Department of Trade

Report on the accident to BAe (Vickers) Viscount 708 G-ARBY near Ottery St Mary, Devon, on 17 July 1980

List of Aircraft Accident Reports issued by AIB in 1981

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Department of Trade
Accidents Investigation Branch
Kingsgate House
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30 October 1981

The Rt Honourable John Biffen MP
Secretary of State for Trade

Sir

I have the honour to submit the report by Mr P J Bardon, an Inspector of Accidents, on the circumstances of the accident to BAe (Vickers) Viscount 708 G–ARBY which occurred near Ottery St Mary, Devon, on 17 July 1980.

I have the honour to be
Sir
Your obedient Servant

G C Wilkinson
Chief Inspector of Accidents

Accidents Investigation Branch

Aircraft Accident Report No 9/81
(EW/C707)

Operator:	Alidair Limited
Aircraft: Type:	British Aerospace (Vickers) Viscount
Model:	708
Nationality:	British
Registration:	G–ARBY
Place of Accident:	South of Ottery St Mary, Devon Latitude 50° 44′N Longitude 003° 18′W
Date and Time:	17 July 1980 at 1953 hrs

All times in this report are GMT.

Synopsis

The accident was notified to the Accidents Investigation Branch by London Air Traffic Control Centre at 2117 hrs on 17 July 1980. An investigation was commenced early the following day.

The aircraft was returning to Exeter airport from a flight to Santander in northern Spain. Whilst at 2000 feet on its final approach to runway 26 and at a distance of approximately 8 nm from touch down, all four engines lost power due to fuel starvation. The landing gear was in the retracted position and the flaps were at 20 degrees. The area over which the aircraft was flying was hilly and wooded.

The aircraft commander carried out a successful forced landing in a small grassy valley that lay to the left of track. None of the 62 occupants was injured and all were able to evacuate the aircraft without difficulty after it had come to rest.

It is concluded that the accident was caused by the aircraft running out of fuel due to the crew's erroneous belief that there was on board sufficient fuel to complete the flight. The aircraft's unreliable fuel gauges, the company pilots' method of establishing total fuel quantity and imprecise company instructions regarding the use of dripsticks were major contributory factors. Meter indications on the refuelling vehicle at Santander, which cannot have reflected the quantity of fuel delivered, are also considered to have been a probable contributory factor.

1. Factual Information

1.1 History of the flight

The aircraft was engaged upon a passenger charter flight from Santander to Exeter and was flying its fourth sector of the day when the accident occurred. The first two sectors, also from Exeter to Santander and return, had been flown by a different crew to that concerned in the accident. These first two flights had passed without incident apart from a minor technical problem during refuelling whilst on the ground at Santander due to an intermittent contact at the external electrical supply socket once the ground power unit was connected. This caused the aircraft's refuelling valve to open and close intermittently, interrupting the refuelling process. This was easily detected since the counters on the refuelling vehicle ceased to turn each time the supply was interrupted. The refuelling was therefore completed using electrical power from the aircraft batteries. A total of 2600 litres was uplifted resulting in a total of 5364 litres on board*. This was not checked with the fuel dripsticks. On return to Exeter the second crew took over the aircraft for a further return flight to Santander and it was with this crew on their return to Exeter that the accident took place.

The operating crew consisted of two pilots and they reported for duty at Exeter at 1215 hrs. They took over the aircraft shortly after 1330 hrs when it landed from Santander some 45 minutes behind schedule. The incoming crew recorded in the Technical Log that 1793 litres of fuel remained in the tanks on shut down and the aircraft commander taking over the flight requested full tanks for his flight to Santander. The co-pilot relayed this instruction to the operator of the refueller, adding words to the effect that this would entail an uplift of about 4540 litres. Using one hose, and refuelling each side of the aircraft at a time, the refuelling operator then filled each wing to capacity, recognising the full tanks condition on each occasion when the counters on his refuelling vehicle stopped turning. This indicated to him that fuel could no longer be transferred due to the operation of the float valves in the aircraft fuel system. Since he was familiar with Viscount aircraft this was to him a routine occurrence. When the refuelling was complete, the indicators on the vehicle recorded a total uplift of 4430 litres and the co-pilot, who had watched the operation, signed the fuel delivery note accordingly. No physical check using the aircraft dripsticks was made of the fuel quantity on board.

Both fuel contents gauges had a history of defects. A recurrent problem in the port fuel gauge was recorded in the Technical Log as a deferred defect, expressed as 'port fuel contents gauge fluctuating occasionally, ie full scale deflection; rectification being carried forward until the next check'. The aircraft commander did not draw the co-pilot's attention to this entry, who remained unaware of it. The starboard gauge also had a history of defects, with regular attempts having been made at rectification. It was not the subject of a current entry in the Technical Log, but pilots, including the crew on this occasion, still tended to regard it as inaccurate. The general interpretation was that it would indicate the equivalent of about 250 litres less than the correct value, but would fall steadily and consistently as fuel was

**Throughout the report, all fuel quantities are expressed in litres, though the operation of the aircraft entailed the use of three different units. See para 1.17.2.*

consumed. Whilst flying this aircraft, therefore, crews mainly based their fuel calculations on the fuel they believed to be in the tanks prior to departure, subtracting from that total the fuel consumed as indicated by the flow meters. The fuel contents gauges were small instruments, situated in front of the co-pilot and not readily visible to the aircraft commander. They were not highly regarded by the pilots within the company, being pacitor type gauges and their indications were treated with some reserve. In particular, the crew involved in the accident were more accustomed to fly another series of Viscount whose fuel content's gauges were of a different type and whose accuracy they accepted. Flowmeters that recorded fuel consumed were, however, not fitted to that series of Viscount.

The aircraft left Exeter at 1418 hrs with the co-pilot at the controls, following the route Exeter – Berry Head – Dinard – Nantes – Santander. The flow meter totals had been set to zero at start up and on departure the port fuel contents gauge read full whilst the starboard gauge read slightly less than full. A fuel check over Nantes, using flow meter totals, was exactly according to plan and on arrival at Santander 8 minutes ahead of schedule at 1622 hrs the flow meters recorded a consumption of 3163 litres, that is 287 litres less than the planned figure. At this time the fuel contents gauges read approximately half full, with the starboard gauge reading slightly less than the port.

The aircraft commander recorded in the Technical Log a fuel state on shut down of 3178 litres and ordered a total fuel load of 5902 litres for the return flight, that is 454 litres less than the figure for full tanks. Whilst the aircraft commander was with the handling agents, the co-pilot supervised the refuelling. He requested a total uplift of 2720 litres and wrote the figures down, showing them to the senior of the two operators of the refuelling vehicle, which was not the one that had refuelled the aircraft on its earlier flight. With the aircraft obtaining its electrical power from the same ground power unit as before apparently quite satisfactorily, the operators then refuelled the two sides of the aircraft one after the other, using the same hose each time. When the refueller finished pumping, its indicators recorded a total delivery of 2720 litres and the co-pilot, who had watched the operation, checked the figures and signed the delivery note accordingly. Neither pilot made a physical check of the aircraft's tanks using the dripsticks. Before starting engines the pilots again set the flow meter totals at zero and the co-pilot states that he recalls the fuel gauges reading substantially the same as on departure from Exeter, that is to say the port gauge showing full and the starboard two thirds full. However the aircraft commander recollects that the starboard gauge was indicating zero prior to departure and that after take-off it flicked to FULL. With 58 passengers on board and the aircraft commander at the controls, the aircraft left Santander at 1733 hrs and was shortly afterwards cleared to its planned cruising level of Flight Level 180, on a route which was the reverse of the outbound route.

The planned flight time was 2 hours and 9 minutes, giving an estimated time of arrival (ETA) at Exeter of 1942 hrs, with an expected fuel consumption of 3375 litres, leaving a reserve of 2527 litres, sufficient for approximately 1½ hours of flight. At 1846 hrs the aircraft passed over Nantes. The flow meters then indicated that 1964 litres had been consumed, which was exactly according to the navigation plan and the crew therefore recorded that at that moment 3320 kgs (4150 litres) remained in the aircraft tanks.* Neither pilot had any recollection of the indicated fuel contents over Nantes, but at approximately 1910 hrs whilst in the area of

** The sum of the fuel consumed and fuel remaining recorded by the crew equals 6114 litres (at 4.54 litres per 1 gallon) whereas the total fuel recorded on departure was 5902 litres. This discrepancy appears to have been due to an error in paperwork on the Fuel Log.*

