No. 34

Starways Limited, Douglas Skymaster C-54A-DC (DC-4), G-ARJY at Cloghran, County Dublin, Republic of Ireland, on 19 September 1961. Report by the Inspector of Accidents (Ireland) released as C.A.P. 190 by the Ministry of Aviation (United Kingdom).

Circumstances

G-ARJY was flying a chartered non-scheduled trip from Speke Airport, Liverpool to Tarbes Airport, Lourdes where passengers were to embark for Dublin, Ireland. Following a normal flight to Lourdes the aircraft was refuelled. The amount taken on appeared to be sufficient for the flight to Dublin. The aircraft was carrying 4 crew and 69 passengers. Take-off for Dublin was at 1710 hours, and the flight to Dublin Approach was uneventful.

At 2035 the aircraft reported to Dublin Air Traffic Control and was informed of the local weather and of the runway in use. Subsequently, at 2058, it was cleared to land on runway 24, and the captain stated that he intended to make a visual approach. Shortly thereafter, at 2104 the flight reported having difficulty and that it was losing power. The captain abandoned the approach, swung the aircraft abruptly to the left and made a successful emergency wheels-up landing away from the airport. There was no fire. Although some occupants were slightly injured and shocked, there were no fatalities or serious injuries.

Investigation and Evidence

The Aircraft

G-ARJY's certificate of airworthiness was valid until 3 July 1962. The certificate of registration, issued by the Ministry of Aviation (U.K.), was dated 17 February 1961.

Since manufacture, the aircraft had flown 31 458 hours.

The maximum take-off and landing weights for the aircraft were the same, i.e. 63 000 lb. At the time of the accident the approximate weight of the aircraft was 57 978 lb.

The Flight Crew

The crew consisted of the captain, a co-pilot and two stewardesses.

The captain's airline transport pilot's licence was valid at the time of the accident and was endorsed in Group 1 for DC-4 aircraft. His instrument rating was renewed on 19 August 1960. His last competency check was in May 1961.

His total number of flying hours amounted to 6 049. His experience on the DC-4 was as follows:

	within the past 90 days
321 hours by day	224 hours by day
81 hours by night	56 hours by night
(356 hours in command)	(all in command)

The co-pilot's commercial pilot's licence was valid at the time of the accident. His last instrument rating was in October 1960, and his last competency check was on 24 April 1961.

He had flown a total of 14 000 hours on DC-4's, Vikings, Dakotas and military aircraft. His experience on the DC-4 was as follows:

	within the past 90 days
3 200 hours by day	245 hours by day
1 000 hours by night	60 hours by night

Weather

The weather conditions en route and at Dublin are not considered to have had any bearing on the accident.

Reconstruction of the flight

Since the evidence available at an early stage in the investigation indicated that fuel management would be chiefly in question, events leading to the accident will be followed up with emphasis on this aspect.

The total fuel capacity of G-ARJY was 1 878 U.S. gal, distributed in four tanks only. The two inner tanks held 508 U.S. gal each, the two outer tanks 431 U.S. gal each. The Starways OPS Manual states that the first officer is responsible for pre-flight checks on the aircraft. The comprehensive pre-flight check list includes the checking of fuel and oil contents with dipstick. This was done at Speke (the Starways base) by the engineer responsible for certifying inspection of the aircraft, and his check was accepted by the captain subject to verification by reading of contents gauges. On the preceding flight (17 September) the captain had entered several defects relating to No. 2 engine in the technical log. Clearance of these defects and balancing of generators necessitated engine running, which was carried out after fuelling for a period which cannot be established but which is not likely to have used more than 10 U.S. gal per engine except on No. 2, for which a maximum use of 30 U.S. gal has been estimated. The captain assumed a round figure of 1 800 U.S. gal for *starting the flight.*

The flight from Speke to Lourdes took four hours and five minutes. The captain assumed a round figure of 250 U.S. gal per engine as the fuel consumption for this flight and asked the refuelling agents at Lourdes to put 100 U.S. gal in each tank. Refulling was carried out by the agents, and the contents of the tanks were dipsticked by them. The figures for tanks Nos. 1, 2, 3 and 4 were 230, 370, 330 and 320 U.S. gal respectively, *(i.e. a total of* 1 250 U.S. gal in all tanks.) These figures were reported to the captain, who took note of them. No further fuel checks were made at Lourdes with the exception of the inspection of contents gauge readings which was done by the pilot and co-pilot, during the pre-starting check. On this check the co-pilot estimated the total fuel contents as about 1 280 U.S. gal. Both pilots noticed that No. 1 tank gauge showed less than the others but did not consider the tank contents low enough to take steps to alter the position. According to the dip figures, the total fuel was ample for the planned flight. The captain did not consider the possibility of No. 1 tank running dry before completion of the flight.

