De Havilland Canada DHC-8-311, G-BRYJ

AAIB Bulletin No: 12/2003	**Ref: EW/C2003/03/01**	**Category: 1.1**
INCIDENT		
Aircraft Type and Registration:	De Havilland Canada DHC-8-311, G-BRYJ	
No & Type of Engines:	2 Pratt & Whitney Canada PW123 turboprop engines	
Year of Manufacture:	1991	
Date & Time (UTC):	2 March 2003 at 1035 hrs	
Location:	25 miles north of Edinburgh, Scotland	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 4	Passengers - 29
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	40 years	
Commander's Flying Experience:	3,300 hours (of which 2,200 were on type)	
	Last 90 days - 86 hours	
	Last 28 days - 25 hours	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft, in the climb with the autopilot engaged, failed to level at the selected altitude of FL170. The combined effort of both pilots to level the aircraft manually was also ineffective. The recall actions for an 'elevator jam' were initiated and reduced elevator authority was regained on selection of the 'pitch disconnect handle'. The crew transmitted a 'MAYDAY' and, without further incident, and with the assistance of radar vectors, carried out as flapless landing on Runway 24 at Edinburgh. Even though the anti-icing systems were used during the climb, flight data analysis suggested that the control difficulties were due to a restriction of the right elevator spring tab brought about by ice contamination. Post flight examination revealed the presence of re-hydrated residues of anti-icing fluids remaining from previous fluid applications. It is possible that this re-hydrated gel, very low in glycol content and with a freezing point of approximately -1.1ºC, had frozen around the bearings. Two safety recommendations are made: The first addresses the implementation of advice given to operators on airframe inspections and cleaning of aerodynamically 'quiet areas' where residues can accumulate, and the second highlights the need for anti-icing fluid manufacturers to develop gelling agents, with suitable holdover times, that are not re-hydratable.

History of the flight

When the crew arrived at Aberdeen they were notified that there had been an aircraft change and they were now scheduled to operate G-BRYJ on a flight to Manchester. The aircraft had been parked at Aberdeen since the previous day and had been subject to steady rain conditions on the morning of the flight. When the First Officer (FO), who was to be the handling pilot, carried out his external checks he noted that everything appeared normal except for some moisture in the baggage door seals.

The aircraft was cleared to taxi to the holding point for Runway 16 at 1013 hrs and was cleared to take off at 1020 hrs. The FO hand flew the aircraft initially and engaged the autopilot (AP) at approximately 6,000 feet in the climb. The aircraft had been cleared to FL170 and the climb was continuous. During the climb all anti-icing systems were selected ON including that for the elevator horn. As the aircraft commenced to level at FL170 the crew noted that the pitch attitude did not appear to be reducing. At about this time the crew recalled seeing brief successive messages for 'MISTRIM (TRIM NOSE UP)' followed by 'MISTRIM (TRIM NOSE DOWN)'; each message appearing for only a second or two before extinguishing.

The FO disengaged the AP but was unable to lower the nose of the aircraft. He requested assistance from the commander but there appeared to be very limited movement of the control column. Both pilots pushed with a considerable force that they were unable to quantify, but the aircraft continued the climb to FL175, with an indicated airspeed of approximately 190 kt. The commander called for the 'recall items' for an elevator jam and immediately upon rotation of the pitch disconnect handle he regained elevator control, albeit with reduced authority. The commander then assumed the role of handling pilot and called for the Quick Reference Handbook (QRH) drill for a jammed elevator. After disconnecting the elevators the commander had normal control of the trim wheel whereas the FO felt that he had some restriction of his trim wheel and no response to his elevator control inputs.

The crew notified ATC of their problem and, as they were still climbing through their assigned level, declared a MAYDAY, requesting diversion to the nearest suitable airfield. They were given radar vectors to finals for Runway 24 at Edinburgh and were visual with the runway at 2,100 feet at a range of 8.5 miles. During the descent and approach the commander was aware of reduced pitch response to his elevator control inputs but experienced no problems in controlling the aircraft. The landing, from a flapless approach, was completed successfully at 1102 hrs.