Dinard, the fuel contents gauges began to cause them some concern. The port gauge, with various fluctuations, occasionally fell to zero, but sometimes read full. The starboard gauge gave a reading equivalent to 500 litres and continued to fall steadily as the flight progressed. The pilots reviewed the fuel situation and although uneasy, considered that in the light of the recorded uplift and the totals on the flow meters, that they must have ample fuel on board. As the aircraft approached Guernsey the aircraft commander considered diverting there in order to take on more fuel, but after further thought decided against this action. During this period a number of passengers visited the flight deck and the possibility of landing at Guernsey was not discussed with the co-pilot. At 1928 hrs when the aircraft was between Guernsey and Berry Head, it received initial descent clearance and shortly afterwards was further cleared to Flight Level 40 on a direct track for the Exeter Non-directional Beacon (NDB). During this period the crew could be heard on the Cockpit Voice Recorder (CVR) to make several references to the fuel gauge indications, which clearly caused them some concern, but not in the sense that they believed that the aircraft was running short of fuel. After the aircraft passed Skerries, one of the pilots could be heard to say 'THAT'S ALRIGHT THAT ONE'S FILLED UP AGAIN NOW', presumably with reference to one of the fuel gauges, but which one was not stated. At 1942 hrs the crew changed frequency to Exeter approach and started to receive radar positioning for runway 26. The cloud was given as one okta at 700 feet, 5 oktas at 1000 feet, and 7 oktas at 2500 feet, with a visibility of 13 kilometres and a surface wind of 280 degrees at 7 knots. At this stage, one of the pilots could again be heard to say on the CVR 'THAT TANK'S FILLED UP AGAIN NOW IT'S GONE FROM ZERO TO FULL TANKS IT'S GONE RIGHT ROUND TO FULL TANKS AGAIN'. At 1944 hrs the crew performed the approach checks, which included selecting flap to 20 degrees and switching on the fuel heaters. As fuel heat was selected, there was momentary flash from one of the two low pressure warning lights and after a brief discussion the crew opened the fuel crossfeed cocks, which had been closed since their pre-flight checks at Exeter. At 1950 hrs the aircraft was at 2000 feet QFE, just below cloud and about 8 miles from touchdown. The flap was still at 20 degrees and the undercarriage was retracted. Suddenly both low pressure fuel warning lights illuminated and in rapid succession all four engines lost power. The aircraft commander made an immediate Mayday call to Exeter and at the same time gave a warning on the passenger address system. Knowing the local terrain, the commander turned left in the best hope of finding a suitable area for a forced landing. With the flap still set at 20 degrees, the aircraft descended on a heading of approximately 190 degrees (magnetic) along a small grassy valley studded with trees, the average elevation of which was 130 feet above mean sea level. As the aircraft crossed the boundary of the field, the port wing struck a tree, damaging the underskin and removing the mid section of the port flap. It then touched down with the nose well up, with the stall warning in operation and the control column hard back. The rear of the fuselage struck the ground first and almost simultaneously the port wing struck a tree causing a noticeable yaw to the left as the nose pitched down. Without hitting any further obstruction the aircraft came to rest after 307 metres on a heading of 074 degrees (magnetic). The crew assisted with the subsequent evacuation, which was orderly and there were no injuries.

The total flight time since take-off from Santander had been 2 hrs 20 minutes, with a fuel consumption, according to the flow meters, of 3458 litres. On examination, all fuel tanks were found to be empty.

The accident happened in daylight at 1953 hrs just south of Ottery St Mary in Devon.

1.2 **Injuries to Persons**

Injuries	Crew	Passengers	Others
Fatal	–	–	–
Serious	–	–	–
Minor/none	4	58	

1.3 **Damage to aircraft**

The aircraft was substantially damaged and was subsequently assessed as being beyond economical repair.

1.4 **Other damage**

A number of livestock were killed and damage was caused to trees and pasture surface by the aircraft during its crash landing.

1.5 **Personnel information**

a Aircraft commander:	Male
Age:	55 years
Licence:	Airline Transport Pilot's Licence valid until 17 March 1981
Ratings:	Viscount, Herald, DC3, Islander, Trislander. Current Certificate of Test of Viscount aircraft, with current Instrument Rating
Last medical examination:	6 March 1980, valid until 30 September 1980, with restriction 'as or with co-pilot'
Flying experience:	
Total hours as pilot:	14,487
Total hours (PI) on type:	1,540
Total preceding 28 days:	36, all on type
Rest period	15 hours 15 minutes
b Co-pilot:	Male
Age:	58 years
Licence:	Airline Transport Pilot's Licence

Ratings:	DHC1, Britannia, Viscount, all as P1. Current Certificate of Test on Viscount aircraft, with current Instrument Rating
Last medical examination:	28 May 1980, valid until 30 November 1980, with restriction 'to have spectacles available in flight'.
Flying experience:	
Total hours as pilot:	3895
Total hours on type:	1022 hours P1, 1882 hours P2
Total in preceding 28 days:	11, all on type
Rest period:	15 hours 50 minutes.

The co-pilot also had extensive experience as a Flight Navigator.

1.6 Aircraft history

1.6.1 The aircraft was a Viscount 708 constructed by Vickers-Armstrong Limited under serial number 10 in 1953. The aircraft had a valid Certificate of Registration, number G–ARBY/R3, issued on 29 July 1975 and a valid Certificate of Airworthiness in the transport category, number 1370, first issued on 11 August 1976 and valid from 12 August 1979 until 11 August 1980.

The current Certificate of Maintenance was issued on 17 June 1980 after a check 1 + 3BC at 35029.03 airframe hours, 29542 landings and valid for 100 days/400 flying hours to 24 September 1980. At the time of the accident, G–ARBY had flown a total of some 35121.36 hours.

Inspection of the Alidair maintenance records revealed no evidence of any problems regarding fuel consumption, fuel leakage, or refuelling procedure although there was considerable evidence of long standing problems associated with the fuel contents gauging system going back to March 1979, with a recurrent intermittent full scale deflection defect on the port gauge and an occasional zero deflection on the starboard fuel contents gauge.

Between this time and the accident, the port fuel contents gauge was reported as defective on some 12 separate occasions, despite attempts to rectify this defect including an investigation carried out during the last check 1 + 3BC in June 1980, following a pre-check inspection report. This recorded fluctuating low resistance in the contents gauge 'feed' cable in the area between the rectifier unit in nacelle number 1 and port wing root. Due to the difficulty in rectifying defects in this cable, because of its location within the wing leading edge structure, this defect was 'carried forward' until the outer wing change which was scheduled within the following six weeks. Subsequent to this check, the port fuel gauge was recorded as defective on 20 June 1980 (Tech Log sheet No 3352), with action deferred. This was the last occasion, before the accident, upon which the port gauge was recorded as defective in the Technical Log.

With regard to the starboard fuel contents gauge, subsequent to the last check 1 + 3A, B, C and D, which was carried out between November 1978 and March 1979, the first record of it being defective was on the 11 November 1979 (Tech Log sheet No 27243) when it was reported as reading 'zero' in the cruise. Examination showed that one of the tank 'probes' (ie pacitors) was defective and due to lack of spares the rectification was carried forward. The next Check 1 on 19 November 1979 recorded that a broken wire in a starboard system probe was remade and the system checked satisfactorily. The symptom of 'reading zero' however returned on 29 April 1980 (Tech Log sheet No 30274). On this occasion, the connection at the contents amplifier was remade and a ground check completed satisfactorily.

On 30 April 1980 (Tech Log sheet No 30278) the starboard fuel contents gauge was again reported as 'intermittent zero'. The tank probe connections were remade and the system again ground checked satisfactorily.

However, during the Check 1 + 3BC in June 1980 the starboard gauge was again reported defective and further work was carried out. An unspecified connection was re-soldered. No further starboard fuel contents system problems were recorded prior to the accident.

No evidence was found within the maintenance records or from conversations with Alidair maintenance personnel of problems associated with the aircraft ground power socket except for isolated occasions when problems had been encountered due to defects in the connections on ground power units. Similarly, there was no evidence of any problems having been encountered with either refuelling valve or the associated circuit breaker.

1.6.2 *Weight and centre of gravity*

The load sheet prepared prior to departure from Santander included the information that there were 25 adult male passengers and 33 adult female passengers on board. Subsequently it was established that in fact the load consisted of 19 adult male passengers, 24 adult female passengers, 13 children and 2 infants. The total traffic load was therefore 512 kg less than that recorded. At the time of the accident, the aircraft's weight was 20,589 kg and the centre of gravity at mid range. The maximum permitted zero fuel weight was 22,226 kg and the maximum authorised weight 27,216 kg. The maximum authorised landing weight was 23,587 kg.

1.6.3 *Fuel dripsticks*

Dripsticks are incorporated in certain wing fuel cells to provide means of measuring the quantity of fuel contained within a tank. Access to each dripstick is from the underside of the wing and to measure the quantity of fuel in each cell, its dripstick is withdrawn downwards out of its tube until fuel just begins to flow or alternatively is first fully withdrawn and pushed back up until the flow of fuel just ceases. The amount by which the dripstick is extended when the fuel either just begins or just ceases to flow is directly related to the quantity of fuel in the cell which can be measured by reference to the calibration marks on the stick itself. Accurate measurement by this method requires the aircraft to be on level ground.

1.7 **Meteorological information**

The accident took place at 1952 hrs. At 2000 hours a special weather observation was made at Exeter Airport and the following items recorded:

Surface wind:	210°/14 knots
Visibility:	10 kilometres
Cloud:	2 oktas at 700 feet 6 oktas at 900 feet 7 oktas at 2,000 feet All cloud heights were estimated
QNH:	1016 milibars
QFE:	1012 milibars
Present weather:	Nil.

