quickly and decisively when he told him he had taken the wrong action. However, he then misled himself into thinking that No 2 engine had flamed-out, since he attempted to re-light it by moving the condition lever into the START/FEATHER detent and operating the start switch. Doubtless this misapprehension resulted from the zero/dashes display on the torque gauge but there were other parameters such as fuel flow, and Ng which could have given clues to the fact that the engine was running normally.

The reason why the No 2 engine torque indication displayed in this manner are not immediately obvious, since the DFDR indicated a peak torque of somewhat less than 100% immediately prior to the loss of indication - much less than the gross overtorque which, as has been explained, can be interpreted by the EEC as out-of-range. Bombardier have advised that they believe they can explain the reason, having experienced it during simulated engine failures which produced similar conditions during flight-test. In these cases it was determined that the *rate of change* of torque signal was beyond the capabilities of the EEC software, which interpreted it as an out-of-range signal. Reset of this condition can be accomplished via the EEC mode selector or by a power reset.



With the benefit of hindsight, and for the crew a review of the incident in a flight simulator, the sequence of events appeared totally logical and easily explained. However, it would be unreasonable to expect the average crew to have done this type of analysis when confronted with this situation under the prevailing flight conditions. The main criticism would be of the commander's overreaction when No 1 propeller unfeathered due to the reduction in torque of No 2 engine and his subsequent lack of consultation with the first officer before shutting down No 2 engine. As, at this point, he did not realise that No 1 propeller had unfeathered, he had effectively taken action to shut down the only source of thrust available to him. Fortunately for the outcome No 1 engine/propeller combination was now producing thrust and a safe landing was made.

When No 1 propeller unfeathered the commander was totally confused, very apprehensive and probably near his workload saturation level. The first officer reacted quickly and positively when he identified the commander's incorrect action but was otherwise probably in a similar mental state. Despite formal flight deck management training and practice under normal flight conditions, it is understandable that a pilot with a mainly single crew initial experience background may revert to trying to do everything himself when under stress. The lesson to be learnt is that it is generally better to take time to consider and discuss the situation rather than to take precipitate action. It is to the credit of the crew that throughout the event they retained control of the flight path of the aircraft.