Meteorological conditions

The Meteorological Office provided an aftercast for the Aberdeen area. The synoptic situation at 1200 hrs UTC on 2 March 2003 showed an occlusion moving away to the east as a ridge of high pressure began to build over the British Isles. At Aberdeen the reported conditions at 1020 hrs were: surface wind of 200°/08 kt, visibility greater than 10 km, a few clouds at 3,000 feet, scattered cloud at 10,000 feet, broken cloud at 16,000 feet, the temperature was +5°C, the dew point was +3°C and the QNH was 1004 hPa. There had been 3.0 mm of rainfall the day before and 5.4 mm of rain on the day of the incident, up to the time of take off.

The temperature gradient, together with dew points and humidity are presented below:

Height agl (ft)	Temp (°C)	Dew Point (°C)	Humidity (%)
Surface	5.1	2.6	84
2,000	1.6	1.2	97
5,000	-4.3	-6.4	85
10,000	-13.3	-20.3	56
14,000	-21.3	-35.3	27
18,000	-31.7	-42.7	33

Pitch control system

There are two independent elevator control cable circuits, each operating independently mounted, spring-tab assisted elevators. The left elevator is actuated by the captain's control column and the right elevator is actuated by the co-pilot's. Both control columns are normally interconnected to provide simultaneous movement of both elevators but can be disconnected should a jam occur.

The pitch disconnect system is operated by a vertically mounted pitch disconnect handle located in the centre console. This disengages a spring-loaded clutch within the pitch interconnect torque tube. Disengagement of the clutch allows each control column to operate its respective elevator circuit independently.

Trim tabs are mounted on the outboard trailing edge of the elevators and they are manually controlled by the elevator trim hand wheels mounted either side of the centre console in the cockpit. The trim wheels are linked by an interconnect shaft. The control movement of the trim tabs is transmitted through chain and cable assemblies to screwjack actuators, which convert rotary motion into linear motion in order to operate pushrods that move the trim tabs to the desired position.

Autopilot pitch control is achieved via servos fitted to both the left hand elevator system and the pitch trim system. The elevator servo is monitored and if a long term load is detected a 'MISTRIM TRIM NOSE DN' or 'UP' message is displayed.

Cockpit Voice Recorder

The aircraft was fitted with a Cockpit Voice Recorder (CVR) which recorded flight crew speech and cockpit area microphone sounds on a continuous 30 minute loop when electrical power was applied to the aircraft. Unfortunately the circuit breaker had not been pulled after the incident flight, and thus any relevant information from the CVR had been over-written.

