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Turboprop Freighter Crashes After Severe Icing Causes Multiple Engine Failures

The official U.K. accident report identified flight crew training, Emergency Checklist use and crew resource management as factors in the accident. The role of air traffic control during emergencies was also examined.

Editorial Staff Report

The four-engine turboprop Vickers Viscount 813 freighter was on a scheduled cargo flight with a two-man crew from Edinburgh, Scotland, to Coventry, England, when it crashed into trees following multiple engine failures. The captain was killed in the Feb. 25, 1994, accident. Bystanders pulled the seriously injured first officer from the burning wreckage. The aircraft was destroyed by the impact and the postcrash fire.

An accident investigation report completed by the U.K. Department of Transport, Air Accidents Investigation Branch (AAIB) concluded that the accident was caused by multiple engine failures [three of the four engines] "as a result of flight in extreme icing conditions" and "excessive ice accretion in the area of the engine air intakes."

The report said that the aircraft's ultimate loss of directional control was caused by a "reduction of the airspeed to the point where the authority of the (ice or snow contaminated) vertical stabiliser was less than that needed to overcome the drag from the two unfeathered propellers."

The AAIB report also concluded that:

- "Incomplete performance of the emergency drills by the crew, as a result of not referring to the Emergency Checklist, prejudiced the chances of successful engine re-starts;
- "Crew actions for securing and re-starting the failed engines, which were not in accordance with the operator's procedures, limited the power available. The drag from two unfeathered propellers of the failed engines and the weight of the heavily iced airframe resulted in a loss of height and control before the chosen diversion airfield could be reached;
- "Poor Crew Resource Management [CRM] reduced the potential for emergency planning, decision making and workload sharing. Consequently, the crew had no contingency plan for the avoidance of the [forecasted] severe icing conditions, and also was unaware of the relative position of a closer diversion airfield which could have been chosen by making more effective use of air traffic services."

The aircraft's flight data recorder was faulty and no useful data were recovered from the device, the report said, so flight information was derived from the cockpit voice recorder (CVR), air traffic control (ATC) recording, radar track and "recollections by the first officer."

The accident flight was scheduled to depart Edinburgh at 1930 hours but was dispatched about 50 minutes early because of forecasted deteriorating weather en route, the AAIB report said. The report said that sleet was falling at

the Edinburgh Airport just prior to departure. An inspection of the aircraft surfaces by the pilots found no ice or slush and the aircraft was not deiced. The report said that the en route forecast "warned of moderate icing in cloud and severe icing in nimbostratus cloud."

The flight, operated by British World Airlines Ltd., departed at 1843 hours, about 13,979 pounds (6,341 kilograms) below its maximum takeoff weight of 72,500 pounds (32,885 kilograms), with the captain as pilot flying, the report said. "Because of the inclement weather conditions, the ice protection systems for all of the engines and the airframe were selected to ON throughout the flight."

The aircraft climbed in cloud to 19,000 feet (5,795 meters). "Six or seven minutes into the climb an OVERHEAT warning indicated that the right wing de-icing duct temperature was excessive and it required manual controlling before establishing … the normal temperature of 165 [degrees C (329 degrees F)]," the report said. "At 1913 [hours], the crew commented that the de-icing system was working well and, at 1920 [hours], the first officer observed that there was a little surface ice on No 4 engine, but that it was shedding. He also remarked that there was some ice on the spinner but none on the wings."

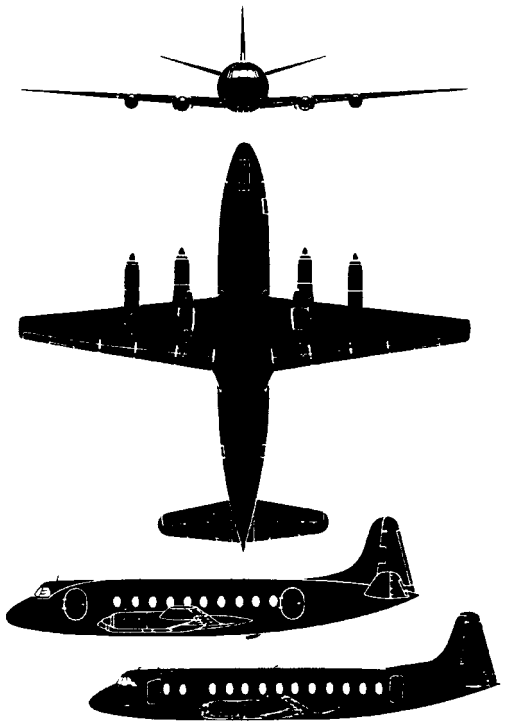
At 1926, the aircraft was recleared by London Air Traffic Control Centre (LATCC) on a direct track to the Manchester (MCT) very high frequency omnidirectional radio range (VOR) and to be at 18,000 feet (5,490 meters) when crossing MCT. The flight transited MCT at 1928 and was told by Manchester radar to descend to 15,000 feet (4,575 meters) with routing to Coventry.

