AAIB Bulletin No: 12/95 **Ref: EW/G95/08/23** **Category: 1.2**

INCIDENT

Aircraft Type and Registration:	Embraer EMB-110 P1 Bandeirante, G-OCSZ	
No & Type of Engines:	2 Pratt & Whitney PT6A-34 turboprops	
Year of Manufacture:	1981	
Date & Time (UTC):	24 August 1995 at 1020 hrs	
Location:	Zaragoza, Spain	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 2	Passengers - None
Injuries:	Crew - None	Passengers - N/A
Nature of Damage:	Damage to electrical components	
Commander's Licence:	Commercial Pilot's Licence	
Commander's Age:	35 years	
Commander's Flying Experience:	1,700 hours (of which 850 were on type) Last 90 days - 172 hours Last 28 days - 40 hours	
Information Source:	Aircraft Accident Report Form submitted by the pilot, reports from component design authorities, and AAIB discussions with the CAA et al	

The aircraft was flying level at FL100 in the cruise with everything normal, the flight had been completely event free, with a direct routing from half way between Zomara & Domingo straight to Zaragoza. The crew had just contacted Zaragoza approach with a position report, and had been asked to call with 20 miles to run.

About three or four minutes later a 'crack' was heard from the electrical rack and the master caution light started to flash simultaneously. The master annunciator panel (MAP) was checked and the right generator and No 1 inverter warning lights were on. Almost immediately the commander heard circuit breakers popping 'like crackers' and saw the flags on his artificial horizon and horizontal situation indicator (HSI) appear.

The circuit breakers which had tripped, and which the crew were unable to reset, included: main fuel pumps left and right, left auxiliary fuel pump, artificial horizon P1 side (but this reset and came on line after selection of emergency bus), P1 audio, marker beacon 1 & 2, gyro compasses 1 & 2 and the cockpit panel lights. The first officer stated that some circuit breakers had tripped on his side too, but he managed to reset them.

The commander looked around the instrument panel and was amazed to see the torque gauges, hydraulic pressure gauges, fuel flow, pressure and contents gauges all reading either zero or maximum. The P2 instruments also had flags showing on the artificial horizon and HSI and, at the same time, all avionics went off line except COM 2. The crew switched off the right generator and No 1 inverter, and switched to Box 2, but that instantly went off line.

The commander stated that he felt somewhat confused at such a massive and complete electrical failure, and could not understand why everything should have failed simultaneously.

All the crew were now left with were the ASIs with the landing gear flags showing, vertical speed indicators and altimeters. There were T5 engine indications and NH, Ng and oil temperature indications. The appropriate emergency checklists were completed, but it was still apparent that nothing would work. An attempt was made to reset the generator, inverter and other circuit breakers, but without success. The No 2 inverter did not show up as failed on the MAP, but the commander suspected that this too had failed because of the nature of the instrument failures.

By this time the crew had tried everything in the emergency checklist so they then tried to reset the No 1 generator, but still no power came back to any of the flight instruments or radio/navigation equipment. The commander then decided to select the emergency busbar, and the only instrument to come back on line was the P1 artificial horizon.

The commander was very concerned that they still had an estimated 40 miles to run to Zaragoza without any radio or navigation aids whatsoever to assist them, but as the weather was clear and they had ground contact, they continued towards the destination airfield by using the standby compass as there were no other options apparent to them.

Then, to the amazement of the crew, the right engine lost power, confirmed by the commander's input of left rudder to keep the aircraft in balance, and by the T5 and Ng instruments. The T5 showed 550° and the Ng showed 50%, the commander tried moving the power lever backwards and forwards on the right engine, but there was no effect. He asked the first officer to confirm that the right engine

indications showed a failure, and upon confirmation he shut down the right engine in accordance with standard operating procedures (SOPs).

The commander could see that they were clear of any high ground and elected to descend to FL80 (Minimum Safety Altitude was 5,500 feet) in order to look for Zaragoza or a suitable airfield or landing site at which to make an emergency landing. He was flying a heading on the HSI as he normally did but then realised, on checking the standby compass, that they were in fact heading 030° instead of 085°. He turned the aircraft to the right and checked their ETA with the first officer and recognised that they should be in the vicinity of Zaragoza. They looked very hard for the airfield but could not see it, so the commander flew the aircraft in a rectangular pattern with the hope of finding a suitable landing airfield.

They were over their ETA by 10 minutes and by now the flight deck was filling with an 'acrid hot burning smell', obviously electrical, so they decided to isolate the battery by pulling the breaker in the electrical rack and to trip the battery relay circuit breaker.

The commander's main concern now was the possibility of a fire in the electrical rack, so he opened the direct vision windows and descended the aircraft visually to 3,500 feet looking for a suitable landing site. The first officer estimated that they had at least 80 minutes of fuel left so they continued to fly visually in search of an airfield. A runway was finally spotted as they flew northbound back up the valley and the commander recognised the two parallel runways as being Zaragoza in accordance with the airfield charts.

The first officer selected gear down, but nothing happened, so the gear was extended manually in accordance with the checklist and SOPs. The commander elected to carry out a flapless landing as the runway length was in excess of 3,000 metres. He felt that there was no point in re-instating the battery at that stage of the flight, and it was most unlikely that the flaps would work.

The aircraft was landed on the military runway which was the first available into wind runway. The aircraft was brought to a stop using the brakes and it was noted that there was no nosewheel steering available. The aircraft was slowly manoeuvred onto the runway exit, and once clear of the runway the left engine was shut down and the crew exited the aircraft in the normal way.

Investigation

The nosewheel steering was not available after landing because the circuit breakers had not been reset following the over voltage.

Electrical failure

An examination of some of the aircraft light bulbs' overload characteristics indicated that the DC busbar voltage had risen to at least 90 volts, and that the voltage rise probably took place in milliseconds. Damage to other components indicated that the voltage remained at this level for several minutes. Analysis of the system indicated that the most likely course of events was that the No 1 generator had produced the high voltage and that the No 2 generator control unit (GCU) had tripped due to a reverse current. Both GCUs were sent to a UK overhaul agency, who confirmed that the No 1 GCU had failed and that the No 2 GCU was still capable of functioning. The GCU has an overhaul life of 6,000 hours; the Nos 1 and 2 GCUs had flown for 1,756 and 5,500 hours respectively.

The GCU contains a voltage regulation board and an over voltage protection circuit; for the failure to occur both functions must have failed. The GCU was sent to the design authority, whose report concluded that a dormant failure of a resistor in the over voltage protection circuit, plus a subsequent (and unrelated) short circuit in a capacitor in the voltage regulation board, had allowed the generator field current to become uncontrolled and the generator output voltage to rise substantially. The sequence of events arising from these failures would have provided the loud 'crack' and the 'acrid hot burning smell' reported by the commander.

In response to this incident a Service Bulletin detailing an on-aircraft over voltage check for satisfactory functioning of the GCU is being produced, and will be mandated by a Brazilian Airworthiness Directive. A 'GCU improvement' service bulletin, addressing minor overheating of components identified during the investigation, will also be mandated by a Brazilian Service Bulletin. These Service Bulletins will be adopted automatically by the CAA.

Engine failure

The PT6 engine fuel system utilises air pressure signals between the fuel control unit and the propeller and engine governors. The governor servo pressure, P_y, is carried in a steel pipe provided with heater coils to prevent the formation of condensation and ice. The heater coils on the P_y pipes on both engines had burnt out due to the over voltage; this had caused the pipe on the right engine to reach a temperature of approximately 800°C and to fail, allowing the P_y signal to fall, and the right engine power to reduce.