The *en route* winds and temperatures encountered by the aircraft between Santander and Exeter at 500 mbs (FL 180) were as follows:

	Santander	Bordeaux	NW France	SW England
1800 hrs	330/25 – 10°	310/30 – 12°	285/40 – 11°	280/50 – 13°

The forecast upper winds were found to be in close agreement with the above values.

1.8 **Aids to navigation**

When the engines lost power the aircraft was engaged in a Surveillance Radar Approach (SRA) to runway 26 at Exeter Airport. The distresss call was made at about 7½ nautical miles from touch down, on the centre-line. Although the Approach Radar Controller continued to offer assistance he received no answers; on the radar he saw the trace diverge to the South and disappear at a range of 6 nautical miles, on a track of 089° (M) from the airfield. The Exeter Non-Directional Beacon was operational and being received by the aircraft.

1.9 **Communications**

Communications were satisfactory on Exeter Approach Frequency, 128.15 MHz.

1.10 **Aerodrome and ground facilities**

Not applicable.

1.11 Flight recorders

1.11.1 Flight data recorder

The aircraft was fitted with a Plessey PV710 digital flight data recording system, which utilised a Davall type 980 protected recorder unit which had stainless steel wire as the recording medium. The unit was mounted at the rear end of the rear baggage bay. The following 5 parameters were recorded:

Air speed, altitude, magnetic heading, normal acceleration, flap angle.

The other mandatory parameters at the time of the accident namely pitch and roll angles and engine power, were not recorded since they had been exempted under the provisions of Scale P in Schedule 5 of the Air Navigation Order 1976.

The recorder was recovered undamaged from the aircraft and a good replay was obtained using the Accidents Investigation Branch replay facilities, all parameters having been recorded satisfactorily. The altitude and air speed transducers were checked and recalibrated and the data so obtained was used in the conversion process. Small datum corrections, deduced from known zero conditions, were also applied to the normal acceleration and flap position calibration data.

In addition to the accident flight, the three preceding flights made by the aircraft were also replayed in order to enable an analysis of the climb performance to be made. The results of this analysis are contained in paragraph 1.17.

1.11.2 Cockpit voice recorder

A Fairchild type 100 4-track cockpit voice recorder was fitted to the aircraft. This was mounted in the rear baggage bay and used plastic based tape as the recording medium. The recorder track allocation was as follows:

Track 1	P1 Headset telephone audio
Track 2	P1 and P2 microphones
Track 3	Cockpit area microphone
Track 4	P2 Headset telephone audio

The recorder was recovered undamaged from the aircraft and a satisfactory replay was obtained. A transcript of the last 30 minutes of flight was produced.

1.12 Examination of wreckage

1.12.1 On-site examination – General

The crash site was a large, essentially flat, grass field approximately one mile south west of the village of Ottery St Mary (some six miles east of Exeter Airport), bounded on its eastern edge by a disused railway track and the river 'Otter' and on its west side by the Fluxton Road. The field was some seven hundred yards in length north/south and apart from numerous isolated trees within its northern area, fairly unobstructed.

The Viscount's port wing had struck a large tree on the line of the northern boundary of this field, damaging the underskin between engine nacelles 1 and 2, and detaching the mid-section of port flap, before the aircraft's first ground contact some two hundred yards south of this tree on a heading of approximately 190° (magnetic). Two linear 'cuts' were found in the grass just before the initial fuselage impact area which had been made by number 1 and 2 propeller assemblies and which indicated that both of these propellers were already 'feathered' at the moment of ground contact. With regard to the starboard propellers, evidence of normal slashes were found which had been made by both starboard propellers and which indicated that neither of these had been feathered at impact. Some thirty-two yards beyond the fuselage mark, a large impression had been made by the number 1 propeller/engine assembly. This propeller assembly (less 1 blade found beside a dead sheep) was found detached and adjacent to a tree located some one hundred and seventy yards beyond the initial fuselage contact mark. This tree show marked evidence of contact on its trunk and the outboard section of the port wing and outboard aileron section were lying near by. Apart from severely damaging the port wing, this second tree impact caused G–ARBY to yaw to port, as it slid across the remainder of the field before coming to rest on a heading of 074° (magnetic) and adjacent to the eastern boundary fence of the field.

Inspection of the port wing showed it to have undergone almost total structural separation, as a result of the number 1 propeller/engine ground contact and subsequent tree-strike, in the area of the number 1 nacelle. The latter suffered failure of forward and aft engine supports due to outboard and downwards displacement. The starboard wing was undamaged and the fuselage had only suffered flattening of its underside, with its tail section intact. All three main undercarriage legs were in their retracted positions prior to touch down. The flaps appeared partially extended and later inspection of associated gauges showed some 22° of flap had been extended.

No evidence of fire was apparent, although one fire extinguisher (carbon dioxide type) from the flight deck aft/starboard wall, was found discharged and lying in front of the port wing. The remaining two fire extinguishers were still in position (ie forward galley 13 pounds carbon dioxide and rear cabin water glycol extinguisher) and undischarged.

Inspection of the crash-switches showed only the two units located in the number 1 nacelle to have tripped (the remaining two in the battery bay of the fuselage and the two units in the number 4 nacelle remaining untripped) causing all four engine bay fire extinguishers to discharge.

With regard to flight deck control settings, all four throttle levers and the associated HP cock/feathering levers were found closed, but not in the feathered position. All four LP fuel cock switches were wire-locked at 'on', both cross-feed switches were selected to 'on' and the four boost pump switches were also at 'on'. The fuel heater switch was at 'on', as was the fuel flow master switch, but the battery switch was 'off'. The undercarriage lever was at 'up' and in its detent. The flap lever was at the 40° selected position (flap range 0, 20, 32, 40 and 47°). The rudder trim was approximately one-tenth of a division 'left of centre'. The elevator trim was approximately two-thirds of a division nose-down. Both the 'fasten belts' and 'no smoking' switches were at 'on'.

The digital read-out of fuel on each fuel flow gauge was as follows:

No 1	891 litres
No 2	794 litres
No 3	911 litres
No 4	862 litres

The captain's altimeter was set at 1012 mb, standby altimeter at 1020 mb and the co-pilot's altimeter set at 1012 mb.

The VHF No 1 set was set to 130.65 MHz, (high volume); Comm 2 was at 128.15 MHz; Nav 1 and 2 were at 112.70 MHz and on; Nav (DME) was at 109.40 MHz and on; the ADF was set at 336 KHz and the transponder was on Mode A, altitude repeating, code 6710.

All four fire extinguisher pull-rings were unpulled. All circuit breakers were in.

1.12.2 *Inspection of the fuel system*

Inspection of the fuel system contents by means of the four underwing dripsticks showed that the fuel tanks were empty.

An attempt was made to obtain a fuel sample from each engine LP filter, except for number 1 engine which had lost its LP filter as a result of ground impact damage. Approximately 1 litre of fuel was drained from number 2 engine filter, but only a few millilitres were present in the LP filters of numbers 3 and 4 engines. In addition the flame-tube burner supply line on each engine was checked for the presence of fuel with negative results in all four cases.

In an effort to obtain fuel samples from the number 3 and 4 LP filters, battery power was switched on after reconnecting the batteries and with one booster pump operated on each side, still no fuel flow was obtained.

Inspection of the port refuelling pipe area showed it to have been badly distorted and cracked as a result of the number 1 nacelle ground impact damage and no fuel had remained in either refuelling or defuelling lines. The starboard refuelling point was by contrast quite undamaged, and separate samples were taken from the re-fuelling line and defuelling line, the latter after operating the associated manually operated defuelling cock.

These two fuel samples including that taken from the number 2 engine LP filter and the sample from the refuelling bowser at Exeter Airport were submitted to MQAD, Harefield on 22 July 1980 for analysis, with a special request for tests to compare the samples.

Both port and starboard booster pump isolation chambers were checked for fuel but only some 50 and 20 ml respectively was obtained. All fuel cell access panels were removed and each of the eight rubber 'bag' tanks per wing inspected internally with the aid of a torch.

Port cell number 1 (ie located between 1 and 2 nacelles, forward) was distorted due to the number 1 nacelle damage and was also torn on its floor due to pene-tration of the wing underskin as a result of the first tree strike. The adjacent cell outboard (number 2) was also distorted as a result of number 1 nacelle damage and also torn just forward of the main spar arising from what appeared to be propeller-blade penetration from the underside of the wing. The associated refuelling valve on the floor of this cell was 'tilted' outboard due to gross cell distortion arising from the number 1 nacelle damage.

The next cell outboard, number 3, appeared satisfactory and the 'overwing' refuelling cap was in place and its seal intact. The refuelling float switch appeared satisfactory.

The last cell outboard, ie number 4, also appeared satisfactory. It was noted that the associated refuelling relief valve (1.6 psi) had its manual operation chain missing from its discharge tube protruding at the lower wing surface, besides which was the placard 'PULL VENT BEFORE REFUELLING'.

