C.A.P. 302



BOARD OF TRADE

# CIVIL AIRCRAFT ACCIDENT

Report of the Public Inquiry into the causes and circumstances of the accident to Canadair C.4 G-ALHG which occurred at Stockport, Cheshire on 4th June 1967



LONDON: HER MAJESTY'S STATIONERY OFFICE

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1968

QUEEN ELIZABETH BUILDING,
TEMPLE, E.C.4.

7th May 1968

Sir,

On 6th June 1967 the Board of Trade directed that a Public Inquiry should be held into the cause and circumstances of the accident which occurred to Canadair C. 4 aircraft G-ALHG at Stockport, Cheshire on 4th June 1967.

On 14th July 1967 the Lord Chancellor appointed me to be the Commissioner to hold the Inquiry, and on 30th August 1967 he appointed William Sturrock Esq., A.F.R. Ae. S. and Captain Philip Brentnall F.C.A. to be assessors.

The Inquiry was held at 6 Burlington Gardens, W.1. It took place on 28th to 30th November, 1st December, 4th - 8th December, and 11th - 13th December 1967 and 25th - 29th March and 1st April 1968. During this period we visited the British Broadcasting Corporation to see a television film taken during flight trials on a sister aircraft G. ALHY, and R.A.E. Farnborough to see the remains of the crashed aircraft. We also visited A & A.E.E. Boscombe Down to discuss the programme of further tests referred to below and to see how the rig tests were being carried out.

During the public hearing a difference of view emerged between the Accident Investigation Branch and the Air Registration Board about the possible cause of the accident, and we therefore adjourned the Inquiry so that this difference might be resolved experimentally by ground and flight tests by A. & A.E.E. at Boscombe Down.

We heard evidence from sixty-three witnesses, a list of whose names appears at Appendix 5.

I now have the honour to present the report, with which my assessors agree.

The problem which had to be investigated was one of considerable technical complexity, and I received the greatest help from my assessors without whose skill and patient understanding my task would have been difficult indeed.

We wish to express our gratitude for the assistance we received from counsel for all parties, and from the Accident Investigation Branch, the Air Registration Board, Canadair Limited, and British Midland Airways Limited. British Midland Airways Limited cooperated to the full with the Accident Investigation Branch throughout the investigation, and not only immediately made available the information which led to the discovery of the cause of the accident but furnished the aircraft and personnel which enabled the further tests to be carried out.

No provision has yet been made in Regulations for a 'preliminary hearing' as recommended in paras. 98 and 99 of the 'Cairns Report', C.A.P. 169, 1961, and our Inquiry was held under the provisions of Reg. 9 of the Civil Aviation (Investigation of Accidents) Regulations 1951, S.I. 1951 no. 1653. Nevertheless relevant documents were freely and voluntarily exchanged between all parties before and during the Inquiry so that little time was spent exploring unimportant issues. We do not think that a 'preliminary hearing' could have resolved the difference of view between the Accident Investigation Branch and the Air Registration Board without further tests being carried out. We think that it was an advantage that those tests were carried out after twelve days of public hearing when the problem involved had been thoroughly considered, although we recognised the administrative inconvenience of adjournment. The presentation of the test results by the Establishments concerned we thought to be admirable.

I have the honour to be, Sir

Your obedient Servant

PETER BRISTOW

*The Right Hon. Anthony Crosland M.P.*
*President of the Board of Trade*

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## Part I. INTRODUCTION

At just after 0909 hours GMT on Sunday 4th June 1967 Argonaut G-ALHG, owned and operated by British Midland Airways Limited under a valid air operator's certificate, and on a charter flight from Palma Majorca to Manchester, crashed at Hope's Carr in the middle of the built up area of Stockport. Of the crew the co-pilot, cabin steward and supernumerary engineer were killed by the impact or the ensuing fire. The stewardess was severely injured but survived. The Captain was less severely injured and survived. Of the full passenger load of 79 men women and children on board, 10 survived injuries of varying degrees of gravity. The remainder 69 died as a result of the impact or of the fire which followed. In October 1967 there were in service with the transport fleets of the world nearly 900 aircraft with fuel systems very similar to if not identical with the Argonaut. A peculiarity of the Argonaut fuel system not referred to in the flight or maintenance manuals was suspected of causing the crash and was the main subject of the investigation before us. The world wide importance of this investigation is therefore obvious.

