INCIDENT

Aircraft Type and Registration:	DHC-8-402 Dash 8, G-JEDI
No & Type of Engines:	2 Pratt & Whitney Canada PW150A turboprop engines
Year of Manufacture:	2001
Date & Time (UTC):	21 December 2009 at 1052 hrs
Location:	London Gatwick Airport
Type of Flight:	Commercial Air Transport (Passenger)
Persons on Board:	Crew - 4 Passengers - 72
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to a wiring loom, and structure, in the left centre-wing section
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	33 years
Commander's Flying Experience:	4,241 hours (of which 2,677 were on type) Last 90 days - 108 hours Last 28 days - 35 hours
Information Source:	AAIB Field Investigation

Synopsis

During departure from London Gatwick Airport, the aircraft suffered a failure of its AC electrical system. A PAN was declared and the aircraft returned to Gatwick for an uneventful landing. Examination revealed wiring damage in the trailing edge area of the left centre wing that was due to chafing from the head of a blind rivet in a loom support bracket. The aircraft manufacturer has since issued a modification to replace the blind rivets with solid rivets and to inspect the wiring for damage.

History of the flight

The aircraft departed London Gatwick Airport on a scheduled passenger flight to Düsseldorf. As it climbed through 6,000 ft the following caution lights illuminated almost simultaneously on the caution and warning annunciator panel:

L AC BUS, R AC BUS, L TRU, R TRU, #1 AC GEN, #2 AC GEN

along with a series of associated system failure captions.

The commander judged that the L and R AC BUS cautions had illuminated first. As the aircraft continued to climb towards its cleared level of FL120 the pilots requested descent to avoid icing conditions. ATC cleared the aircraft to descend to FL110 but, because it remained in icing conditions with limited icing protection available, the pilots made a "PAN PAN" (urgency) transmission and requested further descent and diversion to Gatwick. The aircraft exited icing conditions at approximately FL100 in the subsequent descent.

The commander, as pilot monitoring, handed responsibility for radio communications to the co-pilot and began conducting procedures listed in the Emergency Check List (ECL), in the following order:

LOSS OF BOTH AC GENERATORS
(WITH PROP DE-ICE ON)
AC GEN CAUTION
TRU CAUTION

The commander briefed the senior cabin crew member after completing the ECL procedures and informed the passengers of the intention to return to Gatwick. Although the airframe appeared clear of ice the pilots elected, as a precaution, to conduct the approach using FLAP 35 at increased speed in accordance with company procedures for flight in icing conditions. The landing was uneventful and the aerodrome fire and rescue service that attended was not required to assist.

Engineering activity

The engineers at London Gatwick began to troubleshoot the reported problems with the AC electrical system by carrying out a ground run of both engines to assess the engine AC generator serviceability. Prior to this, the Electrical Power Control Unit (EPCU) had recorded in its memory a fault with the right AC generator. When the engineer selected the right generator to ON, he heard a loud mechanical 'clunk' noise and after this neither the left nor the right generator could be brought online. The Left and Right Generator Control Units were exchanged with each other; the EPCU registered a fault code that related to a fault with the left AC generator. The engineers decided to exchange the left and right AC generators, however, on removal of the left AC generator they discovered that its input drive shaft had sheared.

The right AC generator was then slaved into the left engine and an engine run carried out on the left engine only. Again, as the engineer selected the left generator to ON, there was a repeat of the loud mechanical 'clunk'. On inspection of the generator, they discovered that its input shaft had also sheared.

The engineers then carried out wiring checks and discovered that there had been significant damage to the wiring loom that runs within the trailing edge area of the left centre wing section.

Flight recorders

The two flight recorders were removed from the aircraft and replayed. The two-hour CVR had continued to run during the extensive maintenance activity after the flight and so had recorded over the airborne event and subsequent landing. The FDR had retained the recording from the incident flight and subsequent fault-finding work.

The takeoff and initial climb were uneventful. However, as the aircraft climbed through 5,900 ft, the standby hydraulic system pressure was recorded as reducing from 3,000 psi to about 100 psi over a period of about four seconds. As this pressure reduced, the status of the left and right AC generators and also both left and right AC buses changed to indicate that they were offline. These changes were accompanied by a Master Caution.

The aircraft briefly levelled off at 6,500 ft before the climb was recommenced. A maximum altitude of FL130 was achieved before starting to descend. Just prior to levelling off at FL80 the aircraft commenced a 150° right turn. Once established on a heading of 250°M the left

AC bus and left generator were recorded as coming back online. This was followed, 10 seconds later, by the right AC bus and generator.

The aircraft commenced its final descent and, whilst passing through 4,100 ft, again the status of both AC buses and both generators changed to indicate that they were offline. At the same time, the recorded values of standby hydraulic pressure briefly reduced to zero before returning to a steady-state indication of 92 psi. The landing and subsequent taxi were uneventful. Both AC buses indicated offline as the engines were shut down.