Number 5 cell, (ie inboard aft of number 1) which houses the booster pump chamber, appeared satisfactory.

The next cell outboard, number 6 was torn in the area aft of the access panel aperture due to the structural break-up of this wing.

Cell number 7 appeared satisfactory, as did cell number 8 – although the latter had some seven repair patches on the inner surface of the rubber walls, all of which appeared sound from a sealing viewpoint.

All the above cells had small puddles of fuel present on their floors and corners, but all were dry underneath their cell floors when the latter were lifted from around the access panel aperture and inspected with a torch.

Similar inspection of all eight starboard wing fuel cells showed them to be satisfactory with no evidence of leaks and only slight fuel puddles remaining. All cells were checked beneath their floors and found completely dry. The only defect found during this inspection of the starboard cells was a displaced coupling seal in the 0.4 psi cell vent-line, at the pipe coupling located approximately 2½ inches above the floor of number 7 cell. The underwing vent pipe aperture is located immediately below this area, at the underwing surface.

This seal, part of which was protruding from the pipe coupling, was observed to be of a translucent yellowish colour - quite different from the seal in the equivalent starboard vent-line coupling, which was of the usual black 'nitrile' material.

Both electrically operated cross-feed valves were visually inspected for position status using their in-built indicators on the units and both were found to be at 'open' (in agreement with the associated flight deck switch settings as found).

The number 2 engine LP cock was also checked for its status by disconnecting the fuel line coupling on its forward side, collecting the fuel sample thus obtained (later submitted to MQAD, Harefield for comparative analysis together with the number 2 LP filter sample to evaluate gas/liquid chromatography results 'scatter') and checking the valve position, which was found to be open, again in agreement with the flight deck LP shut-off cock switch setting.

Subsequent to pulling all non-fuel system related circuit breakers and the low voltage sensing relay circuit breaker in the electrical bay, the DC normal electrical supply was made available for fuel system checks. With a fire-tender present, some

23 gallons of Jet A1 fuel was poured into cell number 5 on each side through the tank 'probe' (pacitor) access holes.

Both LP fuel warning lights illuminated with electrical power and could be extinguished by switching any of the four booster pumps on (the latter could also be heard operating individually).

Both cross-feed switch magnetic indicators were at 'open', as were the four LP shut-off cock magnetic indicators. Both cross-feed valves and LP shut-off cocks were checked for repeated operation from their respective switches and then left in the closed position.

Both cross-feed line power drain cocks were checked and found to be closed and completely dry.

Function checks were carried out on both port and starboard refuelling valves 'in situ' before removal and utilizing the associated refuelling access door microswitches. The port solenoid was found to operate satisfactorily, but the starboard refuelling valve was intermittent in operation. Subsequent to the removal of both refuelling valves, microswitches and the associated two float switches, electrical checks on-site confirmed that the starboard refuelling valve appeared to have an intermittent fault. These units, in addition to all fuel system pacitors, the associated rectifiers, contents gauges, fuel flow units, amplifiers, fuel flow gauges, cross-feed valves, power drain cocks, pressure relief valves, vent relief valves, and vent system anti-surge valves were all subsequently removed for further detailed bench-checks.

The on-site examination was completed after a period of 3 weeks.

1.13 Medical and pathological information

Not applicable.

1.14 Fire

There was no fire. All engine fire extinguishers had discharged on touch-down due to the operation of two crash switches. After the aircraft had come to rest, the aircraft commander discharged a CO_2 hand fire extinguisher into the number 2 engine, though no evidence of a fire in that engine was subsequently found.

Units of the Devon Fire Brigade attended the scene of the accident, the first appliance arriving on-site at 2000 hours. No extinguishant media was discharged.

1.15 Survival aspects

The relatively gentle touch-down and smooth deceleration made it possible for all occupants to leave in good order, assisted by the crew, and without deploying chutes. Nearly all the passengers used the normal exits. There were no injuries but five passengers were taken to hospital suffering from shock. Five ambulances attended the scene, the first arriving at 2008 hrs. As found, both cabin doors on the port side were open and the escape rope had been deployed from its roof stowage recess adjacent to the forward door. The aft door escape slide had not been deployed and was still stowed in its floor recess. All 60 passenger seats and associated lap belts were secure, as was the two-place (aft facing) fold-down cabin staff seat adjacent to the forward door. None of the emergency windows had been removed, but one handle of the six emergency windows marked internally (numbers 6, 7, 8) had been pulled breaking the copper securing wire (starboard number 7). In fact, all the windows were equipped with release handles, although only the above six were identified as such internally.

1.16 Test and research

Fuel leak checks

In order to find out if the defective seal in the starboard vent line coupling would allow fuel to leak into the vent pipe through the associated coupling and thus overboard via the vent, a plastic container of a height just less than the cell at that point was fitted around the defective seal coupling and fuel was pumped into the container to represent the effect of an almost full cell. This static leak check (ie with no 0.4 psi differential pressure being applied) produced no fuel leakage from the overboard vent aperture. This vent pipe complete with defective coupling and associated vent valve was removed intact from this cell and submitted to the College of Aeronautics, Cranfield, for further leakage tests using simulated differential pressure. After these tests, the seal was submitted to the MQAD, Woolwich for material specification identification.

In order to check for effective sealing of the cross-feed valves against any possible fuel transfer whilst closed, the port cross-feed valve was first checked by operating one port booster pump for two minutes. A 50 ml sample of fuel was collected from the starboard power drain cock during this time. This was repeated with both port booster pumps operating and only a 20 ml sample was collected, representing the fuel leakage past the closed port cross-feed valve over a period of two minutes.

This test was repeated with the starboard booster pumps functioning, with no leakage at all past the closed starboard cross-feed valve.

The port cross-feed valve was then cycled and finally positioned to closed and the exercise repeated, with the results as before.

In order to check for leakage out of the cross-feed pipe itself, the starboard power drain cock was closed, port cross-feed valve opened (leaving starboard cross-feed valve closed and all four LP shut-off cocks closed) and both port booster pumps operated for some five minutes whilst the cross-feed pipe area was visually inspected from both wing root trailing edges, access panels and internally in the fuselage underfloor area of the centre section. No leakage was observed. In addition, on switching the port booster pumps off, the port LP fuel pressure warning light stayed off for some 28 seconds before illuminating (this switch is set at 5 psi) – confirming the absence of any external leakage from the cross-feed fuel pipe up to the starboard cross-feed valve.

Similar visual checks were carried out on each engine supply line up to its respective shut-off cock (when closed) with booster pumps operating and then, with LP shut-off cocks open on the section of line between shut-off cocks and LP filter (except for number 1 engine where the ruptured LP filter prevented this) but with no evidence of leakage.

Both cross-feed valves were checked for operation and sealing at British Aerospace, Weybridge with satisfactory results, as were both power drain cocks, anti-surge (vent) valves, 0.4 psi vent valves and both refuelling pressure relief valves.

The results of the Cranfield College of Aeronautics tests on the displaced vent coupling seal in the starboard vent line indicated an overboard leakage rate of between 2 and 5 gph only with 0.4 psi differential pressure applied. The seal was submitted to MQAD, Harefield for material analysis who in turn submitted it to P2QD at Woolwich. Their report found the seal material to be a vulcanized silicone rubber material consistent with material specification DTD818 which is only compatible with oil/air systems – ie not fuel systems. In the presence of kerosene, this material can swell in volume.

Refuelling valves

Full bench-checks and pressure tank testing was carried out at Flight Refuelling Limited, Wimborne, on both refuelling valves and showed them to behave intermittently on initial bench-test, but to operate satisfactorily thereafter during full pressure function-testing. Subsequent bench-checks were repeated satisfactorily. Both float switches were checked satisfactorily at British Aerospace, Weybridge, and the associated refuelling door microswitches were also found to operate satisfactorily.

Fuel content gauges

To gain some appreciation of the operation of the fuel contents system, some six plastic containers were obtained and cut to varying heights corresponding to the six starboard fuel cells which had fuel tank 'probes' (pacitors). The pacitors were then removed from cells number 1, 2, 4, 5, 6 and 8, the containers then being placed in the cells below the pacitor aperture, the containers filled with fuel and the pacitors replaced. When battery power was again applied to the aircraft and with one inverter on, the starboard fuel gauge was then checked and found to read '2150 kg' which compared with the correct 'full tanks' indication (based on 700 imperial gallons total per side) of 2524 kg. Most of this error was probably due to the containers not quite representing the maximum available height of the cells.

Upon replacing the starboard pacitors with the pacitors from the port fuel cells (since due to port wing damage, that fuel contents system could not be operated) a reading of '2120 kg' was obtained – ie only some 30 Kg lower than the previous reading.

The depth of fuel in each container was then 'halved' and the following readings taken:

Starboard pacitors	1,000 Kg
Port pacitors	900 Kg

With all fuel removed from the containers, both starboard and port pacitors gave a reading below zero on the starboard fuel contents gauge.