Flight Data Recorder

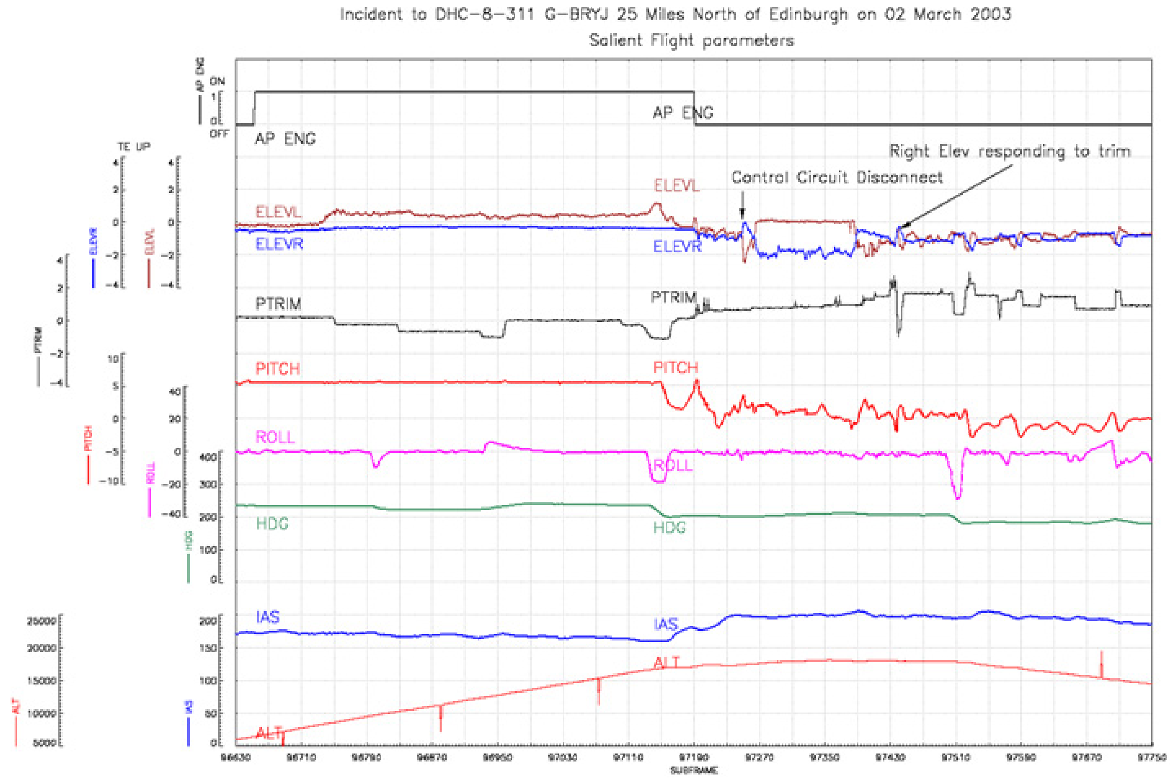
The aircraft was fitted with a solid state Flight Data Recorder (FDR) which recorded about 75 flight data parameters and discretes on a continuous 25 hour loop. These included relevant air data, engine and control surface parameters, but not the cockpit control positions or forces. All of the available flight data was recovered successfully.

Post-Incident Calibration of the Elevator Angles

As it was evident that the incident was related to potential problems with control in pitch, it was requested that the aircraft operator provide the AAIB with a calibration of the FDR left and right elevator angle parameters at 1/2° intervals, about the neutral positions, up to +/- 5°, and at 5° intervals for the remainder of the control surface movements.

Analysis of flight data

The relevant flight data parameters are shown in Figure 1. The autopilot was engaged about 5 minutes after takeoff with the aircraft in the climb at approximately FL64 at 173 kt. At this stage the left and right elevators appeared to be responding normally to the autopilot pitch trim inputs. Approximately 28 sec later however, whilst the aircraft was climbing through FL80, a pitch trim input was made by the autopilot. Whilst the left elevator appeared to respond to the trim input, the right elevator remained at a constant value of about -0.3°. The right elevator remained at this value until the autopilot was disengaged, about 8 minutes later at 181 kt and FL170. There were small movements of the left and right control surfaces at this time before the left and right sides of the pitch control circuit were split using the pitch disconnect handle. The splitting of the control circuit took place at around 180 kt and FL175 whilst climbing, about 57 secs after the autopilot was disengaged.



The left seat pilot subsequently controlled the aircraft using the left side only of the pitch control circuit, as, from Figure 1, the response of the aircraft in pitch matched closely the left elevator angle. It can also be seen that the right elevator was 'trailing', and not following the left elevator angle.

The right elevator appeared to resume responding to pitch trim inputs some 4 minutes after the pitch disconnect handle was operated with the aircraft at 197 kt and level at FL180; approximately 12 minutes after the original right elevator anomaly occurred.

Aircraft examination

The pitch disconnect system had been reconnected by engineers after landing and functional checks of the elevator and pitch trim systems were satisfactory. The cable tensions were checked and were within maintenance manual limits. There was no evidence of any moisture around the control runs and the chain assemblies appeared well lubricated. The hinge bearings for both spring and trim tabs were free to move, and again appeared well lubricated.

There was evidence of a gel with the consistency of 'wallpaper paste' around the spring tab and trim tab bearings. Figure 2 shows the tab arrangement together with a typical gel deposit found in the area of the hinge bearings.

