Beech Super King Air B200, G-BPPM

AAIB Bulletin No: 1/2002	**Ref: EW/G2001/06/16**	**Category: 1.2**
Aircraft Type and Registration:	Beech Super King Air B200, G-BPPM	
No & Type of Engines:	2 Pratt & Whitney Canada PT6A-42 turboprop engines	
Year of Manufacture:	1982	
Date & Time (UTC):	13 June 2001 at 0610 hrs	
Location:	Aberdeen Runway	
Type of Flight:	Public Transport (Passenger)	
Persons on Board:	Crew - 2	Passengers - 4
Injuries:	Crew - None	Passengers - None
Nature of Damage:	Damage to engine and propellers; minor airframe damage	
Commander's Licence:	Airline Transport Pilots Licence	
Commander's Age:	45 years	
Commander's Flying Experience:	6700 hours (of which 1000 were on type)	
	Last 90 days - 200 hours	
	Last 28 days - 35 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot and additional AAIB investigation	

History of the flight

The aircraft was due to conduct a scheduled flight from Aberdeen to Humberside. During taxi it was noted that the flight director annunciator remained it its dimmed condition irrespective of the

switch position. The problem was corrected after the switch was recycled three times. The aircraft then made a normal departure.

Shortly afterwards however, the tower passed a message to the effect that the landing gear had remained in the down position. The crew noted that although the landing gear selector was in the UP position, the three green indicator lights were illuminated indicating that the landing gear was 'down-and-locked'. The landing gear selector was recycled, with no effect, and the landing gear control circuit breaker was checked, but it had not tripped.

The commander handed control to the First Officer whilst he referred to the Emergency Checklist as the aircraft was held orbiting offshore. The landing gear circuit breaker was pulled and reset, but this had no effect. Whilst the aircraft was still orbiting, with the autopilot engaged, the red Master Warning and the AP (Autopilot) FAIL lights both illuminated, followed by disengagement of the autopilot. About one minute later, the commander's attitude indicator and altimeter both failed, with an accompanying 'electrical ozone' smell. The instruments were restored after their electrical supply was selected to the No 2 inverter, although there had been no 'fail' indication for the No 1 inverter. (Note: any inverter failure would be indicated only after the loss of the 28 volts DC input to that inverter, not its AC output).

The commander took control of the aircraft and returned to Aberdeen Airport where he was cleared to conduct a 'fly-past' 100 feet above the runway in order to have the status of the landing gear checked by observers on the ground. He was then informed that the gear appeared locked-down. Following the subsequent go-around a normal circuit and approach was flown, during which the passengers were briefed on the situation. The touchdown was normal, however during the rollout the gear slowly collapsed. The First Officer shut down the engines and feathered the propellers. The passengers exited the aircraft via the rear doors; no injuries were sustained by either passengers or crew.

Description of landing gear system

The tricycle landing gear was operated by an electric motor and gearbox assembly located on the forward face of the main spar under the cabin floor. The screwjack-type main gear actuators were driven by torque shafts from the motor gearbox, and the nose gear actuator was driven by a chain from the gearbox torque shaft. Down-locks were provided by notched hook and plate attachments on the main gear drag braces, with an 'over centre' action on the nose gear drag brace.

The electric motor was a split-field, series wound unit. One field drove the motor in the gear UP direction and the other drove the motor in the gear DOWN direction. The energising of the motor field windings was controlled by a motor control relay box. To prevent overtravel of the landing gear, a dynamic brake relay within the relay box simultaneously breaks the power circuit to the motor winding in use and makes a complete circuit through the armature and the unused field winding. This causes the motor to act as a 'generator' and the resultant electrical load on the armature stops the gear almost instantly. The dynamic brake relay is activated by the 'landing gear UP' and 'landing gear DOWN' limit microswitches, which are operated by cams on the motor gearbox.

The power supply for the landing gear control relays was supplied through a 5 amp. circuit breaker located to the left of the landing gear selector handle. Power to the electric motor was fed through a 60 amp. circuit breaker located beneath the cabin floor, next to the motor and gearbox assembly. (Note: this could not be readily checked during flight).

Figure 1 shows the section of the wiring diagram for the control function. The indication and warning sections are not shown, although the associated wiring generally follows the same looms as the control function wires. The wires all come together in the loom that terminates in the safety switch (squat switch) located on the right hand landing gear torque linkage. This switch prevents gear retraction in the event of an UP selection whilst the aircraft is on the ground with the oleos compressed; this is achieved by opening the circuit between the UP contact in the selector and the motor relay (terminal 'F'). An additional protection is provided by a spring-loaded hook, or latch, that covers the selector handle whilst it is the DOWN position, with the aircraft on the ground. The latch is withdrawn by a solenoid after the aircraft becomes airborne (ie no weight on wheels), when the squat switch connects the solenoid coil to earth. The squat switch was maintained on an 'on condition' basis and had been on the aircraft since September 1992. (Note: a similar component on the left landing gear controlled functions which included the pressurisation and stall warning systems).