The flight plan time for the Lourdes-Dublin trip was three hours and forty minutes. The captain relieved the co-pilot of the responsibility for supervising refuelling at Lourdes. He assumed a total fuel figure of 1 200 U.S. gal for load sheet preparation, enough for a four hour flight with diversion from Dublin to Shannon and reasonable reserves, assuming normal operation.

The Lourdes-Dublin flight was made under instrument flight rules at a cruise altitude of 6 000 and 6 500 ft until some 10 minutes before arrival at Dublin, when descent was commenced. Operation was normal throughout the flight. No cross-feeding was carried out. When on the downwind leg of the Dublin Airport circuit the approach check was carried out. This includes checking of fuel contents, ensuring that main tank selector valves are "on" and cross-feed valves "off" and switching on of electric fuel booster pumps. The co-pilot stated that he noted No. 1 fuel tank

gauge read 80 U.S. gal and that the needle was flickering. The captain also looked at the contents gauges and noted that all tanks totalled about 400 U.S. gal. He thought that No. 1 tank read about 80 U.S. gal.

As the aircraft turned on to final approach, a loss of power occurred on the port side, and the captain noticed No. 1 engine manifold pressure and fuel pressure dropping. He opened Nos. 1 and 2 cross-feed cocks, assuming that fuel starvation had caused the failure of No. 1 engine, and told the co-pilot who then noticed the fuel pressure warning light on for No. 1 engine.

As the turn was completed, and about 5 to 6 seconds after opening Nos. 1 and 2 cross-feed valves, No. 2 engine lost power with accompanying loss of manifold and fuel pressures and lighting of the fuel pressure warning light, causing the aircraft to swing sharply to port. The captain using all his efforts to control the aircraft and keep on track to the runway, told the co-pilot to open all cross-feed selector valves. This was done, but there was no restoration of power to either port engine. Power on the good engines had been increased to 35 inches, 2 550 rpm after the first failure and now had to be increased to take-off rating on Nos. 3 and 4 to avoid losing airspeed and sacrificing height. In this condition and with both port propellers "windmilling", control of the aeroplane was becoming critically difficult even with the co-pilot assisting; with full right rudder it was moving left off the line of approach with the nose swinging to port. Some time (which could not be determined exactly) after the opening of Nos 3 and 4 cross-feed valves, the already serious situation was further complicated by symptoms of power failure from the starboard engines. The time interval involved here was considered to be dependent on the physical layout of various parts of the fuel system, particularly the length of the cross-feed line between port and starboard tanks and also on the extent of mixing of air and fuel in the lines.

After the second power failure (No. 2 engine) the aircraft's height above the aerodrome was estimated by the co-pilot as 300 ft. It is certain that maintenance even of partial control in the extremely adverse circumstances existing (double power failure on the one side with failed propellers windmilling) involved a high rate of descent; a forced landing was, therefore, inevitable. The captain allowed the aircraft to swing further to the left. It made a turn of increasing steepness to clear a hangar and was so low that the port wing appeared to be "hedge clipping". An engineer and another aircraft worker in the vicinity heard "backfiring" and "spluttering" noises from the engines - confirmation that abnormal operation had already spread to the starboard power units. The captain was able to straighten up the aircraft and made a successful belly landing with the landing gear raised. The aircraft came to a stop on the Dublin-Belfast Road without suffering extensive impact damage.

Emergency drill for crash landing was carried out by the flight crew. Although the emergency lighting system could have been manually operated by means of a cockpit switch, this system was not used.

The airport crash and fire services were at the scene in about three minutes.

Discussion

When the aircraft came to rest the captain closed the tank-to-engine fuel selector valves but left the cross-feed valves in the open positions. Inspection of the cockpit about 45 minutes after the accident confirmed these valve positions.

Weather conditions prevented a check on tank contents until about 0800 hours the day after the accident. The following dip readings were then obtained:

No. 1 tank	No. 2 tank	No. 3 tank	No. 4 tank
nil	120 U.S. gal	230 U.S. gal	106 U.S. gal

Although these readings were subject to error in view of the right wing down and tail up position of the aeroplane, it was ascertained with reasonable certainty that No. 1 tank was in fact empty of fuel. Fuel samples were taken from various points of the circuit; no fuel contamination was found, which could have caused engine power failure.

