Boeing 747-100, G-VMIA, 10 October 1996

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Aircraft Type and Registration:	Boeing 747-100, G-VMIA
No & Type of Engines:	4 Pratt & Whitney JTD9D-7 turbofan engines
Year of Manufacture:	1970
Date & Time (UTC):	10 October 1996 at 1459 hrs
Location:	Enroute to Boston, USA
Type of Flight:	Public Transport
Persons on Board:	Crew - 19 - Passengers 359
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:	7,600 hours of which 4,400 were on type)
	Last 90 days - 202 hours
	Last 28 days - 82 hours
Information Source:	AAIB Field Investigation

History of flight

The crew came on duty at 1240 hrs for a 1400 hrs departure ona scheduled 7 hours 10 minutes flight to Boston, USA. The aircrafttook off at 1419 hrs. The commander was the handling pilot andhe reported that, during the climb, at 330 kt IAS, at around FL290,he noticed that the rate of climb had reduced to less than 500ft/min. He noted that the aircraft was in VMC, climb EPR (EnginePressure Ratio) was set and the static air temperature was -44°C. Shortly afterwards, the EPR on the No 1 engine began to fluctuateand reduced to about 1.32; there was little response when theflight engineer manipulated the thrust levers. Nacelle anti icewas selected on as a precaution because the aircraft was aboutto enter a layer of cirrostratus cloud. At about this time, theNo 4 engine also ran down. The commander handed control to thefirst officer and declared a

state of emergency. The flight engineercarried out the memory items of the MULTI ENGINE SHUTDOWN/RESTARTdrill and the status of the nacelle anti ice, ignition, fuel heat,fuel configuration and fuel booster pump were reported to havebeen correct at this time.

A successful windmill start was eventually achieved on the No1 engine. All attempts to restart the No 4 engine resultedin it running with a high egt and low rpm with no thrust leverresponse and so it was shut down. The aircraft returned to Gatwickwhere, after jettisoning 40,200 kg of fuel, a three engined approachwas made and it landed safely at 1556 hrs.

Meteorology

An aftercast prepared by the Meteorological Office at Bracknellreported that there was an upper ridge of high pressure, lyingacross the Irish Sea, which had persisted for several days withassociated north westerly winds. The 1200 hrs upper air soundingfrom Aberporth indicated a slow warm advection with wind veeringslowly with height. There was an increase and thickening of mediumand upper cloud from the west. The wind at 300 mb level (about30,000 feet) was 315°/40 kt, the temperature was - 42°Cand the dew point -50°C.

All information on the recent volcanic activity in Iceland indicatedthat the ash cloud had not penetrated much above FL200 althoughthe vapour cloud had reached FL280 to FL300 with associated cumulonimbusclouds and thunderstorms. Recent trajectories had taken the plumenorth east then east into Scandinavia, well away from the IrishSea.

Flight data recorder

Information obtained from the FDR indicated that the No 1 engineEPR reduced from about 1.5 to about 1.2 as the aircraftpassed through FL300; it then recovered to about 1.32. Two minutes30 seconds after the initial rundown of the No 1 engine,the No 4 engine flamed out; the No 1 engine then flamed out aftera further 30 seconds. After one abortive relight the No 1 enginebegan to function normally and achieved an EPR of 1.4. The No4 engine did not relight successfully and subsequently was shutdown.

Fuel system (see Appendix 1)

There are four main tanks and one centre wing tank; the No 1 and4 reserve tanks are considered as a part of their respective maintanks. Each main tank is associated with an engine and fuel canbe delivered directly to that engine via fuel booster pumps. There are two booster pumps in each tank, those in the centrewing tank (designated override/jettison pumps) having a higheroutput pressure than the others, and all the booster pumps feedthe delivery system via non-return valves. There is also an ejectorpump which scavenges the last 1,400 kg of centre wing tank fuelinto the No 2 main tank. A crossfeed gallery connects the variousengine feed-pipes and fuel management is by selection of the appropriatecombination of cross feed valves and booster pumps. The fuelmanagement procedures are designed to ensure that this crossfeedgallery remains pressurised at all times.

The fuel load on the incident flight was:

Reserve tanks each 1,500 kg

No 1 & 4 tanks each 11,300 kg

No 2 & 3 tanks each 37,300 kg

Centre wing tank 3,000 kg

Fuel handling

G-VMIA was the only 100 series aircraft in the fleet and therewere minor differences from the company Standard Operating Procedure(SOP) for fuel system management; these were covered by a DifferencesSupplement to the aircraft Operations Manual. A placard on theflight engineer's panel also brings to his attention the differencethat the contents of No 1 and 4 tanks must be reduced to between10,000 kg and 9,500 kg before centre wing tank fuel is used. A company Flying Training Note titled "FUEL FEED CONFIGURATIONCHANGES" requires the flight engineer to announce his intentionto the pilots whenever he makes a fuel system configuration change. One of the pilots should then monitor his actions unless it isimprudent to do so; the flight engineer should, however, stillannounce his intention so that the commander may at least havea mental picture of what is happening to the fuel system. Itwas not possible to say with any degree of certainty whether thisoccurred on all occasions when the fuel system configuration waschanged on the incident flight.