The remainder of the FDR recording confirmed the subsequent maintenance activity that had taken place.

Electrical system description and operation (Figure 1)

The Dash 8 electrical system is predominantly DC, however certain systems such as de-icing heaters, fuel auxiliary pumps and the standby power unit (SPU) hydraulic pump are powered from a frequency-wild 115 V AC electrical system. Each engine drives an AC generator which in turn supplies its respective AC Bus. Each generator is controlled by its own Generator

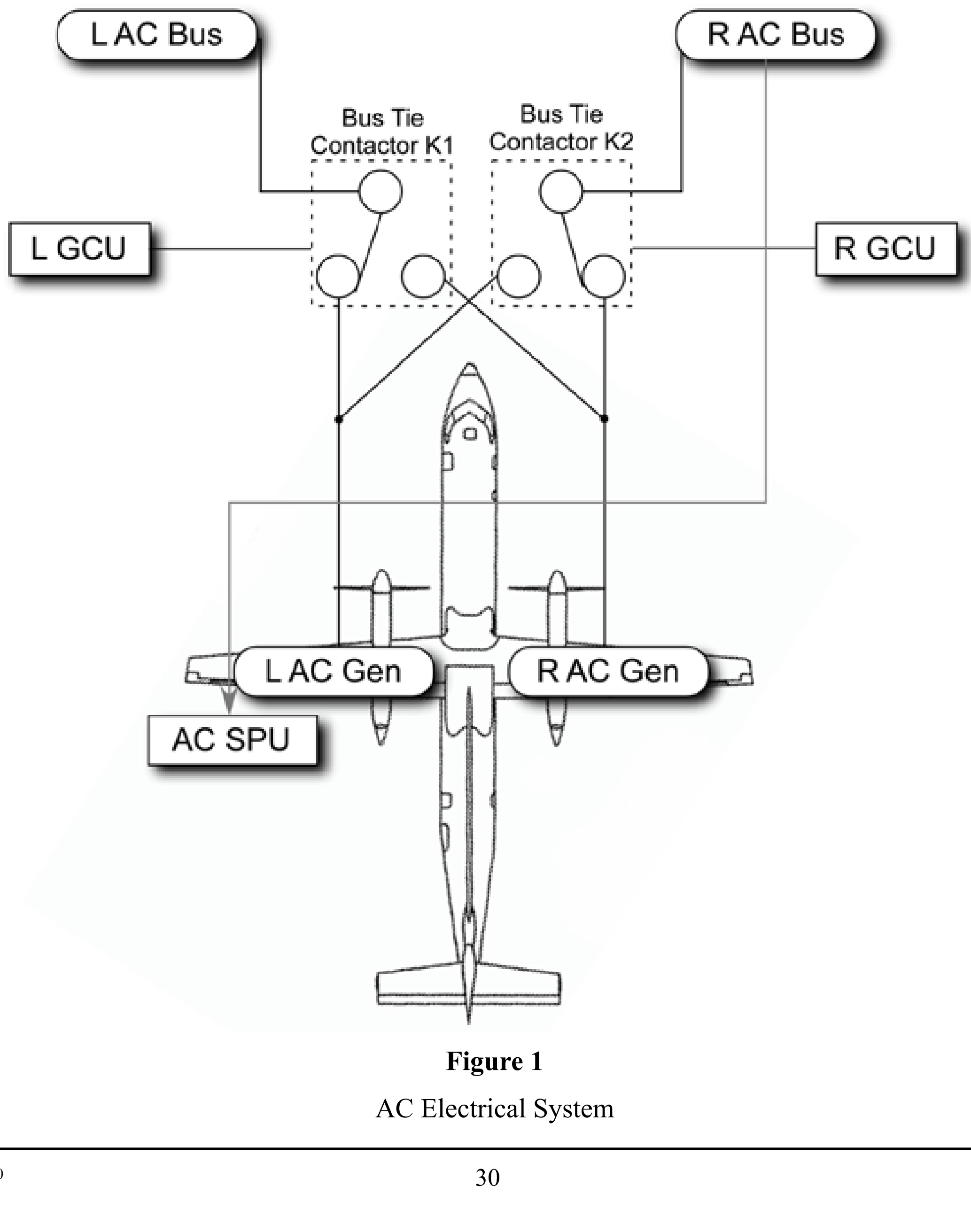

Figure 1

AC Electrical System

Control Unit (GCU). The Electrical Power Control Unit (EPCU) receives voltage and current information and uses this for output to the cockpit display; it also stores the last fault condition in its memory.