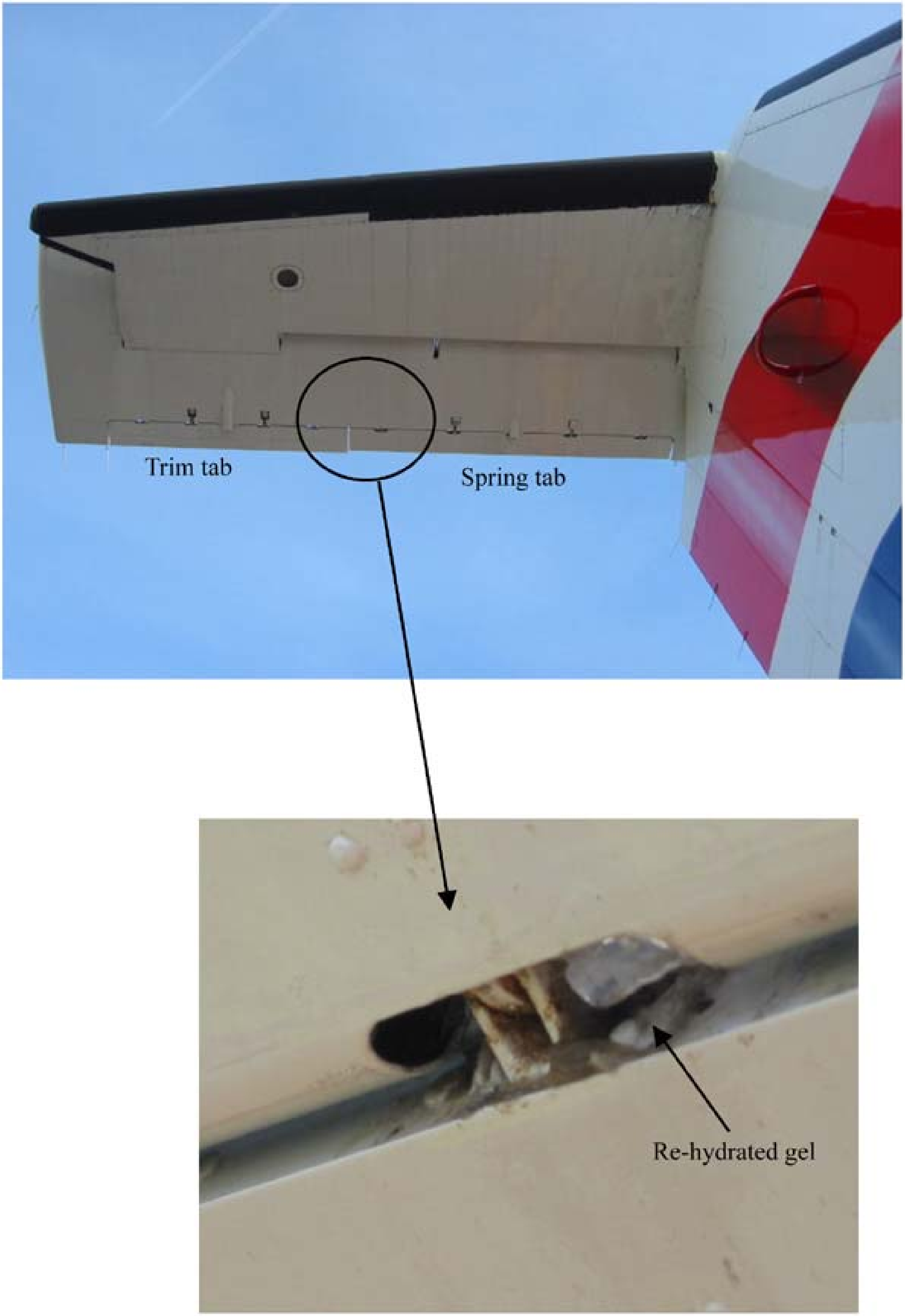


Figure 2
(Typical re-hydrated gel found around area of tab hinges)

The aircraft was ferried to Exeter for a scheduled maintenance check. Tests were also carried out in order to attempt to reproduce the icing conditions by attaching dry ice (frozen carbon dioxide) packs around the hinge bearings. Bearing temperatures were monitored and the tab surfaces tested for freedom of movement during the cooling process. The minimum bearing temperature achieved was -24°C. It was possible to lock the spring tab by spraying water onto the cooled bearings; however this freed immediately if the elevator was moved by a small amount. Both trim tabs remained free at all times.