"At 1932 hours, as the aircraft approached FL [flight level] 150 [15,000 feet (4,575 meters)], the No 2 engine failed and the propeller blades automatically feathered," the report said. "Less than a minute later, when the crew had just completed the shutdown drills on No 2 engine and the first officer had stated that he was selecting Nos 1 and 3 engine igniters ON, the No 3 engine started to run down. At 1933 hours, the first officer stated that he was going to switch Nos 1, 2 and 4 igniters ON.

"At that time the commander instructed the first officer to 'GET AN IMMEDIATE DESCENT' and to 'DECLARE AN EMERGENCY.' The first officer transmitted 'MANCHESTER MANCHESTER THIS IS BRITISH WORLD FOUR TWO SEVEN TWO WE'VE JUST HAD A DOUBLE ENGINE FAILURE DUE [TO] ICE REQUEST IMMEDIATE DESCENT PLEASE AND RADAR VECTORS.' He did not declare an emergency or use the pro-words 'MAYDAY' or 'PAN PAN.' At the time the aircraft was 16 nm [nautical miles] south of Manchester Airport, descending through FL 140 [14,000 feet (4,270 meters)]. Manchester immediately cleared the aircraft to descend to FL 70 [7,000 feet (2,135 meters)] then to FL 50 [5,000 feet (1,525 meters)] on a continued heading of 150 [degrees] and, at 1934, passed control of the aircraft to Birmingham radar. At this point, the failure of Nos 2 and 3 engines had deprived the aircraft of its only source of wing and tail de-icing. The respective airframe de-icing switches are required to be selected to OFF. This checklist item was apparently not performed."

The flight was cleared by ATC at 1936 to descend to 2,500 feet (763 meters) and a minute later the first officer declared an emergency and requested a diversion to Birmingham Airport, the report said. It said that both pilots were familiar with Birmingham Airport and its approaches.

A few seconds later, the first officer informed Birmingham that both the No. 2 and the No. 3 engines had failed. "The pro-words 'MAYDAY' or 'PAN PAN' were again omitted,"



Vickers Viscount

The Vickers Viscount, which first flew in 1948, was the world's first turboprop transport to go into service.

The first production version was the series 700, which had a capacity of up to 59 passengers. The stretched 800 series followed a few years later with seating for up to 65 passengers. Cargo versions were also produced for the 800 series by Scottish Aviation. In all, 441 Viscounts were built and many are still in service around the world. The series 700 cruises at 502 kmph (312 mph) and has a range of 2,815 kilometers (1,748 miles).

Source: *Jane's All the World's Aircraft*

the report said. At this time, the aircraft was descending through 9,400 feet (2,867 meters) and was about 28 nm from Birmingham Airport and 17 nm from East Midlands Airport.

Birmingham ATC then asked the crew, "Is East Midlands [Airport] any good to you[?]" and provided them with East Midlands weather, the report said. "The crew acknowledged this but did not state an intention to change the diversion to East Midlands."

Radio and cockpit intercom communications became increasingly distorted by a "warbling sound" that "forced the pilots to shout in order to communicate with each other," the report said.

The report said that at 1938, the No. 4 engine failed as the aircraft descended through 8,400 feet (2,562 meters). As the No. 4 engine failed, an attempt to restart engine No. 2 succeeded. But the report noted that "in the short period between the No 4 engine failing and the No 2 engine starting there was a momentary loss of all generated electrical power."

Restart Attempts Were Unsuccessful

During the continued descent, further attempts to restart No. 3 and No. 4 engines were not successful, the report said.

"While No 4 engine was running down and No 2 was starting up, the pilot had flown an inadvertent 170 [degree] turn to the right until the aircraft was heading north," the report said. "The Birmingham controller queried this and suggested a heading of 095 [degrees] for East Midlands, which was correctly read back by the crew. A short time later the aircraft made a series of turns and again the Birmingham controller suggested a heading for East Midlands ... . This information was not acknowledged by the crew who shortly after selected the transponder Emergency Code '7700,' stating 'We're on emergency now.'"

… the "commander stated he was losing control in yaw and needed his torch [flashlight] to read the instruments."