All twelve pacitors, both rectifiers and the two fuel contents gauges were bench-checked and calibrated at Marconi Avionics Limited, Rochester, and found to perform satisfactorily. No fault could be found to account for the defect in the port fuel contents gauge.

An inspection of the pacitors carried out at Farnborough showed the starboard number 5 probe to have 2 small screws loose inside the unit between the outer and inner cylinders of the unit. These screws were of sufficient size to bridge the inter-cylinder gap, and thus cause a zero deflection of the starboard contents gauge.

A fuel system maximum capacity test was carried out on another 708 Series Viscount at East Midlands Airport on 18 November 1980, having first installed the 2 float switches from G–ARBY and then completely drained the fuel system to the point where all 4 LP filters were 'dry'. The aircraft was then totally refuelled, bleeding air at all 4 LP filters and until float-switch 'cut-off'. This gave a total maximum fuel uplift of 1415 imperial gallons (6424 litres).

Electrical continuity and insulation checks were carried out on both port and starboard fuel contents circuits between the rectifier units, respective wing roots and associated flight deck contents gauge inputs, without revealing any pre-crash defects. Similar checks on the power supply cables to both rectifier units were also satisfactory.

Flowmeters

All 4 fuel 'sender' units, 4 computer amplifiers and the 4 fuel flow gauges were checked and calibrated at the manufacturers, George Kent Limited, Luton with satisfactory results. Further calibration of the fuel flow sender units was carried out at 90 gph and 86 gph representative of climb and cruise power in order to obtain accurate percentage errors which could be used to modify the recorded fuel usage on the last flight. The total system error was found to be + 2.18%.

Ground power socket

In view of the reported problems with ground power continuity during refuelling at Santander during the aircraft's first visit, inspection was made of the ground power socket area which is located on the underside of the fuselage in the centre section area. The ground power socket terminals on G–ARBY were satisfactory. It was confirmed that the refuelling circuit was controlled by one circuit breaker (number 13) on the circuit breaker panel (located aft starboard wall of the flight deck) and required either battery power to be switched on (associated switch on the port coaming panel in the down position) or ground power selected (switch in up position). With ground power selected, if the latter goes off-line, power will be lost to both refuelling valves and they will close, there being no reversion to battery power.

Fuel sample analysis

MQAD, Harefield carried out the normal specification analysis for Jet A1 Kerosene which was generally satisfactory on all submitted samples. In addition, gas/liquid chromatography tests were carried out on the samples. These tests showed that the Exeter Tanker and the number 2 engine LP fuel filter samples had a common saturated hydrocarbon component ($C_{15}H_{32}$) presence 'peak' which the starboard samples did not have. The latter two samples were found to be almost identical.

1.17 Additional information

1.17.1 Flight data recorder analysis

Since there were clear indications at an early stage of the investigation that the aircraft did not receive the amount of fuel requested either at Exeter or Santander, notwithstanding the evidence to the contrary at both places, it was considered possible that the airfield where the shortfall in fuel uplift occurred could be identified from an analysis of flight recorder data.

The aircraft made four flights on the day of the accident, namely two return flights from Exeter to Santander. An analysis of each of those flights was made to compare the actual climb performance with that which the aircraft should have achieved at the weight stated on the load sheet.

At the request of the AIB, the analysis was carried out by British Aerospace in accordance with a long established method for making such comparisons and was based on the aircraft's original drag equation, FDR data and reported air temperatures prevailing at the operating altitudes.

The analysis showed that on the first three flights, the aircraft's climb performance was, on average, 100 feet per minute less than it should have been. This shortfall could have been due to some slight deterioriation of the engines and airframe or a small mis-setting of engine turbine gas temperatures. However, the overall performance for all three flights was similar and indicated an acceptable consistency in the method of performance measurement used for the analysis. This confirms in each case that the aircraft's take-off weight was in accordance with the load sheet figure.

The climb performance achieved on the fourth flight, that is the accident flight itself, showed a significant reversal of the relationship between estimated and achieved climb performance to that found on the other flights, in as much as the aircraft climbed on average at about 200 feet per minute faster than predicted. In fact the aircraft's actual rate of climb was close to that which would have been achieved had the all up weight been some 2177 kg (4800 lbs) less than that recorded on the load sheet, after allowing for the error noted in paragraph 1.6.2. This weight is equivalent to 600 gallons of fuel, which in fact is the amount of fuel which was presumed to have been put on board prior to the aircraft's departure from Santander.

The higher rate of climb on the fourth flight was not noticed by the crew.

1.17.2 Units of fuel measurement

During the operation of the aircraft it was necessary to use several different units for the purposes of measuring fuel quantities. Fuel was delivered in litres, which were also the units indicated on the flow meter totals and which also recorded rate of flow in litres per hour.

The fuel contents gauges were calibrated in kilogrammes. Within the company, it was the practice to record imperial gallons in the technical log and to refer to the gallon scale when using the dripstick. The technical logs and navigation plans for the six weeks preceding the accident showed that, apart from small clerical errors typical of day-to-day operation, the system of fuel measurement worked satisfactorily. There was nothing to suggest that confusion over units of measurement could have contributed to the accident.

1.17.3 *Examination of the refuelling vehicle at Exeter airport*

The vehicle used to refuel G–ARBY at Exeter Airport on the day of the accident was a Cornwall type refueller, manufactured by Thompson Brothers in September 1961. The inspection of this vehicle was directed towards its defuelling capability to determine whether or not it was possible for accidental defuelling to take place. In order to carry out a defuelling operation two connecters are removed from blanking points on the vehicle body and connected to adjacent couplings linking the delivery hoses to the pump suction pipe. In addition, defuelling requires the manipulation of a small defuel meter valve, the operation of which requires a handle which the operator denied possessing. However, it was noted that the square drive which accepted the handle was clean and bright relative to the other adjacent equipment. It was apparent that if the defuel connectors were coupled to the blanking points all fuel passing through and recorded by the delivery meters could only be delivered to the aircraft. It was stated that the vehicle concerned was never used for defuelling as to do so would contaminate the vehicle. Therefore the defuel connectors were never removed from the blanking points and the defuel meter was always closed.

The vehicle's refuelling records were examined and the following uplifts and deliveries were noted:

16 July 1980	Quantity in tanker at start of operations (dipstick measurement)	11,250 litres
	Delivered	2,765 litres
	Uplift from bulk store	4,982 litres
	Estimated fuel in tanker at end of day	13,467 litres
17 July 1980	Quantity in tanker at start of operations (dipstick measurement)	13,490 litres
	Delivered	7,580 litres
	Estimated fuel in tanker at end of day	5,910 litres
18 July 1980	Quantity in tanker at start of operations (dipstick measurement)	6,135 litres
	Difference between estimated and measured quantities	+ 225 litres

1.17.4 *Examination of the refuelling vehicle at Santander*

The aircraft refuelling vehicles at Santander are kept parked on a separate hard-standing just off the aircraft apron. These vehicles do not leave the airfield other than for exceptional maintenance and are themselves refuelled by separate vehicles which visit the bulk storage tanks.

The vehicle that refuelled G–ARBY on 17 July 1980 at 1841 hrs has a single tank, one pump, two aircraft refuelling hoses and three flow meters. Meter No 1 and No 2 are designed to measure the quantity of fuel delivered from their respective hoses and No 3 measures the quantity of fuel accepted during a defuel operation.

Since the rear smaller diameter hose only was used for filling Viscount aircraft, this hose was used to fill a known volume tank to verify the accuracy of the No 2 meter.

The refuel and defuel valves on the tanker are mechanically linked by slotted rods so that opening the main fuel valve would close either of the two defuel valves should they be open. However by partially closing the main fuel valve it was possible to open the defuel valves which permitted some of the fuel that was being indicated by the delivery meter to be returned to the vehicle main tank. The percentage returned could vary according to the back pressure on the delivery line; in the extreme case of the delivery line being blanked off 100% of indicated delivery being returned to the vehicle tanks. This required considerable mis-positioning of the valve control levers and as no defuelling had been carried out by this vehicle on the day of the accident with successful refuelling being carried out before and after the refuelling of the accident aircraft such mis-poisitoning would seem unlikely.

The refuelling vehicle had been sealed following notification of the accident leaving in it the fuel that remained at the end of operations on the day of the accident except for about 100 litres removed by the authorities for a check of quality. This check, by an independent laboratory, confirmed the fuel to be within specification.

The vehicle was unsealed and its contents measured with a dipstick as 10,100 litres.

A photocopy of the stockcheck and aircraft refuelling quantities relating to vehicle No 109 for 17 July 1980 were supplied by the Spanish authorities. The individual documents used to produce this report were seen and the figures verified. A summary of the refuelling record is as follows:

17 July 1980	Measured quantity of fuel in tanker before operations	17,850 litres
	Fuel dispensed by tanker up to and including G–ARBY as detailed in the table	7,820 litres
	Fuel added to tanker	4,000 litres
	Fuel dispensed by tanker after G–ARBY	3,779 litres
	Amount of fuel that should have been left in tanker after operations	10,251 litres
18 July 1980	Amount of fuel in tanker before the start of operations. (Measurement carried out before Santander personnel knew of accident)	10,200 litres
	Measured amount of fuel in tanker when inspected by AIB after unsealing and after removal of samples	10,100 litres

It was demonstrated by AIB personnel to the Spanish Authorities and officials of the refuelling company that it was possible to so adjust the tanker controls as to cause the indicators to show delivery of fuel to an aircraft when in fact the fuel remained in the tanker. This was a feature of which the personnel at Santander stated that they were totally unaware.