The elevator trim screw jacks were removed together with the spring and trim tab hinge bearings. Unfortunately the hinge bearings were not returned to the AAIB for further examination.

The aircraft then flew without problems until a subsequent incident occurred on this aircraft on 17 April 2003, where the crew reported heavy elevator control forces. Investigation of this event found that the LH elevator cable was frayed and 'kinked' and the AP servo was 'notchy'. Both the cables and the servo were replaced and the aircraft has flown subsequently without any further incident.

De-icing history

The aircraft had been de-iced/anti-iced, due to the prevailing weather conditions, during the early part of February 2003 as follows:

Date	**De-Icing Fluid Type**	**Mixture Strength (fluid/water)**
3/2/03	Type II	50/50
3/2/03	Type II	75/25
3/2/03	Type II	75/25
5/2/03	Type II	100%
9/2/03	Type II	50/50
13/2/03	Type II+	100%
14/2/03	Type II	50/50
17/2/03	Type II	75/25
18/2/03	Type II	100%
19/2/03	Type II+	50/50

Since the last de-icing record on 18 February 2003 the aircraft had spent five nights at Aberdeen where it had been kept inside a hangar. There had been no rainfall at the other locations where the aircraft had been positioned overnight where it would have been parked outside.

The night before the incident flight the aircraft was again at Aberdeen, but on this occasion it was parked outside as the operator was no longer using the hangar facilities. There had been 3.0 mm of rainfall on 1 March and 5.4 mm of rain on 2 March up to the time of takeoff.

External cosmetic cleaning was a scheduled task controlled by Ground Operations and under this programme the aircraft was last washed at Southampton on 11 January 2003.

Aircraft de-icing and anti-icing fluids

A number of different types of de-icing and anti-icing fluids are used on aircraft.

Type I

International Organization for Standardization (ISO) Type I Fluid is unthickened with a high glycol content. Its de-icing performance is good but it provides only limited anti-icing protection during freezing precipitation.

Type II

ISO Type II fluid generally has a lower glycol content in its concentrated form than a Type I fluid due to the inclusion of a thickening agent. The presence of this thickening agent means that when the fluid is applied to the surface it remains on the surface protecting against freezing precipitation for a period of time. With this type of fluid the 'holdover time', when the anti-icing fluid prevents the formation of ice, can be extended by increasing the concentration of fluid in the fluid/water mix.

Type IV

ISO Type IV Fluid is similar to Type II however, with an advanced thickening system it is able to provide longer 'holdover times' when used in concentrated form.

Type II+

Type II+ Fluid is a new branded fluid of the same standard as Type II but with improved cohesive properties giving extended 'holdover times'.

The repeated application of Type II and/or Type IV Fluids may lead to the build-up of residues in 'aerodynamically quiet' areas, such as flying control cavities. These residues are from previous treatments which subsequently dry out and are actually deposits of the thickening agent and appear as a dirty dry stain on the airframe. Residues can accumulate over a period of time and subsequently be re-hydrated by moisture, generally in the form of rain or drizzle, to form a gel like substance. This has the consistency and appearance similar to wallpaper paste.

Analysis of fluid residues

The concentration of aircraft de-icing or anti-icing fluids is checked with a refractometer calibrated to measure refractive index (RI). The refractive index of water is 1.333. The RI increases with the concentration of fluid present and typically a 75% Type II de-icing fluid will have an RI of 1.377. The RI of the residues recovered from the area around the tab hinges on 'YJ' was between 1.3345 and 1.338. Laboratory analysis of the recovered residue gave a glycol content of less than 3% and a freezing point of between -1.1°C and -1.2°C.

