

# Boeing 737-4Y0, G-OBMM

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## INCIDENT

**Aircraft Type and Registration:** Boeing 737-4Y0, G-OBMM

**No & Type of Engines:** 2 CFM56-3C1 turbofan engines

**Year of Manufacture:** 1991

**Date & Time (UTC):** 13 June 1999 at 0550 hrs

**Location:** London Heathrow Airport

**Type of Flight:** Public Transport (Passenger)

**Persons on Board:** Crew - 7 - Passengers - Approx.'30 to 40'

**Injuries:** Crew - Nil - Passengers - Nil

**Nature of Damage:** Auxiliary power unit seriously damaged

**Commander's Licence:** Airline Transport Pilot's Licence

**Commander's Age:** 40 years

**Commander's Flying Experience:** 11,140 hours (of which 6,200 were on type)  
Last 90 days - 157 hours  
Last 28 days - 60 hours

**Information Source:** AAIB Field Investigation

## The ground incident

The aircraft was parked on its stand and the passengers had started to embark as the crew were carrying out their pre-departure checks. The first officer had started the auxiliary power unit (APU) and, after it had run for about two minutes, he switched on one of the air conditioning packs. After a further two minutes, he selected the APU to supply electrical power to the aircraft busses. At about the same time, cabin crew members in the aft cabin noticed a whining sound being emitted from behind the rear ovens. About one minute after the selection of aircraft electrical power from the APU, it dropped off line.

The commander immediately reinstated ground power and at the same time noticed that the exhaust temperature of the APU was decreasing rapidly. Almost immediately the APU fire warning

activated and the ground engineer, outside the aircraft, indicated to the first officer that there was smoke and fire coming from the APU exhaust. The APU fire drill was executed, the Airfield Fire Service (AFS) alerted and the senior cabin attendant instructed to immediately disembark those passengers, who had already boarded, through the forward left exit.

The commander then left the flight deck and went outside to look for signs of fire around the APU area. As the AFS arrived at that time, he also briefed their personnel on the incident. The first officer, who had remained on the flight deck, observed that the APU fire warning light remained illuminated for 2 to 3 minutes after the fire extinguisher had been discharged. When the warning eventually extinguished, he informed the commander outside the aircraft.

### **Initial inspection of the APU**

A company maintenance engineer gained access to the APU and, having removed its shroud assembly, inspected the unit. He saw no evidence of mechanical failure but noted that the electrical looms to the exhaust temperature thermocouples and to the exhaust firewire had burnt out. He saw no sign of any damage in the rear fuselage structure around the APU. The engineer tripped the circuit breakers for the damaged wiring looms and the APU starter, and then released the aircraft to service with the APU placarded as inoperative. The aircraft was due to return for a base maintenance engineering check four days later, and so rectification of the APU problem was deferred until then.

### **Subsequent APU inspection**

During this later base maintenance check, further inspection confirmed that there was no sign of fire or scorching on the airframe structure outside the APU shroud, nor was there any additional damage observed in the electrical looming within the shroud. When the APU unit was removed from the aircraft, the APU rotor could not be turned and damage to the compressor could be seen, with small metal fragments in the compressor inlet. The exhaust/muffler was also observed to have suffered heat distress. Inspection of the APU air intake duct did not reveal any evidence of ingress of hard particles. A borescope inspection of the compressor revealed evidence of hard particle passage through both compressor stages and evidence of substantial impeller vane rubs against their volutes. The turbine area exhibited considerable heat distress on the turbine nozzle guide vanes and on the turbine impeller vane tips. There was also evidence of passage of hard particles through the hot section and into the exhaust.

The APU was therefore returned to the associated overhaul company for a detailed strip examination in the presence of a quality engineer from the operator.

### **Strip examination of the APU**

Strip examination of the APU disclosed severe internal damage. Metal particle contamination was found in the oil filter and in a sample taken from the accessory gearbox sump. When the accessory gearbox assembly was removed from the front of the engine, to enable the engine dismantling to be carried out, it was found that the APU rotor shaft and the powertrain in the accessory gearbox were both individually seized. There was evidence of hard particles having been thrown outwards from the compressor inlets which had caused damage to the inner surface of the intake plenum and the compressor inlet support struts.