Subsequent to the AIB visit to Santander, further tests were conducted by the Spanish Authorities on the refuelling vehicle. A number of valve positions were tried and in the worst case they were able to achieve a recirculation of 29.5% of the fuel with the simulated aircraft refuelling valve partially open. The tests were carried out at a flow rate of 1,100 litres per minute. When the tests were carried out with the simulated aircraft refuelling valve completely closed, it was reported that there was a great deal of noise from the gears of the tanker pumps when an attempt was made to pass fuel. It is felt that had this happened during a normal refuelling operation, it would have been readily detected by the operator. As a result of the tests carried out by the Spanish Authorities, they consider that taking the worst case of valve misplacement, G–ARBY should still have received 1,900 litres of fuel. They could not envisage any electrical fault that would result in neither wing receiving any fuel. Finally, it is stated that as soon as the airport authorities learned of the accident, the tanker was sealed. The seals were broken in the presence of the UK representatives and Spanish Civil Aviation Authorities.

1.17.5 *Allowable deficiencies and deferred defect procedures*

Section 15 of the Alidair Viscount Operations Manual, Volume 2, contains a list of those items of aircraft equipment which are permitted to be inoperative in certain specified flight conditions. The list is entitled Minimum Equipment though a note at the beginning of the Section draws attention to the fact this is an incorrect description, and that the preferred term is Allowable Deficiencies. Under the heading Instruments (Electrical), it is stated that a fuel contents gauge may be unserviceable, with the following proviso:

'Provided flowmeters and dipsticks (sic) serviceable NOT essential under all conditions'.

Following the accident to G–ARBY, the company amended this entry as follows:

'Fuel contents gauges:	One acceptable inoperative under all conditions provided flowmeters and dripsticks serviceable. Quantity of fuel in the tank with the affected gauges to be measured by means of driptubes.

Against the original and amended entry, an inoperative fuel contents gauge is classified as a Category I defect. This is defined in the Manual as one requiring rectification at the next Check A, subject to spares and facilities being available.

The procedure for the rectification of a defect which is deferred is contained in the Alidair Exposition I of July 1974 which was submitted to the CAA at the time when the company was obtaining its Air Operator's Certificate (AOC).

In essence, the Deferred Defect Procedure requires an entry in the Technical Log 'Action Taken' column to the effect that the defect has been transferred to an Acceptable Deferred Defect (ADD) sheet. This entry is numbered, dated and signed by a licensed engineer. The ADD sheet records the details of the defect, the serial number of the Technical Log sheet on which the defect was originally recorded and a note of the period for which the rectification of the defect may be deferred. The ADD sheet also states that if the period is to exceed 7 days, the authority of the Quality Manager is required. It is stated that this procedure was followed in the case of the port fuel contents gauge.

When the defect is subsequently rectified or cleared, an appropriate entry is made on the ADD sheet. At the same time an entry is made in the current Technical Log sheet recording the details of the original defect, its rectification and the relevant ADD sheet number.

In order to identify those defects that recur, all defects are recorded in the Repetitive Defect (RD) System, the details of which are also contained in Alidair's Exposition I. The system requires that all defects entered in the Technical Log are also recorded on an RD sheet. In the case of deferred defects, the RD sheet entry is not made until after the defect has been rectified.

The RD sheet records a description of the defect, the Technical Log sheet serial number and the date that the defect either arose or if deferred, was rectified. When the defect is arising for the first time on a particular RD sheet, the date is inserted in the 'First Record' column. If the defect is arising for the second time, the date is entered into the 'First Repeat' column and so on up to the 'Third Repeat' column in the case of a defect that recurs four times within the time span of the particular RD sheet. At that stage, the defect becomes a 'Red Alert' item and a report is compiled and submitted to the Quality Manager, who decides upon a time limit for rectification.

The system as described is particular to Alidair and does not reflect common practice. In fact there is no ADD or RD system common throughout the industry; each operator determines his own procedure and sets it out in his Exposition, which is then submitted to the CAA for approval.

In fact the company did not operate the procedure strictly in accordance with the CAA's understanding of the Exposition, inasmuch as the RD sheets were removed from the Technical Log after a check I, III and IV, whereas they should have been retained. This resulted in the port fuel gauge defect never progressing beyond the Second Repeat column of any RD sheet and thus never reaching the Red Alert stage.

However, the company did operate a second system, which repeated the information on the ADD and RD sheets in documentation left in the Technical Records Department at its main base. The Exposition allowed for the provision of a Defects Engineer whose responsibility it was to monitor and analyse repetitive defects. In fact this position was never filled with the result that the RD sheets which has been removed from the Technical Log were not reviewed.

1.17.6 *Certificate of maintenance*

It is stated in the CAA Civil Aircraft Inspection Procedures (CAIP) Manual, reference BL/1–8, that before a Certificate of Maintenance can be issued, the licensed aircraft maintenance engineers must be satisfied, inter alia, that the recorded defects have been rectified and certified.

Airworthiness Notice No 9, Issue 3, of 10 January 1977 reiterates this statement, but in a note adds that:

'Some operators have an acceptable system for carrying forward defects beyond the maintenance check at which a Certificate of Maintenance is required to be issued. In these cases such defects are declared as 'Carry Forward Items' by properly authorised company personnel and are recorded for future action. Before issuing a Certificate of Maintenance the licensed aircraft engineer should satisfy himself that such defects are acceptable for 'Carry Forward' action and that they are properly recorded'.

Alidair had adopted the practice permitted by this note up to and beyond the date of the accident to G–ARBY. The company was unaware that the Notice had been cancelled on 31 August 1977, though the CAA have stated that authority to carry forward defects when a Certificate of Maintenance is raised has been continued.

The advice of the CAA was sought on this matter and the Authority commented as follows:

'Civil Aircraft Inspection Procedures (CAIP) are published to give those engaged in aircraft maintenance at all levels, guidance of a general nature concerning procedures. Licensed engineers, inspectors, quality control managers etc will have detailed knowledge of the specific procedures that are contained in the British Civil Airworthiness Requirements. The current issue of Section BL/1-8 of CAIP is No 3 issued in 1973. Where a BCAR section is referred to in CAIP the latest issue of that section must be consulted. BCAR Chapter A6-4 as amended 1 June 1979 does not require all recorded defects to be rectified and certified before the issue of a Certificate of Maintenance.

For reasons not associated with the issue of a C of M, Airworthiness Notice No 9 was cancelled and the revised contents list of Airworthiness Notices issued in January and again in July 1979 stated that Notice No 9 was cancelled.

Alidair are permitted to issue a C of M with deferred defects remaining on the aircraft based on a declared procedure for recording and monitoring such defects as defined in the company exposition'.

2. Analysis

2.1 Introduction

At the time of the accident the aircraft had totally exhausted its fuel, yet there was no question of the planned fuel load being insufficient for the flight. The shortfall, on the basis of flowmeter indications, amounted to 2455 litres, but the aircraft, which was largely intact, contained no evidence of leaks or syphoning. Moreover, the manner of the final loss of power made it very unlikely that a leak could be the cause of the aircraft running out of fuel, since there was no time for significant cross-feeding between the opening of the cross-feed cocks during the approach checks and the moment when all four engines stopped nearly simultaneously. In these circumstances any suggestion of fuel escaping in flight depended on there being more than one leak, with the effects of the leaks distributed evenly between the two wings. Such a hypothesis can be discarded for all practical purposes. The simplicity of the fuel system and of engine operation rule out any possibility of mismanagement in flight to an extent which could account for such a large discrepancy.

There seems little doubt, therefore, that the reason for the aircraft's shortage of fuel had its origins in the refuelling operations carried out at either Exeter or Santander and also in the degree of monitoring of those operations by the flight crew. The analysis is therefore directed towards a consideration of the evidence in order to determine at which of the two places the shortfall in fuel uplift occurred and why it was not detected by the crew.

It should be borne in mind that since each wing was for refuelling purposes a self-contained unit, and since both at Exeter and Santander the refuelling vehicle dealt with one wing at a time, using one hose, each refuelling process was effectively two operations, one for each wing.

2.2 Refuelling at Exeter

When G–ARBY landed back at Exeter from the first flight to Santander, the first crew recorded a fuel state of 1793 litres before handing the aircraft over. The technical and fuel logs for the flights since the last physical check of fuel using the dripsticks on the day preceding the accident indicate that this figure was accurate. Whilst being refuelled for the next flight to Santander each wing apparently received fuel until transfer was brought to a halt by the action of the refuelling shut off valves, whose serviceability has since been established. It is significant that the recorded fuel delivery of 4430 litres was very close to the figure which the crew expected, on the basis of the 1793 litres said to be in tanks before refuelling commenced.

