No: 5/91 **Ref: EW/C1191** **Category: 1a**

Aircraft Type and Registration:	Fokker F27-200, G-BHMX	
No & Type of Engines:	2 Rolls-Royce Dart 528-7E turboprop engines	
Year of Manufacture:	1963	
Date and Time (UTC):	7 January 1991 at 1756 hrs	
Location:	En-route, on airway B1, 15 nm west of Ottringham VOR	
Type of Flight:	Public Transport	
Persons on Board:	Crew - 4	Passengers - 20 + 1 infant
Injuries:	Crew - None	Passengers - None
Nature of Damage:	None	
Commander's Licence:	Airline Transport Pilot's Licence	
Commander's Age:	51 years	
Commander's Total Flying Experience:	10,000 hours (of which 200 were on type)	
Information Source:	AAIB Field Investigation	

The aircraft had been scheduled for four sectors between Leeds and Amsterdam. The first, from Leeds to Amsterdam, was uneventful and the aircraft landed at 1547 hrs.

The significant weather for the return journey was a cloud layer between 3000 feet and 5000 feet at Amsterdam, followed by thickening layers of cloud, associated with a trough over the North Sea, with a probability of severe ice accretion. Similar circumstances prevailed for the descent into Leeds, where the cloud base was reported as 5 oktas at 1500 feet, with a surface wind of 220°/18-40 kt and a temperature of +4°C. At the return flight cruising level, FL 140, the indicated outside air temperature was -20°C and the flight penetrtrated the tops of stratiform cloud. The Leeds Airport weather, at 1720 hrs, was 260°/10kt, 9km, continuous light snow, 1 okta at 300 feet, 4 oktas at 500 feet, -0°C. This meteorological situation was expected to improve to CAVOK, which it had done by the time that the next readings were taken at 1750 hrs.

History of the flight

The co-pilot was the handling pilot for the return sector and the flight took off at dusk from Amsterdam at 1620 hrs and climbed, en-route, directly to FL 140. During this period the crew did not notice any

airframe ice. At FL 140 the aircraft was flying in and out of the cloud layer and the flight was uneventful until, at 1737 hrs, the co-pilot noticed a slight yaw and saw both the fire warning light and the feathering pump light of the right engine illuminate. Following appropriate confirmation, the commander, who had seen only the fire warning light, carried out the engine fire drills whilst the co-pilot reduced the airspeed to the required 140 kt 'single engine speed'. Neither crew member recalls hearing any fire warning bell. The commander also does not recall seeing the feathering pump light but, during the fire drills, when he asked the co-pilot to confirm that the propeller was feathering, it had already stopped rotating. This, together with the lack of severity of the yaw, suggests that it had already auto-feathered. The fire warning light went out as the first extinguisher bottle was discharged.

At 1740 hrs, the commander informed Manchester ATC that 'WE'VE HAD TO SHUT AN ENGINE DOWN, WE HAD A POSSIBLE FIRE.....' and, being aware that other aircraft were 'holding' at Leeds, waiting for an improvement in the weather, in accordance with company operating proceedures he diverted to Humberside Airport. The controller acknowledged this and gave clearance for descent at the commander's discretion. Although the commander still had not declared an emergency, the ATC controller declared a 'Full Emergency' and transferred control of the aircraft to Humberside Approach Control. On contact with Humberside, the commander informed them that they (the crew) were '...JUST SORTING OUT ONE OR TWO THINGS.....'.

The descent was begun at 1742 hrs and the descent checks included switching the engine anticing to 'FAST'. As the aircraft passed FL 115, at 1744 hrs, the left engine began to run down and the 'PROP BELOW LOCK' light illuminated, indicating that the propeller had run below the flight fine pitch stop. Despite the co-pilot's action in increasing the airspeed and advancing the throttle, the engine continued to run down with decreasing torque and TGT. At 1746 hrs, the commander informed ATC that 'WE'VE GOT A BIT OF TROUBLE ON THE NEXT ENGINE NOW, SO WE'RE GOING TO COME TOWARDS THE FIELD AND THEN MAKE A GLIDE APPROACH'. Two minutes later, at 1748 hrs, on the second attempt, the engine was re-started.

The descent was continued, in and out of cloud, until it was possible to make an ILS aided visual approach to runway 21 at Humberside. At this point, the co-pilot realised that, without the right engine, there would be no electrical power to his windscreen de-icing system and so he passed control to the commander. After experiencing some difficulty in maintaining the glideslope the commander made a safe landing, bringing the aircraft to a stop on the runway and shutting down the left engine.

The Senior Air Traffic Control Officer at Humberside had declared a 'Full Emergency' and, as the aircraft landed safely at 1756 hrs, the Airport Fire Service vehicles were in position along the runway. When the aircraft had stopped, the fire officer made an inspection of the right engine and informed the commander that there were no signs of fire. However, the fire officer and the attendant airport manager did notice that all frontal surfaces on the aircraft, including all flying surface leading edges, were covered in a thick layer of clear ice. This was estimated as being between 1.5 and 2 inches (38-51 mm) thick.