The report added: "Following the declaration of emergency, seeing that the aircraft was in a position to make a [straight-in] approach to Runway 09 at East Midlands, Birmingham radar transmitted 'THE RUNWAY IN USE AT EAST MIDLANDS IS ZERO NINE.' Although it was obvious to the radar controller that East Midlands was the closest suitable airport to the flight, he has since stated that, being aware that the crew had declared the intention to proceed to Birmingham, he did not wish to cause them any undue distraction by informing them of this."

The report said that for three minutes after 1940 hours, the aircraft turned left toward 295 degrees and continued through that heading to the south, during which time the first officer tried unsuccessfully to restart the No. 3 engine and the "commander stated he was losing control in yaw and needed his torch [flashlight] to read the instruments."

[The report noted that with the failure of the No. 3 engine, a "change in the operation of the electrical system was apparent from the short break in the CVR … recording and the indication that two inverters, identified as the Emergency Inverter and the Main Busbar inverter, were running when the recording resumed.

["It is apparent therefore that there was a temporary drop in the Main Busbar voltage following the loss of the No 3 engine sufficient to energise the EPAC (emergency power auto control) relay and the flashing LOW VOLTAGE lights would have illuminated briefly. The EPAC would then remain activated, unless the GEPS (generator emergency power switch) was switched to No 4, even when the Main Busbar voltage recovered from this temporary (and undiscovered) interruption and the low voltage indicator lights went out. The Main Busbar, supplied by No 4 generator, would remain separated from the essential services on the Emergency Busbars. The batteries would supply all the essential services ... .

["If the crew had been aware of this brief indication, then the correct procedure would have been to pull the gang bar down and select the GEPS to the No 4 engine generator. ... If the procedure of pulling down the gang bar and selecting the GEPS to No 4 generator had been followed after the failure of No 3 engine, then ... the electrical supply may have been protected up to the time that No 4 engine failed."

[The report added: "Some five minutes after No 3 engine had failed, the Main Busbar had an adequate and stable voltage supply from No 4 generator. The GEB and essential services were being supplied from the batteries whose output was already showing signs of deterioration. Although a single generator (No 2) was working during the final minutes of the flight, its power was not directed to the essential services because the emergency procedure for the electrical system had not been properly followed."]

The report continued: "At 1942:20 hours, the aircraft descended through its cleared altitude of 2,500 feet [763 meters] and appears to have been unable to maintain altitude, despite the nose being raised a second or two later. This adjustment in pitch, [while] momentarily arresting the descent, resulted in approximately [a] 45 [knot] loss of airspeed before descent had to be resumed in order to maintain flying speed.

"At 1944 [hours], the first officer again tried to re-start No 3 engine and the commander said 'We're going to stall.' No 3 engine did not re-start but the propeller remained unfeathered and it was apparent that an attempt to re-start it was still being made at impact."

"Mayday" Went Unheard

The report said that between 1945:17 and 1945:28 the first officer made two "Mayday" calls, but the messages were not heard or recorded by ATC, apparently because of the aircraft's failing electrical system.

"At about 1946 hours the aircraft struck a down-sloping forest of mature trees [about 80 feet (25 meters) tall at approximately 400 feet (122 meters) mean sea level] which caused considerable disintegration of the aircraft structure," the report said. "It came to rest in a field on the edge of the forest. An intense fire consumed the cabin section between the rear of the flight deck and the front of the empennage."

Two people who were nearby when the aircraft crashed pulled the injured first officer through a hole torn in the inverted and crushed cockpit, the report said. "The commander was found out of his seat lying against the right side window and roof panel. Much of the flight deck left wall and floor had been removed by impact damage[,] which had also released the commander's seat."

Weather in the area at the time of the accident was determined to be "occasional rain and snow; visibility 2,000 [meters] to 3,000 [meters] [6,562 feet to 9,843 feet], overcast with stratus, base 200 [feet] to 400 feet [61 meters to 122 meters], with broken/overcast thick layer, base 1,000 [feet] to 1,500 feet [305 meters to 458 meters], tops 24,000 feet [7,320 meters]," the report said.

The captain, age 32, held an airline transport pilot (ATP) certificate and ratings in the Viscount 700 and 800 series with a conversion to the 810 in May 1993. He had logged a total of 5,121 flight hours, with 1,121 on type.

The first officer, age 39, also held an ATP certificate and ratings in the Viscount 800 series and the Shorts SD3-30. He had logged a total of 3,334 flight hours, with 2,181 hours on type.

The accident aircraft was manufactured in 1958 and was equipped with four Rolls-Royce Dart Mk 530 turboprop engines. It had logged a total of 50,995 airframe hours at the time of the accident, the report said.