## Part II. NARRATIVE

1. The aircraft, which is referred to in this report by its call sign 'Hotel Golf', had flown from Manchester to Palma on the evening of 3rd June landing at Palma at 0220 GMT on 4th June. Hotel Golf refuelled and took off on the return flight to Manchester at 0406 GMT. The flight crew consisted of Captain Marlow and First Officer Pollard. Mr. Lloyd, a ground engineer, was carried on the flight deck in order to perform ground duties during any time spent by Hotel Golf on airfields away from base at East Midland Airport, Castle Donington. He also gave such assistance to the pilots as he might be asked to do during flight, for example keeping the fuel logs, though nothing he did in the air formed any part of his duties.

2. During the homeward flight Captain Marlow occupied the port pilots seat and First Officer Pollard the starboard seat. First Officer Pollard was flying the aircraft until about 0902 GMT when the emergency took place which resulted some 7 minutes later in the crash. When the emergency took place Captain Marlow took over the controls.

3. Captain Marlow's flight plan provided for Birmingham as alternate. At Palma he uplifted fuel equivalent to the amount 'burned off' on the outward flight, so that Hotel Golf took off for Manchester with the standard Palma-to-Manchester total fuel load, which was ample for the flight as planned.

4. The flight as far as Congleton beacon 9½ miles SSE. of Manchester Airport, which was reached at 0856 GMT, was in all outward respects uneventful, as had been the outward flight. At this time the weather report for Manchester Airport as broadcast to aircraft gave the visibility as 1600 metres in rain and drizzle, 3/8 cloud at 300 feet, 7/8 at 400, and 8/8 at 5,000.

5. Instrument Landing System (ILS) was available on the runway in use at Manchester, runway 24. Because of an improvement in the weather at Manchester at about 0900 the Precision Approach Radar (PAR) which had been in use earlier that morning was put out of service for a short time for a very minor technical adjustment. Approach Radar Control was in operation throughout.

6. At 0856 GMT the Controller cleared Hotel Golf to flight level 5000 feet and vectored her onto a heading of 030° M. At 0857 he ordered the descent to continue to 3500 feet, and shortly after checked the barometric pressure at sea level (QNH) as 1025 mb. At 0858.05 Hotel Golf was told she was 8 miles SE. of the airfield, and half a minute later was vectored onto 350° M towards the ILS localiser. Fifty seconds later Hotel Golf was ordered to continue the turn onto 290° M and then onto 245° M.

7. At 0901-30 Captain Marlow was told he was 9 miles from touchdown and well left of the centre line, and the Controller asked if he was receiving the ILS. Captain Marlow replied that he was and would turn right a little. Shortly after one engine ceased to deliver power followed very shortly by a second engine. No. 4 the starboard outer almost certainly went first, followed by no. 3. The first engine ceased to deliver power during or immediately after the approach check, when 15° flap had been extended. It is probably that the crew did not immediately recognise that a second engine had ceased to deliver power, if indeed they ever did so.

8. Just after 0903 the Controller told Hotel Golf she was 6 miles from touch down and asked if she was established on the ILS localiser. The aircraft did not acknowledge this message, and so 7 seconds later the Controller asked if she was still receiving. Captain Marlow then replied 'Hotel Golf is overshooting, we've got a little bit of trouble with rpm'. His indicated air speed was then only 116 kts, and his height above sea level 1838 feet.

9. Accordingly the Controller ordered Captain Marlow to turn left onto 160° M and climb to 2500 feet on QNH. He then asked why he was overshooting and was told 'We've a little bit of trouble with rpm, will advise you'.