Flight Recorders

The Flight Data Recorder fitted to the aircraft was a Sundstrand Universal Flight Data Recorder (UFDR), with a 25 hour recycling tape which recorded four analogue parameters, airspeed, altitude, heading and normal acceleration, together with a number of discrete channels recording radio transmissions, an event marker and a recorder checkword. The FDR has its own pitot/static transducer to measure airspeed and altitude and these are connected to the co-pilots pitot static system. A calibration of the flight recorder transducer found it to be within the published limits for the system.

The Air Navigation Order states that *pitch, roll and engine power* are required to be recorded 'if the equipment provided in the aeroplane is of such a nature as to enable this item to be recorded'. None of these parameters are recorded on the incident aircraft. The lack of engine information in this incident considerably hampered investigation into the causes of the double engine failure.

A plot of the data from just before the first engine failure until touchdown is shown at Figure 1. The time of the second engine failure and the relight are shown on the graph.

The Cockpit Voice Recorder (CVR), a Fairchild A100 with a 30 minute recycling tape, had been allowed to run-on, on the ground after landing and, consequently, the recording began just as the second engine failed some 12 minutes before touchdown. From the area microphone it was possible to derive engine power from compressor rpm and detect the engine relight; only one engine frequency was detected showing that the right engine was feathered. A longer period of recording would have preserved the data during the period of the engine failures and provided information on the engine power which was not available on the FDR. [Existing ICAO recommendations already suggest that a CVR with a two hour recording duration should be installed in aeroplanes of a maximum certificated take-off mass of over 5,700 kg.]

Subsequent investigations (Engineering)

As it was apparent that there had been no fire, attention was initially centred on the fire detection system. Resistance and continuity checks of the right engine fire detection wire were found to meet the Maintenance Manual requirements. Operation of the 'PRESS TO TEST' switch on the flight deck functioned the fire warning relay box which in turn operated the alarm bell and the fire warning light. The light and bell are wired in parallel, ensuring simultaneous operation. No fault was found on the fire detection system.

Fuel samples were taken from the tanks and engines and were examined for evidence of water. None was found and the samples were later fully analysed by the Materials Quality Assurance Directorate at Woolwich. The results revealed no significant departure from the specification for aviation turbine fuel.

With no evidence of damage to the engines or propellers, both engines were subjected to a ground run. This established that engine and propeller indications were normal for all power settings. The propeller,

spinner and intake anti-icing system was also functioned and found to be satisfactory at both the 'FAST' and 'SLOW' cycle settings.

It was clear from the crew's evidence that the auto-feather system had operated on the right hand propeller. This system is activated when the torque pressure in the engine falls below 50 psi, at which point the feathering pump feathers the propeller blades. The crew's drills include moving the fuel control lever to the feather position which then de-activates the auto-feather system on the remaining engine. The propellers' electrical system is independent of the fire detection system. Thus operation of the former should not result in activation of the latter other than by, possibly, inductance or a direct electrical short in the looms and/or components in the junction box located behind the co-pilot station. Such an event could not be reproduced however when the right hand propeller was feathered at the end of the ground run.

Since the aircraft appeared to be serviceable, a flight test was carried out and the aircraft resumed normal service with the operator. Later, a full propeller functional check revealed no faults.

The CVR was analysed, with regard to the engine compressor rpm (from which could be derived the propeller rpm), following the second engine failure. The 'PROP BELOW LOCK' light reportedly illuminated at this time, but the rpm trace, together with the appropriate performance information from the propeller manufacturer, revealed that this had been a spurious indication. Had the flight fine pitch stop been withdrawn (a condition which normally only applies during deceleration after landing), then the propeller blade angle would have continued to reduce with reducing airspeed as the Propeller Control Unit (PCU) attempted to maintain the rpm. In fact the trace showed that the rpm continued to decline, indicating that the blades had not fined off below the flight fine stop.

Some days after the aircraft had been returned to service, the same 'PROP BELOW LOCK' light illuminated several times during a training detail. The left hand propeller hub switches and brushes were replaced but the light again illuminated the following day during a series of approaches and go-arounds. This time the PCU was replaced which apparently cured the problem. The propeller manufacturer has suggested that moisture ingress may have affected the solenoids within the PCU, thereby leading to the false indications.

During the course of the investigaton the AAIB learned of an earlier incident, on 5 January 1991, that occurred to an F27 belonging to another operator. One engine ran down but it recovered after the igniters were selected ON and the second engine 'coughed' but did not flame out.