The report noted that "single or double engine failures by themselves should not prove catastrophic to a [four-engine] aircraft in the cruise. Proper emergency drills should ensure a successful completion of the flight. In this accident the situation grew steadily worse from the moment of the first engine failure through successive failures and their effect on airframe ice protection systems to the inability to restore adequate power and then to loss of height and, ultimately, control. Tragically, even this progression of problems need not have prejudiced a safe landing at the nearest airfield given better management of the emergencies by the crew."

According to the report, drag from the unfeathered propellers of the failed engines "would have exacerbated the situation, as did the 0% setting of the fuel trimmers[,] which considerably limited the maximum power available from the live engines."

The report said that when the first restart was attempted on the No. 2 engine, there "was no (spoken) action taken to reset the fuel trimmer to an appropriate setting, from the previous selection of 0% (fully weak). Assuming this action to have been forgotten during this drill, it was unlikely to have been remembered by the first officer during subsequent attempts when there was greater urgency and this is confirmed by the 0% position found in the wreckage."

The report continued: "The meteorological forecasts available to the crew and the decision to advance the [dispatch] time of the flight in anticipation of bad weather should have alerted the crew to the probability of encountering severe weather. There is no evidence from the aircraft's track or from ATC communications that any avoidance was made. During the flight from north to south it was necessary to traverse the frontal system and the warning of severe icing in nimbostratus cloud should have triggered the need for some alternative course of action when such conditions were encountered.

The report noted that "single or double engine failures by themselves should not prove catastrophic to a [four-engine] aircraft in the cruise."

"A suitable routing might have been considered during the planning stage but, in flight, such avoidance would have been difficult to achieve without using the weather radar, which was not in operation at the time. This was a serious and surprising omission from the effective operation of the aircraft, although the commander was known to make little use of weather radar. It is difficult to understand why such an essential aid for the avoidance of severe weather conditions was not used."

The Emergency Checklist on board the aircraft was deficient in several significant aspects, the report said. It said that the checklist was printed on sheets of pink paper held in a loose-leaf binder. "They were not an accurate reflection of the lists detailed in the Flight Manual, which was prepared by the manufacturer," the report said.

The first officer told accident investigators that the Emergency Checklist was not used, "even for the first engine shutdown drill when there was little pressure on the crew," the report said.

"Furthermore, the spoken drill used for the attempted re-start of No 2 engine did not conform with the Emergency Checklist," the report said. "Thereafter, with the pressure on the crew increasing rapidly, still no reference was made to the

Emergency Checklist and consequently omissions and errors of procedure were made, including the following:

- "Propeller synchronisation, not de-selected, thus reducing the power available on the live engines. [The report said that if the No. 3 engine fails and the "system is not switched to OFF then, as the reference RPM from No 3 reduces, the other operating engines will have their RPM reduced by an amount between zero and 800 RPM."];

- "Correct airspeed re-start envelope, not verified;

- "Fuel trimmers, not re-set for the attempted re-starts, thus reducing the chances of success. [The report said that the engine manufacturer stated that chances of a successful relight are considerably reduced when the fuel trimmers are (incorrectly) set at less than 50 percent, the minimum level called for in the Emergency Checklist.];

- "Airframe de-icing system of Nos 2 and 3 engines, not closed, thus allowing the worst possible airframe icing to occur;

- "Electrical system, omission of emergency actions, resulting in the loss of several electrical services;

- "Propellers, those of the two failed engines were not feathered. However, No 3 may have been in the process of being re-started and it may not have been possible to feather No 4 fully because of reduced electrical power supply."

The report said that the captain "made no comment about the Emergency Checklist not being used and he appeared not to have monitored the (incorrect) actions of the first officer. Use of the Emergency Checklist is designed to assist in such circumstances and it is unfortunate that the first officer, who was known to have reservations about its design and layout, did not use such aid as [the Emergency Checklist] could have given him."

Because not using the Emergency Checklist was a significant factor contributing to the accident, the report said a behavioral psychologist was asked to assess the checklist's design and efficiency. The psychologist concluded that "overall, the checklist gives the impression of having been reproduced more from considerations of expediency rather than ease of use or utility. It has apparently not been specifically designed for the purpose and is rather a collection of pages poorly reproduced from the manual in a careless fashion, which takes no account of the importance of the information or the conditions under which it is going to be used.

" … Emergency Checklists are, presumably, not in very frequent use and when they are used, the situation is, by definition, likely to be abnormal and possibly stressful. Individuals under stress often have difficulty in absorbing information. It is therefore particularly important that any material likely to be needed under abnormal or stressful conditions be tailored to the purpose. This document infringes most of the basic human factors considerations in the design and presentation of visual information."