Advice to operators

The CAA issued a 'Letter to Owners/Operators' (LTO) (No 2121 dated 13 November 2000) concerning 'Aeroplanes equipped with manual flight control systems and dealing with the use of Type II and Type IV de-icing/anti-icing fluid'. The letter included:

> *'CAUTION: The repeated application of Type II or Type IV anti-icing fluid may cause residues to collect in aerodynamic 'quiet' areas, cavities and gaps. These residues may re-hydrate and freeze under certain temperature changes, in high humidity and/or rain conditions. These residues may block or impede critical flight control systems and may require removal....*
>
> *....The operator shall review his anti-icing procedures when using Type II or Type IV fluid in order to ensure the absence of residue which could re-hydrate and adversely affect the operation of the aeroplane.....*

The LTO was cancelled at Revision A, on 10 December 2001, and superseded by the information contained in CAA Aeronautical Information Circular (AIC) No 81/2001 dated 15 November 2001 (cancelling the previously issued AIC 99/2000) that describes the effect of residues from Type II fluids as follows:

> *'Repetitive application of thickened fluids may lead to a build up of residues in aerodynamically quiet areas such as balance bays, and on wing and stabiliser trailing edges and rear spars. This residue may re-hydrate, and increase in volume to many times its original size during flight and freeze under conditions of certain temperature, high humidity and/or rain causing moving parts such as elevators, ailerons, and flap actuating mechanism to stiffen or jam in flight. It may also form on exterior surfaces which can reduce lift and increase drag and stall speed, block or impede critical flight control systems, and cause aerials to malfunction.'*

'Residues may also collect in hidden areas, around flight control hinges, pulleys on cables and in gaps, and inside flight control surfaces affecting water drainage and control balance.'

'Additional inspections may therefore be required to ensure that no build-up of residues has occurred in critical areas not visible from the ground. The operator should request guidance/instructions from the aeroplane manufacturer in order to establish satisfactory procedures to prevent, detect and remove residues of dried fluid with the potential to cause any of the problems as described above. Appropriate inspection intervals should be established.'

The information contained in the original LTO was updated by the issue of a new JAA Operations Directive and the findings of a Specific Objective Check (SOC) with a selection of Operators. Flight Operations Department Communication (FODCOM) 17/2001 also refers to the de-icing and anti-icing of aircraft.

'Following a fatal accident to one UK registered aircraft and a serious incident to another, a recent Specific Objective Check (SOC 1/2001) was completed to review the manner in which operators address the hazards associated with ice and snow accretion in the air intakes of turbo-prop and low bypass turbine engines. Analysis of the reports identified that, in some cases, a number of safety related issues exist, which should be considered by all operators.'

A manufacturer's Service Letter, DH8-SL-12-006H, dated 18 October 2002 gives advice on icing precautions and procedures for the DHC-8 concerning the use of anti-icing and de-icing fluids. The Service Letter relates 'no reported problems with the use of Type IV Fluid on the DHC-8, when the aircraft is operated in accordance with the information contained in the above referenced Service Letter. However, for those Operators that regularly use Type IV Fluids, it is recommended that they periodically wash the aircraft with hot water or a diluted Type I Fluid to ensure no residual Type IV Fluid accumulates in recesses or crevices on the airframe; especially in the region of the ailerons, aileron tabs, elevators and elevator tabs.' It is also stated that 'aircraft anti-iced with Type II Fluids be treated in a similar manner to those which are anti-iced with Type IV Fluids'.

Operator procedures

The operator issued a Technical Instruction (TI) D83-12-02, 15 days after the incident, on the subject of 'Inspection Following Application Of Approved Type IV and Type II+ De-Icing Fluids'. It required the following inspections to be carried out:

'Inspect all flying control surfaces and empennage for residue or gel from Type IV de-icing fluids.

If any contamination is found all traces should be washed off, preferably using a Type I de-icing fluid either at 100% or diluted at a temperature and concentration in accordance with the fluid manufacturers instructions.

If internal contamination is suspected, all drain holes, open areas and vents should be cleared and cleaned as necessary. If any doubt exists as to the amount of internal contamination then the control surface should be inspected via access panel or boroscope if necessary.'

and stated that:

'Where TypeII+ fluids are used it is recommended that if contamination of the aircraft's aerodynamic quiet area is suspected during an aircraft's post and pre-flight inspections the aircraft should be treated as per the Type IV inspection requirement in the main part of the TI0 prior to further application of de-ice / anti-ice fluids'

Prior to this there was no generic TI in force as all TIs had been converted to an 'aircraft-type-based issue system'. This conversion covered all company aircraft types except the DHC-8 which joined the

Company JAR 145 approval after this date with integration processes not fully completed by the date of the incident.