The refuelling vehicle was never used for defuelling, and if it had been, it would have required the connection of a special pipe coupling within the fuel circuits on the vehicle, as well as manipulating the appropriate valves. Accidental mishandling during refuelling was therefore virtually impossible.

All the fuel records were in order, and in particular, the dipstick checks on the refuelling vehicle balanced the recorded deliveries of fuel to individual aircraft. However, this evidence did not, by itself, constitute absolute proof that refuelling took place. The possibility that the aircraft did not receive the amount of fuel recorded on the tanker's meters was therefore considered. It is clear that the aircraft must have received some fuel, for on the original 1793 litres remaining in the tanks, it would not have reached Santander. For it to have received less than the amount recorded, the shortfall would have had to have been symmetrically disposed between both wings and the refuelling valves on each side would have had to have cut-off when each wing was still just over half full. This possibility is so remote that it can safely be discounted. The alternative possibility that only one side of the aircraft was refuelled can equally well be discounted, for the resulting lateral imbalance would have been immediately apparent after take-off and probably would have posed a serious handling problem for the pilot.

In conclusion therefore, there would appear to be strong circumstantial evidence that on departure from Exeter the aircraft had full tanks, as planned.

2.3 Refuelling at Santander

During the investigation the Spanish authorities offered complete co-operation, and freely provided information as it was requested. A study of the Spanish refuelling operation, similar to the investigation at Exeter, produced an equally complete set of records and stock checks, all of which were in order and indicated that G–ARBY had received the requested quantity of fuel. The refuelling vehicle was of a type where it was possible to mishandle the controls in such a way as to produce erroneous indications of fuel delivery, to the genuine surprise of the senior officials present, though they strenuously deny that any such mishandling occurred, and of course, there is no direct evidence that it did. The quantity of fuel requested was not sufficient to bring the float valves into operation and there was no check made of the fuel on board by means of the dripsticks.

The crew's recollection of the fuel contents gauge readings was contradictory and inconclusive, possibly because of erratic behaviour of the gauges. There is therefore no direct evidence of the refuelling at Santander that can support a conclusion that the aircraft was or was not refuelled there.

2.4 Aircraft endurance

In G–ARBY the total error of the 'fuel consumed' indicators on the flowmeters was found to be +2.18%. Because of the damage to the aircraft it was not possible to establish the exact capacity of the fuel system, but an identical aircraft, fitted with the float valves from G–ARBY, was found to have an actual fuel capacity of 6424 litres, slightly greater than the nominal value. The effect of those adjustments on the nominal fuel figures is to show that the aircraft ran out of fuel after an airborne time that was within three minutes of its theoretical endurance with full tanks. There would seem to be three possible explanations for this close correlation, the first being that the aircraft left Exeter with full tanks as planned and received no further uplift of fuel. The second possibility, which would have produced the same result, is that the aircraft received the amount of fuel requested at Santander but that there was a shortfall in fuel uplift of an equivalent amount at Exeter; that is, that the aircraft received some but not all of the fuel stated to have been delivered there. The third possibility, which is a variation of the second, is that there was a shortfall in fuel uplift at both places, the sum of which, by coincidence, equalled the amount of fuel requested at Santander. Since both the second and third explanations require the acceptance of a fairly unlikely coincidence, it would seem reasonably safe to reject them in favour of the first, and to conclude, once again, that the aircraft left Exeter with full tanks.

2.5 **Analysis of information from the flight data recorder**

The Flight Data Recorder made it possible to calculate rates of climb at Exeter and Santander for the two pairs of flights on the day in question. For the first three flights, that is to say, for both flights out of Exeter, and for the first of the two flights from Santander, there was a close correlation between actual performance and theoretical predictions, with actual performance generally falling slightly short of the theoretical values. For the final flight from Santander, however, actual performance was markedly superior to the rate of climb which could be expected if the aircraft had taken-off at the revised weight as detailed in para 1.6.2. The improved performance was equivalent to what might be expected if the weight was approximately 2200 kg less than expected, corresponding to the fuel quantity which had been requested at Santander. The alternative explanation for the improved climb performance, an abnormal power setting, would have meant a considerable departure from standard operating techniques, and both pilots are adamant that this was not the case. The higher rate of climb on the fourth flight was not noticed by the crew and it would have required unusual powers of observation and deduction for it to have been noticed and related to a lighter aircraft weight than that recorded on the load sheet. Had the higher rate of climb been noticed, it would probably have been ascribed by the crew to atmospheric effects.

2.6 **Fuel sample analysis**

The analysis of the very small amount of fuel trapped in the aircraft system indicated that at least two separate sources of fuel were involved. In particular, it was apparent that the fuel remaining in the refuelling and defuelling lines on the starboard side of the aircraft had not come from Exeter. Whether or not it came from Santander could not be established since it was not possible to obtain a sample from that source to be subject to the same analysis but it is reasonable to assume that it did. The fuel remaining in the No 2 LP filter, that is on the port side of the aircraft, did however exhibit common characteristics with the Exeter fuel sample.

In order to assess the significance of these tests, one would first have to know how fuel being put aboard an aircraft mixes with that which is already in tanks and furthermore to know in what sequence fuel is fed from each part of each tank to the LP filters. None of this information is known nor was it practicable to obtain it.

Therefore any conclusions about the fuel sample analysis can at best be only speculative, but tentatively these results do suggest the possibility that some fuel was put into the starboard side of the aircraft at Santander but none into the port.

2.7 **Conclusions regarding fuel uplifts**

There is no direct evidence that provides incontravertible proof that the shortfall in fuel uplift occurred at one place rather than the other. Since the fuel records at both Exeter and Santander balanced and were complete, and since neither set of records could be shown to be in error, there is therefore no alternative to setting both aside and leaving them out of account. Likewise the fuel sample analysis results are too inconclusive to enable any use to be made of them. The evidence that remains, and upon which a view can be formed, is largely circumstantial, but it all appears to support only one conclusion and that is that at Santander the aircraft received relatively few litres of fuel at the most, notwithstanding the indications on the tanker's meters. During the investigation it was learnt that in the recent past there have been several instances of this having occurred to other operators at other airfields. It should be stated that neither the Spanish authorities nor the petroleum company concerned accept that an error of this kind occurred at Santander and consider that the aircraft received the amount of fuel requested.

The evidence upon which this conclusion is based can be summarised as follows:

1) No significant quantity of fuel leaked from the aircraft at any stage of flight.

2) The aircraft ran out of fuel after a flight time that was calculated to be within 3 minutes of its theoretical endurance with full tanks.

3) Fuel was pumped into the aircraft at Exeter until the refuelling shut off valve operated on both sides of the aircraft. The refuelling of each wing was a separate and distinct operation. The amount of fuel requested at Santander would not have brought the shut off valves into operation.

4) The controls of the Exeter refuelling vehicle were inherently incapable of inadvertent mishandling, whereas those on the vehicle at Santander could be so mishandled.

5) The climb performance out of Santander on the fourth flight of the day was consistent with an aircraft weight less than that recorded on the load sheet by an amount that approximated to the weight of fuel uplift that was requested at Santander.

Though it is concluded that the aircraft did not receive the expected amount of fuel at Santander, it does not follow that therein lay the cause of the accident. Though there is a clear obligation on the refuelling agency to check that the quantity of fuel stated on the delivery voucher has in fact been supplied, it does not follow that it has also a responsibility to ensure that the aircraft has on board sufficient fuel for flight. This is the sole responsibility of the aircraft commander as is stated unequivocally in Article 31(e) of the Air Navigation Order (ANO) 1976, the issue current at the time of the accident. The action of the crew, must therefore now be considered to determine why it was that they accepted their aircraft when it had not been properly refuelled and continued the flight when there were indications on the fuel contents gauges of a shortage of fuel.

2.8 Conduct of the flight

Given the apparent action of the float valves, and the correlation between the quantity of fuel expected to fill the tanks and the fuel actually required to do so, it was not essential that the aircraft commander should have asked for a dripstick check of fuel at Exeter, notwithstanding the unsatisfactory state of the fuel gauges. It was reasonable therefore that on arrival at Santander the pilots should have been satisfied in their own minds that they had left Exeter with full tanks. Furthermore they felt sure that they had arrived at Santander with the tanks almost exactly half-full, and had no idea that it was technically possible for a refuelling vehicle to give erroneous indications. The co-pilot, who was known for his thoroughness and reliability, had supervised the refuelling with particular care because he did not wish any misunderstandings to arise due to his lack of Spanish. The operations manual did not give precise instructions at the time regarding the use of dripsticks nor did the co-pilot consider using them, since as he saw it, there was no reason to doubt that the fuel had been properly loaded. The aircraft commander was clearly of the same mind.