10. At 0903-51 Captain Marlow asked what the left turn was onto. The Controller saw that he had already turned through 25° to the right instead of to the left, so ordered him to continue turning right onto 020° and climb to 2500 feet on QNH. This message was acknowledged by First Officer Pollard.

11. First Officer Pollard asked for the heading to be repeated and acknowledged the answer, and at 0904-41 the Controller asked the aircraft to advise him when ready to recommence the approach. By this time Hotel Golf's IAS was down to 111 kts, and she had lost height to 1287 feet QNH. By this time also she had broken cloud and was seen by an eye-witness, and thereafter was flying below cloud in conditions of reasonable visibility.

12. At 0905-26 the Controller gave Hotel Golf her position as 7 miles bearing 040° from the airfield and asked her to report her height. This he could not see on his approach control radar which gives the aircraft position in plan only. The reply, part by Captain Marlow and part by First Officer Pollard, was 'Hotel Golf 1,000'. This was the first indication to the Controller that the aircraft was faced with an emergency, and after checking that the height given was correct he put full emergency procedure into operation at the airfield and ordered Hotel Golf to turn right onto 180° M, so that she would close the ILS localiser.

13. At 0905-47 the Controller asked if Hotel Golf could maintain height - Captain Marlow, now at 981 feet above sea level and only some 800 feet above the ground replied 'just about', and was told he was 8 miles from touch down and to continue his right turn onto 200° M and maintain as much height as possible. At this point 341 feet of height was lost in 10 seconds after the IAS had fallen to 100 kts, and Captain Marlow said he was unable to maintain height at the moment. The Controller told him he was 8 miles from touch down and closing the ILS localiser from the right, and at 0907-09 told him that he had lost contact due to Hotel Golf's low height, and asked him to adjust his heading on the ILS and report when established. First Officer Pollard replied that they had 'the lights to our right' and were at 800 feet and just maintaining height, and Captain Marlow asked for the emergency to be laid on. At 0907-35 Captain Marlow asked for his position from the airfield and was told 7½ miles to run to touch down. Half a minute later the Controller repeated that he had no radar contact, and told him he was clear to land, and gave him the surface wind of 270° at 12 kts.

14. At this stage the PAR Controller, who had overheard that the Approach Controller had lost radar contact, saw a contact at the bottom of his elevation display, and told the aircraft she was 6 miles from touch down. Captain Marlow asked how far, and when the distance had been repeated First Officer Pollard said they were now at 500 feet. The terrain clearance was only some 300 feet, and the IAS below 105 kts, and falling. The aircraft was approximately on the line of the ILS localiser, and heading for the very centre of the built up area of Stockport.

15. A few seconds after 0909 hours Hotel Golf struck the ground more or less level in pitch, slightly right wing down, and slightly yawed to the right. From the evidence of two eye-witnesses who saw her just before the crash it is clear that Captain Marlow deliberately cut the power very shortly before impact and deliberately put the aircraft down on what was the only pocket handkerchief of relatively open space available. Immediately beyond where Hotel Golf crashed were tall blocks of flats, the town hall, the police station, and Stockport Infirmary. A combination of good fortune and Captain Marlow's decision to put the aircraft down when and where he did had the result that in spite of the very serious casualties to his passengers and crew there were no casualties among people on the ground.

16. When Hotel Golf struck, the port wing was knocked off complete with engines by a three storey building which it partly demolished. The fuselage and starboard wing and engines were brought to a stop within 15 yards of the first point of contact by a low concrete garage building containing cars. The cockpit was largely broken away clear forward of the fuselage, and the tail was left projecting over the edge of the building in the air. A gaping hole was torn in the port side of the fuselage in way of the wing leading edge. At first there was no fuel fire, only small flames here and there which were not enough to beat back rescuers.