A further issue of this TI, dated 29 April 2003, was under discussion but was never issued as the Company concluded that an alternative method of addressing the risks, using a 'Company Engineering Technical Requirement (ETR)', was more appropriate. This ETR, due to be issued by the end of October 2003, will require the inspection of the aileron, rudder and elevator control surfaces, hinge points and associated 'quiet areas' for the presence of re-hydrated de-ice/anti-icing fluids on the DHC-8 at 30 day intervals from November 1 to April 30 inclusive each year. Furthermore it details the procedures to be employed.

Previous icing events

DHC-8 Aircraft

There have been reported incidents on the DHC-8 where freezing of the pitch trim tabs has been found to have been caused by water contamination of the grease inside the screw jack actuator. This problem was addressed by the introduction of dedicated lubrication points on the screw jack actuator and a modification to the lubrication procedure.

(All of this operator's aircraft have been modified. The screw jacks were re-greased following the incident, no visible moisture contaminant was evident, and subsequent examination of the grease samples taken showed no significant moisture content.)

DC9-82 Aircraft

A Swiss Accident Report described an incident involving a DC9-82 (also fitted with manual controls) on 29 January 1999 where the crew declared an emergency when the elevator became difficult to control. The investigation, that identified re-hydrated residues around the elevator and recommended that 'the Civil Aviation Authorities and the aircraft operators encourage anti-icing fluid producers to look at the use of non-rehydratable gelling agents'

BAe 146 Aircraft

An incident to a BAe 146 aircraft (G-JEAX), enroute from Birmingham to Belfast on 12 December 2002, in which elevator restrictions occurred is also under investigation by the AAIB.

Discussion

Analysis of the FDR evidence would suggest that the control difficulties experienced by the crew were due to a restriction of the right elevator spring tab. This prevented both the autopilot and the crew from achieving the desired pitch control using the normal elevator system with the left and right systems interconnected. When the pilots disconnected the left and right systems the commander regained pitch control but the FO still reported control difficulties. No problems were found with the elevator control system post-flight. The subsequent incident which occurred on this aircraft was considered to be unconnected with this event.

It is probable that the movement of the right spring tab was affected by ice. There had been significant rainfall prior to the incident flight which could have allowed trapped moisture to cause the formation of ice around the spring tab area. Post-flight examination also revealed the presence of re-hydrated residues from previous anti-icing applications around the hinge bearings. Laboratory analysis showed a very low glycol content, and a freezing point of around -1.1°C. Therefore the possibility existed that this re-hydrated gel had frozen around the bearings and thus caused a restriction. This phenomena has also been seen to effect other aircraft types fitted with manual controls.

CAA AIC 81/2001 states that additional inspections may be required to ensure that there has been no build-up of residues in critical areas, and that appropriate inspection intervals should be established. This operator issued a T1, following this incident, detailing new procedures for inspections to be carried out should contamination of the flying control surfaces with de-ice/anti-icing fluid residues be observed on their DHC-8 aircraft. Additionally the company will issue an ETR for precautionary routine winter period inspections.

Despite SOC 1/2001, that identified a number of safety related issues, and an AIC that gives information and advice, it would appear that some operators have not been fully aware of the effect of residues from anti-icing/de-icing fluids and do not have in place a suitable aircraft maintenance/inspection programme to negate the effects of re-hydrated anti-icing/de-icing residues.

The following recommendations are therefore made:

Safety Recommendation 2003-81

It is recommended that the Civil Aviation Authority satisfy itself that operators have in place the necessary measures to ensure that they have adopted the advice given in AIC 81/2001.

Safety Recommendation 2003-82

The Civil Aviation Authority should consult with anti-icing fluid manufacturers with a view to encouraging them to develop fluids, with suitable 'holdover' times, that incorporate gelling agents that are not re-hydratable.