It is noteworthy that the previous crew also chose not to use the dripsticks after refuelling at Santander, notwithstanding the difficulties they experienced with the aircraft's external power socket and also the fuel contents gauges. Since three of the four pilots who operated the aircraft out of Santander that day were senior captains within the company, the failure of any of them to use the dripsticks as a routine measure at a time when their use was clearly suggested must be indicative of a general attitude within the company, which the crew of G–ARBY, by their actions, were simply reflecting. Though the crew had at no time reason to doubt the accuracy of the tanker meter indications nor grounds for suspecting that virtually no fuel had been put aboard the aircraft, they still nevertheless had a responsibility to establish precisely the total fuel quantity on board. Since the fuel gauges could not be relied upon to ascertain this, there was no practicable alternative to using the dripsticks. This was implied, if not positively stated in the company's operations manual. The crew's preferred method, which was to establish the fuel quantity by calculation was demonstrably vulnerable to error and ought not to have been relied upon.

The crew's attitude towards the fuel contents gauges in G–ARBY was curiously ambivalent. Whereas the commander appeared to pay them scant regard before departure from Exeter, he nevertheless took note of their readings on the flight down to Santander, when they seem to have given sensible indications. Also on arrival at Santander, the pilots' statements that both gauges were reading approximately half full, which is what they should have been reading, again suggests that the instruments were indicating correctly at that stage. However, on departure, each pilot had a different recollection of the starboard gauge reading but both agree that the port gauge was reading full. If, as has been concluded, that virtually no fuel was uplifted at Santander, then both gauges should have been reading the same as on arrival, that is half full. Had they done so, then it is probable that the crew would have had a clear recollection of this. It seems likely therefore that when the crew did take note of the gauge indications, the fault in the port gauge had manifested itself and gave a tanks full indication. However, the starboard gauge cannot have been reading about two thirds full, as the co-pilot states. It can only have been reading either just under half full or was at zero deflection, which is in accordance with the aircraft commander's recollection. Either way, the gauge indications could not have supported the quantity of fuel that the crew believed was on board the aircraft. It seems likely, therefore, that it was from this point onwards that the crew chose to discount the fuel gauge indications as having any validity whatever, and thereafter saw no reason to change their minds. It can only be presumed that their attitude towards the gauges in G–ARBY was strongly influenced not only by the prevailing view within the company that the gauges were not to be relied upon, but also because they regarded them as being considerably inferior in performance to the ones they were more accustomed to using in the Viscount 724 and upon which they placed total reliance. In their representations, both pilots claimed that the only accurate method of determining the quantity of fuel on board was to measure the amount in the tanks with the dripsticks before refuelling and then to uplift a further known quantity of fuel, presumably by reference to the meters on the tanker vehicle. It was further claimed that this procedure was acceptable to the company. If, as the pilots claim, they believed in the efficacy of this procedure, then it might have been expected that they would have used it at Santander, but they did not. In point of fact, no support for this method of establishing fuel quantity was to be found amongst those familiar with the operation of the Viscount. In particular, it was learnt that one operator has for some time stipulated that the tanks be dripped after each refuelling, this being considered the only effective way of establishing fuel quantities prior to departure. It is, of course, self-evident that had this latter procedure been followed at Santander, the accident would not have happened. Nor would it have happened had the fuel gauges been serviceable.

Given that the crew had, by the time they left Santander, decided to accord to the fuel gauges little or no credence, their actions subsequently when over Dinard become explicable. Faced with a total disparity between fuel contents gauge readings and flowmeter indications, it was perhaps inevitable that the aircraft commander should choose to believe the latter, though not, it should be said, without some misgivings. According to his statement, he did consider landing at Guernsey, which being a company base would have been wholly appropriate, but decided against doing so for a variety of reasons. It follows therefore that he cannot have had any serious doubts about the fuel situation, notwithstanding his misgivings and preferred to trust his own computations based on flowmeter indications versus presumed fuel uplift.

He did not discuss the matter with the co-pilot, and it is unlikely that had he done so, the outcome would have been any different. Whether or not the presence of visitors on the flight deck had an inhibiting effect on the pilots cannot be proved (the aircraft commander denies that it had any effect) but on balance it is considered that it was at least a distraction and this in itself is wholly undesirable.

Thus, at a time when a safe diversion was still possible and should have been made, both pilots were firm in their belief that there was sufficient fuel on board to complete the flight. There was nothing inherent in the situation at that stage that was likely to change that conviction, which amounted to a virtual mental block.

2.9 Maintenance procedures

Notwithstanding the Acceptable Deferred Defects (ADD) procedure and Repetitive Defect (RD) system employed by the company, the port fuel contents gauge in G–ARBY was reported as defective on 12 occasions between March 1979 and July 1980. Yet the defect never got beyond the 'Second Repeat' column of any RD sheet, and thus did not reach the Red Alert stage at which point a report would have been sent to the Quality Manager. In fact, he did eventually receive a report as the result of a pre-check inspection and an investigation was instituted, but this was long after the Red Alert procedure would have come into operation.

The situation arose principally because after each check, I, III and IV, new ADD and RD sheets were raised, resulting in the counting mode of the RD system being effectively re-set to zero. This procedure was not strictly in accordance with CAA's understanding of the company's Exposition in so far as it applied the RD sheets. In fact, this would not have mattered if the second system employed by Alidair had been fully effective. As it was the absence of a Defects Engineer, allowed for in the Exposition, resulted in the old RD sheets not being reviewed and repetitive defects not being identified. This situation has now been rectified.

The CAA did not specify a calender period or flying hours cycle for the renewal of the RD sheets in the Technical Log, but left it to the discretion of the operator. The CAA state that to give precise guidance as to when the sheets should be renewed would be impracticable since it would vary with each operator's utilisation and route structure. However, it is clear that the absence of any such guidance was at least partly instrumental in the RD system employed by the company failing in its primary task. Nevertheless, the main reason for the failure of the system to identify the repetitive defect of the port fuel gauge system lay within the company itself in that the terms of its Exposition were not rigidly followed.

3. Conclusions

(a) *Findings*

(i) The aircraft had been maintained in accordance with an approved maintenance schedule and its documentation was in order.

(ii) The Repetitive Defect System records failed to identify the frequency at which defects in the port fuel contents system recurred. Frequent rectification action had not eliminated the defect.

(iii) The port fuel contents gauge was chronically unserviceable and unacceptable for continued public transport operations: this was a major contributory factor in the accident. A defect in the starboard pacitor system was capable of causing a zero deflection on the starboard fuel contents gauge.

(iv) The crew were properly licensed and well experienced.

(v) In the absence of reliable fuel contents gauges, there was no practicable alternative to a dripstick measurement to establish accurately the total fuel quantity on board, which it was the aircraft commander's responsibility to check before flight.

(vi) The method by which the pilots in the company determined the total fuel quantity, when this was less than full capacity, relied completely upon the indications of the refuelling vehicle's meters and the accuracy of their own fuel computations. This method was vulnerable to error and therefore did not satisfy the requirements of ANO 31(e) 1976 with respect to the aircraft commander's responsibilities with regard to fuel.

(vii) It could be inferred from the advice contained in the company's operations manual with regard to the use of dripsticks that discretion could be exercised as to their use in the event of a fuel contents gauge being inoperative, though this was not the intent.

(viii) The aircraft had full tanks on departure from Exeter though at Santander, notwithstanding the refuelling vehicle's meter indications to the contrary, it received at the most relatively few litres of fuel. No reason for this could be established.

(ix) The aircraft commander's decision to continue the flight to Exeter whilst in the region of Dinard, despite conflicting information regarding the aircraft's fuel state, was influenced by the prevailing view within the company that the fuel contents gauges fitted to G–ARBY could not be wholly relied upon.

(x) The aircraft's fuel became exhausted in flight because there was an insufficient quantity in the tanks prior to departure from Santander. The unsatisfactory condition of the fuel contents gauges and the non-use of the dripsticks directly contributed to the fuel exhaustion.

(xi) At a time when the conduct of the flight required the closest possible concentration from the crew, there were visitors on the flight deck, whose presence may have inhibited complete discussion between the two pilots as to possible courses of action.

(xii) The aircraft commander's handling of the emergency after all four engines had stopped was skilful and assured. Had he not acted as he did, there could have been a considerable loss of life.

(b) *Cause*

The accident was caused by the aircraft running out of fuel due to the crew's erroneous belief that there was on board sufficient fuel to complete the flight. The aircraft's unreliable fuel gauges, the company pilots' method of establishing the total fuel quantity and lack of precise company instructions regarding the use of dripsticks were major contributory factors. Meter indications on the refuelling vehicle at Santander, which cannot have reflected the quantity of fuel delivered, are also considered to have been a probable contributory factor.

4. Safety Recommendations

It is recommended that:

4.1 A re-appraisal of the operation and effectiveness of the Repetitive Defects System be undertaken with a view to ensuring that the rectification of acceptable deferred defects is not unnecessarily delayed.

4.2 The attention of operators and airport refuelling agencies be drawn to the possibility that certain fuel tanker delivery systems may not always correctly indicate the amount of fuel transferred and that total reliance by flight crews and others should not be placed on meter indications as a sole means of establishing the total quantity of fuel on board aircraft.

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