Complete drainage of all tanks was undertaken and supervised. Comprehensive tests on the selector valves, fuel lines and tanks during and after the draining process led to the conclusion that the lack of fuel in No. 1 tank had not been due to any defect in the fuel system and that, with cross-feed valves closed, no appreciable transfer of fuel from one tank to another could have taken place.

Tests on the electrically-operated fuel contents gauges showed No. 1 tank gauge to be reading low (10 U.S. gal) with 60 U.S. gal in the tank. The electric fuel booster pump for No. 1 engine was found to operate satisfactorily. Final drainage of fuel from all tanks produced the following quantities:

No. 1	nil
No. 2	131 U.S. gal
No. 3	208 U.S. gal
No. 4	83 U.S. gal
Total	422 U.S. gal

Assuming normal engine operation and fuel management, the flight from Lourdes to Dublin (3 hr 55 min) could reasonably have entailed a fuel consumption of 230 U.S. gal per engine. If this is applied to the tank dip figures obtained at Lourdes, the final draw-off figures given above are reasonably what can be expected for tanks 1, 2 and 4 but more than 100 U.S. gal high for tank 3.

The excess of fuel found in No. 3 tank could have been due to:

a) a fuel system defect,

b) cross-feeding in flight, or

c) a mistake in carrying out refuelling instructions at Lourdes.

Under (a) it is considered that tests made and information available exclude the likelihood of a system defect having a significant bearing. In regard to (b), the flight crew state that cross-feeding had no part in their fuel management procedure during flights on the day of the accident. The possibility of an error in refuelling and/or taking dip readings at Lourdes cannot be excluded (in view of inconclusive results of inquiries made at Lourdes).

The fuel content of No. 1 tank at the commencement of the Lourdes-Dublin flight (230 U.S. gal as dipped by Esso employees at Lourdes) was such that, using the fuel calculation methods recommended in the OPS Manual, there would be barely sufficient fuel in that tank for the Lourdes-Dublin leg of the flight plan (3 hr 40 min - 210 U.S. gal) without "balancing" of tanks in flight by cross-feeding. The "expected" surplus of 20 U.S. gal would not only have been inadequate for flight to the alternate had this been necessary, or for holding for a reasonable time, but could have been used up in the time taken to make two abortive landing attempts at Dublin. The actual flight overran the flight plan time by 15 minutes so that the emptying of No. 1 tank in the circumstances, and at the time of first engine failure, was a foreseeable occurrence almost without any intervention from factors such as inaccuracy in tank dipping or high fuel consumption by No. 1 engine.

It is considered that shortcomings in fuel management were the major contributory factor in this accident.

The dip reading for No. 1 tank at Lourdes should immediately have aroused suspicion as being a "wrong figure" due either to incorrect use of the dipstick, engine or fuel system defect, or to the tank not having been refuelled.

It is considered, having regard to checks made during the investigation on the contents gauging system, that proper

in-flight checks of fuel tank contents (and consumption) would have made obvious the need to "balance" the fuel system. The captain accepted responsibility for management of the fuel system during flight, and his evidence is that he did not maintain a fuel/distance graph because the aeroplane was not equipped with fuel flow meters. Nevertheless, application of known engine fuel consumption to dip figures and gauge readings should inevitably have alerted him to the possibility of No. 1 tank becoming exhausted before the end of the flight.

The emergency action carried out on failure of No. 1 engine, to restore fuel supply to that engine, was incorrect. The position of the electric fuel booster pumps in the physical layout of the fuel system is such that, if cross-feeding has to be resorted to as an emergency measure consequent on lack of fuel in any tank, it is essential to close the tank selector valve of that tank as soon as possible, and preferably before opening the cross-feed valves immediately concerned. If this is not done air will be drawn into the fuel system from the empty tank by the combined suction effect of engine-driven and electric (booster) pumps and, if the cross-feed valves are open, not only will the in-drawn air prevent restoration of fuel supply to the failed engine but it will also induce fuel starvation, through aeration, in any engine to which open cross-feed valves allow access. It was concluded that failure to close the tank selector valve for No. 1 fuel tank whilst operating the cross-feed system was in fact the immediate cause of the multiple power failure which led to this accident.