In the event of a fault with a generator, the related GCU will isolate the generator and illuminate the related '#1 AC GEN' or '#2 AC GEN' caution light on the cockpit warning panel. Contactors (K1 and K2) provide a means of powering an AC Bus from the opposite engine. In the event of a generator failure, the related contactor automatically connects the affected AC Bus to the serviceable generator. If the AC Bus is not powered, the 'L AC BUS' or 'R AC BUS' cautions lights are illuminated on the cockpit warning panel. The FDR records the status of the cockpit warning lights as an indication of the status of the AC Gen and the AC Buses.

The failure of the both the left and right AC Buses results in the loss of electrical power to the anti-ice heaters fitted to the pitot probes, the propellers and the engines. This results in the illumination of the associated caution lights on the cockpit panel. The majority of the remaining aircraft systems are powered by the DC electrical system and therefore remain functional.

On the ground, the two AC electrical buses can be supplied with external power when this is connected to the aircraft.

Aircraft examination

A wiring loom routed in the left centre-wing section had sustained extensive fire and overheat damage and was localised to an area where the loom was supported by the use of plastic tie straps attached to a support bracket riveted to the lower wing skin. The plastic tie strap and protective fibreglass tape, used to protect the loom from damage from the tie strap, were no longer attached to the loom and the plastic support bracket had melted (Figure 2).

There was evidence of arcing between the wires within the loom, as well as between the wiring and the aircraft structure close to the loom support bracket. Arcing had also taken place between the wiring and the head of the cadmium-plated blind rivet that attached the loom support bracket to the structure (Figure 3).