After the gearbox had been removed, it was observed that the APU shaft nut locking tab had broken and pieces of this were found in the gearbox/intake housing space. It was also observed that the locking wire to one of the APU front bearing retaining plate bolts was fractured, but the fractured end of the wire had a molten appearance. The front bearing of the APU rotor shaft had failed and completely disintegrated. Whilst the bearing assembly was being dismantled it was observed that there appeared to be a 'line of damage' close to one of the bolt holes, which had the appearance of arc-burning, and which ran through the faces of the bearing retaining plate, two shims and into the bearing carrier. There were also areas of more diffuse pitting and matching metal transfer onto the intervening shim on the joint between the front bearing carrier and the inlet housing.

The rotating guide vane sections of both of the back-to-back 1st stage impellers had evidence of heavy hard object damage and large pieces had broken off. The forward impeller rotating guide vanes were more damaged than the aft. There was also severe abrasion of the volutes and outer vane leading edges, and evidence of the passage of hard particles through to the 2nd stage of the compressor. The second stage impeller had also rubbed on its volute and there was evidence of the passage of metallic particles through, and having become embedded in, the diffuser. Several of the aft bearing housing securing bolts were found to be loose and evidence of fretting was found on the rear face of the diffuser housing. The turbine nozzle guide vanes were severely burned and the tips of the turbine blades, at the inlet from the combustion chamber, had all melted and burned away evenly.

Examination of the accessory gearbox revealed that one of the input pinion support bearings was seized as a result of displacement of the bearing cage. There was no evidence of any other defect within the accessory gearbox.

### **APU service history**

A review of the recent service history showed that the APU had been removed from another aircraft on 8 March 1999 for compressor overhaul and hot section inspection, having accumulated a total running time of 4,333 hrs and 4,775 cycles. After this overhaul it was fitted to G-OBMM on 27 May 1999. Between the time that it was fitted to G-OBMM and the incident, the APU had accumulated a further 148 hours of running time with 134 starts.

A review of its recent operating history revealed that two days before this incident the APU could not be started. Investigation of the problem revealed that the unit had a defective igniter high tension (HT) lead, which had failed very close to the igniter plug. After replacement of this lead, two successful test starts were made. The APU failure occurred following the third start after rectification of the failed igniter lead.

### **Discussion**

An overall assessment of the damage sustained indicated that the APU had suffered major damage to the 1st stage compressors, which had released relatively large metal fragments. These fragments had caused severe damage to the 2nd stage compressor, resulting in a loss of airflow and causing a severe turbine overheat. The uneven loss of mass within the compressor had resulted in a severe imbalance of the APU rotor, leading to intense vibration. The front rotor bearing had disintegrated completely and the rear bearing also exhibited symptoms of having suffered high vibratory loading.

In attempting to establish the cause of the damage to the 1st stage compressor, two initiating mechanisms were considered.

A simple explanation could have involved ingestion by the APU of a foreign object which had damaged the compressor rotating guide vanes. Such damage would have quickly compounded, leading to a severe imbalance of the APU rotor and all the subsequent failures observed, including the failure of the front bearing due to excessive vibration. Although there was no evidence of the passage of a hard foreign object down the intake, this did not entirely exclude this possibility. Although such an object is unlikely to have entered the intake, it was possible that a foreign object had lodged, undetected, in the intake or in the inlet plenum of the APU itself, and became free to be sucked into the APU compressor.

The second possibility was that the APU front bearing had begun to break up or to develop excessive radial play. This would have reduced the radial constraint of the forward end of the rotor shaft and allowed the 1st stage compressor impellers to contact their volutes, causing fragments of their vanes to be released and a cascade of damage, identical to that caused by the ingestion of a foreign object, to be initiated. The out-of-balance forces caused by the loss of material from the compressor impellers would have increased the rate of failure of the front bearing.

Potential reasons for the initiation of failure of the front bearing would include inadequate lubrication or the development of pre-existing critical damage to the balls, or races. However, the extent of damage to the bearing precluded the survival of evidence of either mechanism and there was no other evidence to suggest the malfunction of the APU lubrication system. The presence of a damaged HT lead and the arcing-like damage observed on the front bearing housing components suggested a possible mechanism for causing recent damage to the balls and races, by arc-burning, which could have developed during subsequent running. There was, however, no known history of this having occurred on previous occasions nor of supporting evidence of arc damage elsewhere on this APU.

### **Action by the operator**

To minimise the possibility of arcing between the HT lead and the APU, the Operator has instigated a pre-fitment inspection of the igniter leads.