It was concluded from statements by the crew that they were unaware at the time of the accident of the vital necessity of isolating a suspect tank when cross-feeding in emergency. It is considered that this was largely because their previous experience of DC-4 type aeroplanes had been confined to models, other than the four-tank C-54A, in which different fuel system layouts, especially in regard to electric booster pump position, would render cross-feeding possible without the closing of individual tank selector valves. The lack of knowledge shown by them in this most important matter of the fuel system was certainly contributed to by deficiencies in the information made available to them by the Operator.

The OPS Manual for this aeroplane, although marked G-ARJY on the cover, appears to have been, except for a small number of amended or added pages, that used for all the DC-4 type aeroplanes operated by the Company before the acquisition in February 1961 of G-ARJY. The technical information on the fuel system appears to apply to these other aeroplanes and not to have been amended for the C-54A. It is considered inadequate in essential items, including those discussed in relation to cross-feeding. No clear cut warning is given in the manual as to the danger involved if the selector valve of an empty tank is not promptly closed when cross-feeding in emergency rather than as a fuel management procedure.

The captain gave two reasons for not attempting to feather the propeller of the failed No. 1 engine. He did not think that No. 1 tank had run dry but that momentary starvation had occurred through movement of fuel in the turn. He was confident that his action in opening Nos. 1 and 2 cross-feed valves would assist recovery by allowing No. 1 engine to draw fuel from No. 2 tank. Had he feathered the propeller as soon as No. 1 engine failed, there is little doubt that a successful landing could have been completed without difficulty. It would be improper to consider his decision an error of judgement since it was based on the expectation that the engine would pick up again almost immediately, or at any rate soon after he had operated the appropriate cross-feed valves; an expectation which would have been fulfilled if the fuel controls had been correctly used. His choice of emergency action, incorrectly carried out, led to such a critical deterioration in the situation that he had neither time nor opportunity to reconsider it.

Fuel records

Provision for recording of fuel amounts is made in Starways Technical Log in total form, not for individual tanks. Space is provided for entering fuel brought forward from previous flight, fuel added for starting the day's flights, and total at take-off. There is also space for en route additions, and for carry-forward figure in U.S. gallons. Although this scheme does not provide a ready means of checking consumption on individual engines, it would, if properly used, allow a general fuel consumption check on an aeroplane as well as a useful check on accuracy of both contents gauge and dipstick indications. However, in the case of this aircraft the usefulness of the record was nullified by careless and inaccurate use. (Omissions were found, and some entries were questionable).

Attempts to check fuel consumption for the aircraft during its period of operation by Starways met with failure, partly because of lack of record in the technical log and partly because there appears to be no reliable measurement of fuel loaded on the Company's aeroplanes at Speke.

Emergency lighting

Control of the emergency lighting system in the aeroplane was possible by means of a manual switch in the cockpit as well as by an inertia (impact-operated) switch. All other DC-4 type aeroplanes of the Starways fleet are fitted with emergency lighting of which the manual control switch is located in the passenger compartment. The stewardess has the duty of switching them on in an emergency; this duty is included only in her emergency check list.

The OPS Manual for G-ARJY was not amended as it should have been in this respect. (Ditching and Crash Landing Drills). None of the flight crew members was apparently aware of how to operate the emergency lighting. Disembarkation of passengers was accomplished successfully without lighting on this occasion; but had the circumstances of the landing been more serious the hazard to passengers would have been substantially increased by the absence of lighting.

Probable Cause

The accident was attributed to incorrect management of the fuel system by the flight crew which resulted in partial loss of power and control and a forced landing outside the airport.

Recommendations

1. Operator's pilot training methods

   a) greater emphasis should be placed on the importance of comprehensive knowledge of the fuel system of all aeroplanes in use;

   b) techniques at present used in relation to emergency action after engine failure should be re-considered taking into account in particular the stage in flight at which the emergency occurs.

2. Operator's methods of keeping fuel records

The attention of the Operator should be drawn to his responsibility for ensuring proper use both by maintenance engineers and flight crew of the Technical Log fuel records.

Re-design of the Technical Log to analyze fuel information in terms of individual tanks would, it is considered, reduce the likelihood of errors in fuel management in flight by alerting flight crew members to the state of individual tanks, facilitate proper maintenance by making fuel consumption checks simpler; and possibly lead to greater economy in operation.

3. Operational information made available to the Operator's employees

Particular care should be taken, especially in the case of an aeroplane of older type which has seen considerable service, to establish by physical test the actual capacities of fuel tanks and the accuracy of dipsticks; and to ensure that any difference in design or layout affecting operation (e.g. in relation to fuel systems) is fully covered in relevant parts of the Operations Manual before the aeroplane is put into service.

- - - - - - - - - - - - - - -