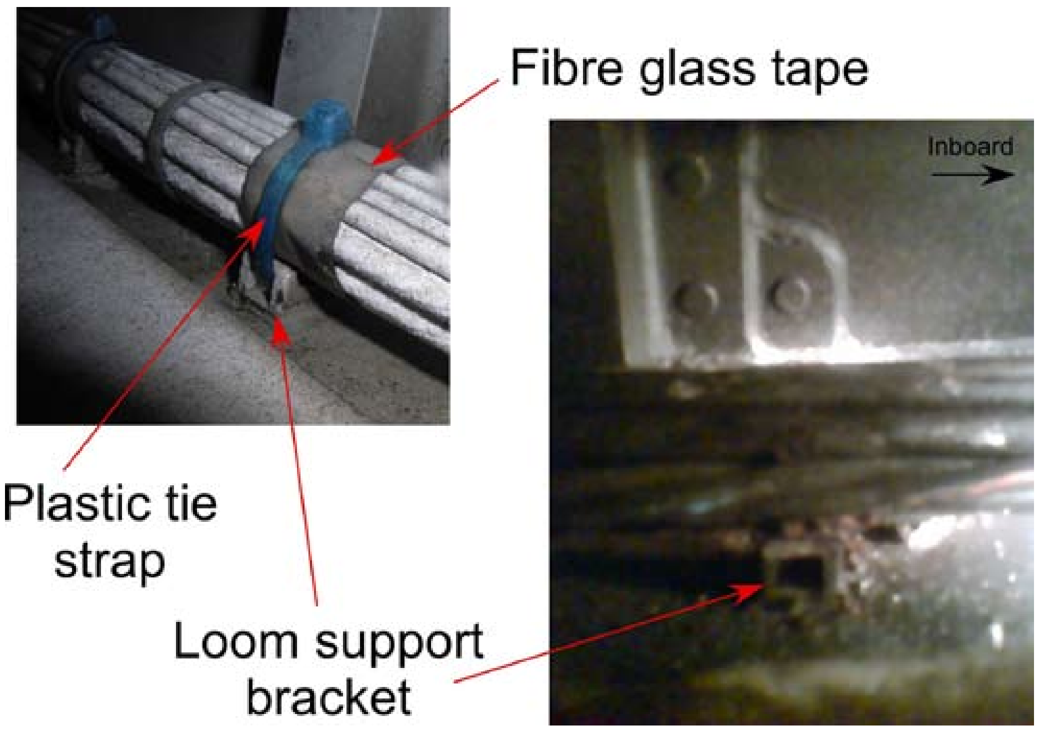

Figure 2

Loom support bracket

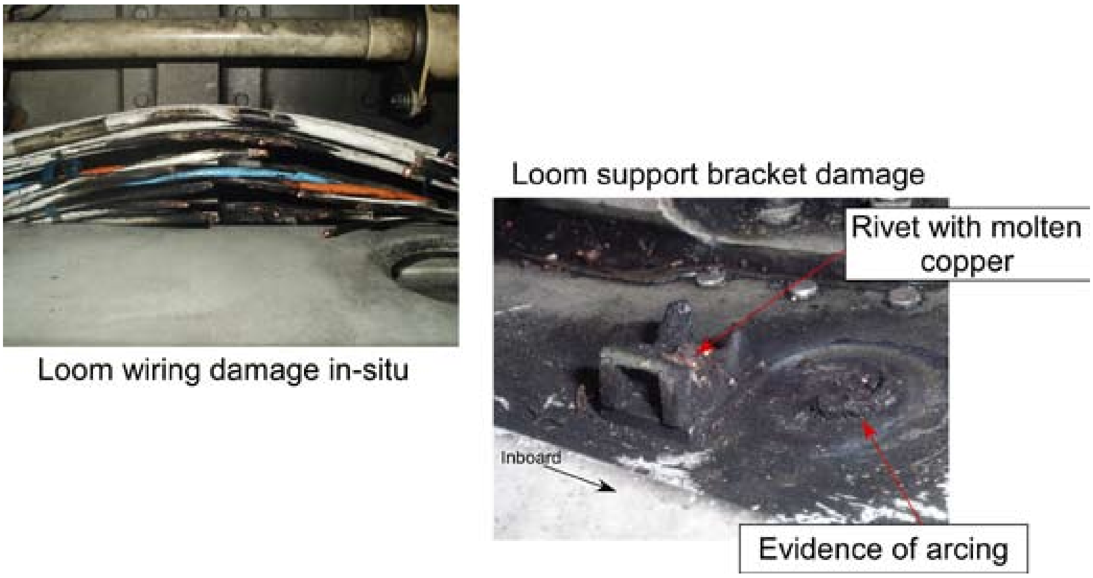

Figure 3

Wiring damage and evidence of arcing

The wiring loom and the remains of the tie straps, fibreglass tape and the loom support bracket were sent to a forensic laboratory for a detailed examination. The loom contained 22 wires, some of which had fused due to the arcing and fire, this had resulted in the loss of most of the evidence of the original mode of failure. The wires were analysed using various methods of microscopy, which showed that they had signs of localised mechanical damage, with one wire showing abrasion with a sharp object. Later examination of the abrasions on the wire showed them to contain particles of cadmium and iron.

Analysis of the remains of the tie straps and protective fibreglass tape recovered from the aircraft were also analysed. These had suffered from the effects of the fire. However, one of the tie straps had a notch which appeared to be due to mechanical damage and heat, and contained a considerable number of cadmium particles.

The affected wiring loom contained wires providing power from:

- The left AC bus to the left propeller de-icing system
- The right AC generator power feed to the contactor K1 in the left engine nacelle
- The left AC generator electrical power feed to the contactor K2 in the right engine nacelle
- The right AC bus to the standby power unit (SPU) in the left engine nacelle
- The left AC bus to the volt sense input to the EPCU
- The external power bus to contactor K1 in the left engine nacelle

The manufacturer examined and tested the AC generators removed from G-JEDI and, apart from the fractured spline shafts, they were found to be serviceable. Also, contactors K1 and K2 were removed and tested and were also found to be serviceable.

Analysis

Engineering issues

The examination of the wiring loom indicated that the failure resulted from chafing by the head of the blind rivet that secures the loom support bracket to the aircraft structure. The action of inserting a blind rivet causes a shear lip on the inner stem. The loom sits upon the loom support bracket and the tie wrap is inserted around the loom and over the head of the rivet and its stem. Over time the relative movement of the wiring loom to the fixed support bracket caused localised chafing, firstly, of the tie strap and then of the wiring loom itself. The stem of the rivet is cadmium plated and particles of cadmium were found in the tie strap and wiring recovered from the area of the fire. There are no other items in the affected area that are cadmium plated and therefore the particles can only have come from the blind rivet stem.

The chafing reached an extent where the insulation of one of the wires was compromised and a short, with associated arcing, occurred between the wire and rivet stem, which would have had a ground potential. This arcing would have led to localised heating and damage to the other wire's insulation and eventual arcing between wires as well as the structure.

The first indication that the chafing had reached the extent that shorting was taking place was the indication to the flight crew of the failures of the AC electrical system. It is likely that the GCU detected over current due to shorting in the left generator supply. The GCU would then have automatically switched over contactor K1 so that the Right AC generator was supplying the Left AC bus. However, the affected wiring loom also contained wiring that was supplied from the left AC bus, and this therefore led to faults being detected by the right GCU and the subsequent shutting down of the Right AC generator. With both generators now deactivated, there was no longer an AC supply to the left and right AC Buses and the systems supplied by them would also have failed as a result of the loss of power.

It is likely that the left generator drive shaft was still attached during and following the flight. However, when the engineers powered up the AC electrical system on the ground, high currents within the system, from the potential paralleling of the frequency wild generators due to the wiring loom damage, would have caused the generator to electro-magnetically lock and the drive shaft to shear as designed.

Safety action

Based on the findings of this investigation the aircraft manufacturer issued a modification for operators to replace the blind rivets on the loom support bracket with solid rivets, and to inspect the wiring for damage. Transport Canada has since issued Airworthiness Directive CF-2010-08 which mandates the rivet replacement and wiring inspections.