The accident report examined the flight crew's performance in determining to which airport they should divert. "Although the level of activity on the flight deck was high, there was a lack of geographic orientation, which denied the crew awareness that East Midlands [Airport] was considerably closer than Birmingham [Airport]. This was understandable given the normal reliance on positions based upon aeronautical beacons rather than ground features. Based on subsequent track miles flown by the aircraft, if the crew had chosen to change the diversion to East Midlands Airport, the aircraft would have almost certainly been able to land there."

The report added: "It is therefore unfortunate that the crew did not ask ATC for 'a diversion to the nearest suitable airfield' and that ATC did not advise the crew of the relative distances to the other diversion airfields. Improved training in the handling of emergencies by ATC should include this aspect."

Following another aircraft accident in 1990, the report said, the AAIB made several recommendations (that were later approved) concerning initial and continuation training for air traffic controllers in the theoretical and practical handling of emergencies. "A number of controllers had completed the initial continuation package, but the Birmingham radar controller had not undergone the course at the time of the accident," the report said.

Situation Became "Irretrievable"

The accident, the report concluded, occurred because many factors contributed to "putting the aircraft and crew ultimately into an irretrievable situation."

"Two consecutive engine failures (Nos 2 and 3) deprived the aircraft of any airframe de-icing," the report said. "A third (No 4) then failed but shortly afterwards No 2 engine was successfully re-started and this should then have enabled the aircraft to maintain height and continue the flight.

"This sequence of emergencies with their attendant consequences was demanding enough of any crew. The situation required clear thinking and decisive action if an accident was to be avoided. In fact, the deteriorating situation escaped this particular crew and they never successfully caught up with it. The lack of a contingency plan for the avoidance of the [forecasted] severe icing conditions, the decision to descend immediately following the first engine failure, the early decision to divert to Birmingham and the lack of a decision to change to the nearer diversion of East Midlands, all contributed to the deterioration of the situation.

"Without reference to the Emergency Checklist, there were important omissions of emergency selections of the electrical system; the airframe de-icing system; the fuel trimmers; and, possibly, the propeller feathering. All of these omissions and their consequences might have been avoided if the principles of CRM had been applied to decision making, monitoring and workload sharing."

The report noted that the seriousness of the emergencies, which the crew faced, should not be underestimated, and comprised "a rapidly worsening situation at night, in IMC [instrument meteorological conditions], in severe icing and turbulence, in an aircraft [that] was heavily contaminated by ice or snow and with engines failing sporadically.

"It is therefore perhaps understandable that the emergencies were not handled as they might have been for example, on a LOFT [line-oriented flight training] exercise in the simulator. Nevertheless, it is commendable that, despite the deterioration of the essential electrical system, especially the flight deck lighting and the crew intercommunications, and the fact that the commander had lost directional control of the aircraft, the first officer had the presence of mind to transmit two 'MAYDAY' messages whilst continuing attempted engine re-starts."

The U.K. Civil Aviation Authority's (CAA's) flight operations inspectors also failed to "identify, report and call for correction of the several deficiencies in the company's operating procedures which were subsequently identified by the IDA [in-depth audit] conducted after the accident," the report said.

An audit of the operator was conducted by an FOI (Flight Operations Inspectorate) team in May 1994, the report said. It said that the audit report listed four areas relevant to the accident that required attention: "A review of all manuals, a review of 'ab initio' training for pilots, formalisation of command training [and] lack of [LOFT] or practical CRM." The report noted that the operator was introducing CRM training to all of its pilots at the time of the accident. "The operating crew in this accident were due to attend their courses the following month," the report said.

Based on its investigation, the AAIB report recommended that the CAA should:

- "Consider further reminding pilots and operators about the correct meaning and use of the 'Distress message.' The correct use of pro-words [Mayday or Pan] together with information about what actions will be taken by ATS [air traffic services] on receipt of a distress message should be covered. The fact that the message can be easily cancelled, if the situation of the aircraft improves, should also be emphasised"; and,

- "Commission research into the most effective form of presentation of emergency reference material which may be required on a flight deck. This should include both manual Checklists and electronic screen displays. Suitable advice from human factor specialists should be included in guidance material." ♦

Editorial note: This article was adapted from *Report on the accident to Vickers Viscount 813, G-OHOT near Uttoxeter, Staffordshire on 25 February 1994.* Aircraft Accident Report 3/95. U.K. Department of Transport, Air Accidents Investigation Branch. The 53-page report also contains illustrations and nine appendices.

ACCIDENT PREVENTION

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