Examination of aircraft at Aberdeen Airport

Following the incident, the Chief Engineer of the operator's maintenance organisation, based at Plymouth, examined the aircraft at Aberdeen Airport after it had been placed on jacks. He noted that the gear selector was in the DOWN position. It was apparent that the landing gear doors were fully closed and had sustained comparatively little damage. Moreover, no damage had occurred to the landing gear actuator supports. This indicated that the landing gear had been driven by the motor to the retracted position, as opposed to collapsing due, for example, to a failure to achieve the fully down-and-locked position. It was noted that both the 5 and 60 amp circuit breakers had not tripped, and that the 'gear UP' limit microswitch had been activated by its controlling gearbox cam. The landing gear selector handle, motor/gearbox assembly and the adjacent wiring were examined for obvious damage, foreign objects and loose articles, but none was found.

The landing gear was extended manually, with electric power disconnected, by means of the emergency landing gear handle. Electric power was then reinstated and the three green 'down-and-locked' indicator lights illuminated. It was then possible to retract and extend the landing gear normally using the selector handle. The as-found position of the selector handle thus became difficult to explain.

Subsequent investigations centred on the safety (squat) switch, since these have been known to cause problems on this type of aircraft, principally due to their exposed position on the landing gear rendering them susceptible to contamination and moisture ingress. It was found that by physically moving the switch, the retraction cycle could be interrupted. Lightly tapping the switch with a screwdriver handle would cause the landing gear to resume its travel intermittently. Subsequent examination of the switch revealed that the internal soldered joints were extensively corroded due to moisture ingress, and some of the wires broke away when roughly handled. It was therefore considered that the condition of the safety switch fully explained the problem of the gear failing to retract after the take-off at Aberdeen.

Investigation was also conducted into the electrical problems that were encountered prior to the take-off and during the period that the aircraft had been orbiting. However the reported faults were not apparent after the incident, and the flight director annunciator dimming problem was attributed to a transient fault with the switch. The subsequent instrument failures were thought to have occurred as a result of a temporary fault, in terms of frequency and/or voltage, with the associated inverter output. The fact that these events occurred at around the same time as the landing gear

problem was an apparent coincidence, but nevertheless must have presented a considerable distraction to the pilots.

During the weeks following the incident, both engines and propellers were changed. The aircraft was then ferry-flown, with the landing gear down, to the maintenance base at Plymouth, where additional investigation was carried out under the observation of the AAIB.

Further examination of the aircraft

The maintenance organisation decided to replace all of the components associated with landing gear control and operation. This included the squat switches, the motor and gearbox assembly, drivetrain and the selector assembly. In addition, all the wires running between the selector, the motor/gearbox area and the right main gear were renewed. The removed wires were examined for evidence of chafing and a small number of damaged areas were found; however these amounted to no more than minor abrasions to the insulation and in no cases had the conductors been exposed.

The landing gear selector assembly and the relay control box were removed from the aircraft and examined internally, with no evidence of damage, bridged contacts or foreign objects being found. Both components were then connected to a 28 volt DC power supply and to two simple switches, which simulated the UP and DOWN limit microswitches, so that it was possible to check the operation of both the selector and the relays. After each UP or DOWN movement of the landing gear selector handle, the associated relay could be seen and heard to operate. Similarly, when the limit switches were operated (after each gear selector handle movement), it was possible to check that the relevant UP or DOWN relay had released, and that the dynamic brake relay had operated.

The properties of the UP relay were measured by applying a positive voltage to terminal F on the control box (see Figure 1), with the negative lead attached to the NEG terminal. It was found that with rising voltage, the relay closed at 20 volts, and with decreasing voltage it de-energised at 5 volts. A maximum current of approximately 3 amps. was observed during the increasing volts stage, falling to 0.5 amps. after the relay had energised. The dynamic brake relay remained latched in either of its two positions after each selector handle/limit switch operation. Depending on which position this relay was in, the resistance across the control box (ie the UP relay in series with the dynamic brake relay) was either 17.3 or 75 ohms (). It was found that the above figures also applied to the DOWN relay.