For take off the fuel system is configured as follows:

All main tank booster pumps ON

Centre wing tank override/jettison pumps OFF

No 1 & 4 crossfeed valves OPEN

No 2 & 3 crossfeed valves CLOSED

This crossfeed valve configuration serves no purpose other thanto maintain standardisation with the rest of the fleet in whichthe centre wing tank override/jettsion pumps are ON for take off. Ideally this configuration is maintained until the quantity inNo 1 and 4 tanks has reduced to 10,000 to 9,500 kg when fuel fromthe centre wing tank can be used. However, on G-VMIA there isno flow equaliser in the crossfeed system and itis usual for the No 4 tank content to reach the desired levelfirst. In this event one or both No 4 tank booster pumps shouldbe switched off and both No 1 & 4 engines fed from No 1 tankto correct the imbalance. This had occurred on the incident flightand the flight engineer had indeed switched off both No 4 tankbooster pumps.

When the contents of No 1 and 4 tanks are both between 10,000and 9,500 kg, the fuel system is reconfigured in the followingorder:

Centre wing tank override/jettison pumps	ON
All crossfeed valves	OPEN

(Since No 1 & 4 valves would normally be OPEN at this point, the only selection required is of the No 2 & 3 valves)

No 1 & 4 booster pumps	OFF

Since the output pressure of the centre wing tank override/jettisonpumps is higher than that of the booster pumps, the fuel fromthe centre wing tank is fed to all four engines. When the fuelquantity in the centre wing tank is reduced to a pre-determinedlevel, or its pump low pressure lights illuminate, the centrewing tank pumps are turned 'OFF' and all the engines will thenbe fed from No 2 & 3 main tanks. This will continue untilsuch time as the quantity in those tanks falls to the same levelas the No 1 & 4 tanks when 'main tank to engine' feedis reinstated. The remaining fuel in the centre wing tank, normallyabout 1,400 kg, is scavenged into the No 2 main tank.

Air test

G-VMIA was air tested on 11 October with an AAIB Operations Inspectoron board. The first test involved the aircraft climbing withthe fuel system being configured as in the SOP. The exhaustionof the centre wing tank fuel was simulated by switching off thecentre wing tank override/jettison pumps once the quantity hadreduced to 3,000 kg. The aircraft reached FL390 without incident.

The second test started at FL100 and when, at FL150, the quantitiesin No 1 and 4 tank were down to between 10,000 and 9,500 kg, thecentre wing tank override/jettison pumps were switched on andthe No 1 and 4 booster pumps were switched off. The crossfeedvalves were, however, left in the configuration they would havebeen in since take off *ie* No 1 and 4 OPEN and No 2 and3 CLOSED. At FL280, the centre wing tank low pressure (LP) lightsbegan to flash; the contents were about 1,300 kg. All fourengines were set to about 1.46 EPR. The LP lights came on continuouslyby FL290, so the centre wing tank pumps were turned off and thescavenge pump turned on; the centre wing tank contents were about1,200 kg at this point. The No 1 engine ran down almost immediatelyto about 1.29 EPR and was closely followed by the No 4 enginewhich reacted in a similar manner. Neither engine responded tothrottle lever movement. The aircraft was levelled off and theNo 1 engine restarted immediately ignition was selected. Withthe aircraft level at FL300, IAS 300 kt, it continued to run normally,on gravity feed, at 1.49 EPR/782° EGT. The No 4 engine wouldnot restart with gravity feed only and was shut down. The fuelsystem was then reconfigured with all booster pumps on and allcrossfeed valves open and a further attempt was made to startthe No 4 engine using the Inflight Start procedure. The enginelit but the N_2 did not rise above 54% evenwith RICH selected; there was little or no response to throttlelever movement. The engine was shut down and the aircraft descendedto FL250 and another inflight start was attempted, again at 300kt. The engine lit but the N_2 stabilisedat 49% (0.78 EPR/660°EGT) and again there was little or noresponse to throttle lever movement. The engine was shut downand the IAS was reduced to 245 kt so that the Ground Start procedurecould be used. This was successful and the N_2stabilised at 62%. The aircraft then descended to FL200, IAS300 kt, and the No 4 engine was again shut down; at this levelthe Inflight Start procedure was successful and the engine restartednormally. The aircraft returned to London Gatwick Airport where,after replacement of the No 4 engine igniters, the aircraft wasreturned to service.

Operations Manual

Instructions on fuel system management are clearly laid out inthe Operations Manual; the procedures which are peculiar to G-VMIAare specified in an approved Differences Supplement. In the interestsof standardisation, clarity and ease of access the content ofthe Flying Training Note entitled Fuel Feed Configuration Changesis being transferred to the Operations Manual.