Information from the engine manufacturer has indicated that a Dart engine could flame-out following the ingestion of a 3.5 lb (1.6 kg) piece of ice. There have been a number of reported flame-outs which have been attributed to ice ingestion, but most are thought to have involved either late or non-selection of the power unit de-icing system. The system consists of electrical heater elements round the main air intake. Both anti-icing and de-icing techniques are employed by using continuously heated and intermittently heated elements respectively. A continuously heated element prevents ice from forming on the leading edge of the intake. Behind the leading edge,on both the internal and external surfaces,

ice is allowed to form and is dislodged by the cyclic heating of the de-icer elements. The rate of cycling, 'FAST' for when the OAT is above -6°C and 'SLOW' for below -6°C, is selected on the cyclic timer. The engine manufacturer considers that inappropriate selection of cycling speeds may also have been a factor in some flame-outs.

The engines of G-BHMX had been the subject of a modification (No. 1860) which introduced a new compressor designed to improve fuel efficiency. The airline had been progressively incorporating this modification across its fleet for the past five years. The aircraft involved in the incident of 5 January, had not been so modified but was the subject of another modification (No. 1800), which introduced a different intake designed to attenuate compressor noise. This airline has had this modification for approximately two years and plans to fit its entire fleet to 1800 and 1860 standard.

Subsequent investigations (Operational)

Considerable research was carried out in an attempt to identify any similarities between this and the incident experienced by an F27 belonging to another operator two days previously. Both aircraft were operating in and out of stratiform cloud tops at a temperature of -20°C and this was found to be the sole common factor. It is therefore noteworthy that meteorological research has shown that the liquid water content may be higher at the top of a cloud than at lower levels.

Notwithstanding the similarities between the two flight regimes, it was not clear why an aircraft type, which has flown for many years without similar event, should suddenly produce two nearly identical malfunctions in the course of two days. In the earlier incident, the engines had been fitted with an air intake modification and in the case of G-BHMX, the engines had a later standard of compressor. Neither modification was common to both aircraft. The possibility of these modifications causing increased vulnerability to ice ingestion was considered. However the engine manufacturer conducted a review of ice ingestion/flame-out events for the Dart, and this revealed that a calendar association to events had been recorded on two previous occasions.

The engine manufacturer's Engine Operating Instructions contains the following advice:

> 'If abnormal icing is encountered, switch ON the ignition switches for both engines whilst these conditions exist and then OFF. Record and report such ignition switches.
> WARNING: INDISCRIMINATE AND EXCESSIVE USE OF THE IGNITERS WILL ADVERSELY AFFECT THE LIFE OF THE IGNITER BOXES. FURTHER DETAILS ARE CONTAINED IN THE MAINTENANCE MANUAL.'

The Operations Manual and training syllabus of both companies reflected the handling advice provided by the Fokker Flight Manual which, apart from that in the event of partial flame extinction and a late selection or loss of the engine antice system, makes reference to the use of engine igniters only in the case of 'extremely severe icing'. It has been recommended to the CAA that operators should select

igniters ON, routinely, when flying in all icing conditions. In addition, the engine manufacturer is reviewing the advice contained in the Engine Operating Instructions concerning the use of the igniters.

Final approaches made in icing conditions

Aircraft Accident Report (AAR) 7/88, published 21 November 1988, reported on the circumstances of a similar type of aircraft that crashed two miles west of East Midlands Airport. The report's final finding was that 'The aircraft flight manual contained no warning of a likely increase in stalling speed with ice on the wings and no recommendation that approach speed should be increased for landing in icing conditions'. The probable cause of the accident was that 'the aircraft became uncontrollable at an airspeed well above its stalling speed and minimum control speed because its flying and handling characteristics were degraded by an accumulation of ice.' Recommendation 4.2 of the AAR was that 'A minimum safe airspeed for approaches in icing conditions should be specified in flight manuals where appropriate.'

CAA response to this was contained in FACTAR F1/89 published 23 January 1989 which said: 'Minimum safe airspeeds for symmetric flight in icing conditions are specified in the Flight Manual where testing has shown this to be necessary.' Despite another report of an exactly similar (Danish) accident on 27 December 1969, such an inclusion was not contained in the Flight Manuals of any UK operators examined at the time of the incident to G-BHMX. In two accidents at East Midlands Airport, the F27 (AAR 7/88) and the Short 360 (AAR 6/87) a year earlier, lateral control of the aircraft was lost. It is therefore apparent that any approach made in icing conditions, particularly when in asymmetric flight., is an emergency state for which Flight and/or Operations Manual guidance is essential.

Safety Recommendations made to the CAA

1. The occasions when engine igniters (continuous ignition) on Dart engines are already required to be selected ON are extended to include flight in moderate or severe icing irrespective of the number of engines operating.

2. A minimum safe airspeed for approaches in icing conditions, irrespective of the number of engines operating, should be specified in Operations Manuals.

FIGURE 1