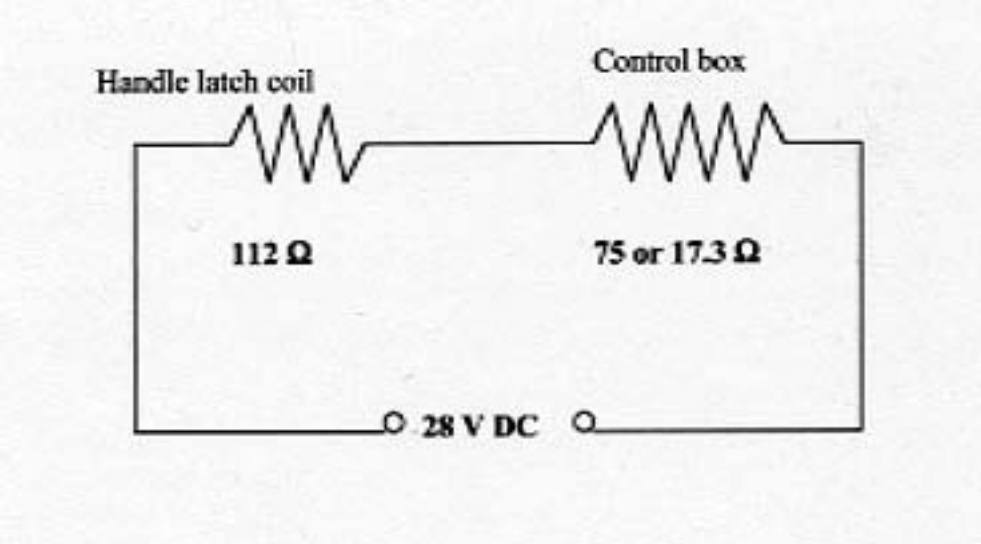
Finally, the resistance of the selector handle latch coil was measured and found to be 112 .

Possible failure conditions

In order for the landing gear to have been subjected to an uncommanded retraction, only two possibilities were apparent. The first possibility was that the UP winding of the motor had received a 'spurious' supply of electrical power. It was considered that this could be discounted for two reasons. The first reason was that the relatively large amounts of electrical power required to operate the motor would have been expected to have left evidence, in the form of arcing within the control box, together with burnt and damaged components. In fact the control box was found to be in good condition internally, as noted earlier. The second reason was that a spurious power supply, if it persisted beyond the normal landing gear travelling time, would have resulted in the landing gear having been driven beyond its uplock position, causing the gearbox clutch to slip and (eventually) the 60 amp breaker to trip. However the gear had stopped at its normal, rigged position, as defined by the gearbox-driven cam that operated the UP limit switch. It thus appeared

that the retraction had been 'controlled' (remembering that overtravel of the landing gear is prevented by dynamic braking) and that any uncommanded signal must have been routed via terminal 'F' of the control box. This introduced the second possibility:

With the landing gear down-and-locked, and the gear selector handle in the DOWN position, the wires at 28 volts DC are indicated on the diagram at Figure 1. It can be seen that this includes the wire identified as G21A22, which leads to Pin 'H' on the plug upstream of the safety switch. In order for this voltage to find an earth via terminal 'F', there would have to be a short circuit onto wire G8A22 or G8B22. Such a condition could arise as a result of 'chafing', or perhaps an internal short circuit within the safety switch. The complete circuit could then be represented thus:



Depending on the position of the dynamic brake relay, the total resistance would be either 187 or 129.3 (assuming the short circuit condition contributed zero Ohms). From Ohm's Law, the current is V/R, ie approximately 0.15 or 0.22 amps. Again from Ohm's Law, the voltage drop across the handle latch coil is 16.8 or 24.6 volts, leaving either a 11.2 or 3.8 voltage drop across the control box. Both values are considerably less than the 20 volts required to operate the UP relay.

The safety switch contains additional wires, not shown in Figure 1, which are connected to the flight hour meter. This unit is normally activated when the aircraft leaves the ground and also contains a coil, which similarly results in a voltage drop in the event of a short circuit. The possibility of such a condition being the cause of an uncommanded gear retraction was thus discounted.

Remedial action

Whist a number of incidents involving landing gear collapses have occurred to this aircraft type, only one was found which appeared to be similar to this incident. This occurred in Australia in October 1990 and, as with G-BPPM, followed the failure of the landing gear to retract when selected UP after take off. The associated investigation found that the retraction failure was due to 'varying resistance' in the right landing gear safety switch, but that the subsequent gear collapse occurred as a result of the gear selector being left in the UP position.

Following the accident to G-BPPM, the operator's King Air fleet had all squat switches replaced. The maintenance organisation will in future replace these squat switches on a periodic basis, as

opposed to an 'on condition' maintenance policy. This procedure has been recommended to the aircraft manufacturer for consideration for inclusion in the Aircraft Maintenance Manual.

The operator has revised the Operations Manual to include the procedure to be followed in the event of failure of the landing gear to retract. This includes placing the landing gear selector handle in the DOWN position and isolating the gear relay circuit breaker. In addition, this landing gear retraction failure situation has been introduced into the initial and recurrent training syllabi.