17. Police officers and other rescuers arrived at the scene within seconds, and rescue started at once through the rent in the fuselage. The rescuers found that there was a confused heap of passengers at the forward end of the cabin, some dead, some alive and injured, all still strapped in their seats which had come away from their securing points to the cabin floor. The floor had been shattered by the impact. Most of those still alive had severe leg injuries which prevented them from making any effort at escape, and which made it very difficult for the rescuers to get them out. Rescuers also had difficulty with seat belts because they did not know how to undo them. Rescue was concentrated exclusively on

the forward part of the cabin because it was here that the rent in the fuselage made it easy for rescuers to get in and get the injured out. No attempt was made in the time which was in the event available to use the emergency exits further aft, no doubt because the rent in the fuselage was so obviously the best place to start. As a result no passengers in the after part of the cabin escaped.

18. After some 10 minutes from impact 10 injured passengers had been rescued from the cabin. The stewardess had apparently been thrown clear through the rent in the fuselage on impact. There was then an explosion as the fuel in the ruptured tanks in the starboard wing took fire. Fire started in the fuselage where the dead and injured were still trapped at the forward end of the cabin, and quickly beat the rescuers back. It spread very quickly and strongly aft to where the passengers from the rear of the cabin were trapped. Ultimately as a result of the fire the tail section of the aircraft subsided to the ground. Meanwhile the rescuers, beaten back from the cabin, set about the cockpit which was clear forward of the flames. They had difficulty in getting inside because of the mass of instruments and controls, but ultimately succeeded in getting both pilots out. First Officer Pollard was found to be dead on arrival in hospital. Captain Marlow sustained only moderate head injuries including a broken jaw, but these were accompanied by retrograde amnesia, with the result that he can remember nothing about Hotel Golf's last flight beyond her arrival at the Congleton beacon.

19. Captain Marlow was however seen in hospital on 5th June when still under sedation by Mr. Wilkinson of the Accident Investigation Branch. What he said, allowing for the fact that he was still severely shocked and under sedation, is significant. He said that:

(i) First Officer Pollard had been flying the aircraft until the trouble started and then he (Marlow) had taken over control

(ii) He couldn't hold the aircraft straight 'even with rudder'

(iii) He had been trying to find somewhere to 'put the aircraft down'

(iv) 'Which engine was it?'.

20. The position of the flap ram extensions after the crash showed that the flaps were set at $10^{o}$ at the time of impact. The position of the radiator flap actuators for nos. 1, 2 and 3 engines, which escaped destruction, showed that the main radiator flaps were closed and the auxiliary radiator flaps were open.

## Part III. RESCUE CONSIDERATIONS

### A. Police Aspects

1. Hotel Golf crashed about 100 yards from police headquarters in the middle of Stockport. The crash was seen by a police motor cyclist in Waterloo Road who at once told the Information Room by radio telephone and then ran to the scene with other rescuers. The Deputy Chief Constable was on the spot with a number of other officers within two or three minutes of impact.

2. The scene of the crash was cordoned off shortly after the event, and good communications, including an emergency service by the Radio Amateurs and a special GPO landline to police headquarters, were promptly established. Within an hour on that Sunday morning sightseers had crowded to the site and nearly every main road leading to it was blocked by their parked cars. Within the first few hours the police estimate that 10,000 people came to the scene, and but for the establishment of the cordon, the area covered by which was later greatly enlarged, rescue operations and the movement of fire engines and ambulances would have been severely hampered. A senior police officer said that in the whole of his service he had never witnessed such irrational carelessness. Even 8 or 9 hours later streets within half a mile were thronged with cars and pedestrians, and this persisted, though to a less degree, for several days.

3. No warning had reached the Stockport police from Manchester Air Traffic Control of the risk of an aircraft crashing in their area. This was because the Emergency Warning List did not include the Stockport force though Manchester City and the Altringham Division of the Cheshire Constabulary were included.

4. The police report included among other recommendations the following which bear upon the rescue after the crash:

1. that police forces situated in heavily used 'glide in' areas should receive special training in aircraft crash drill

2. that areas such as Stockport, which is directly in the run-in area for Ringway (Manchester) Airport, and which is used by large numbers of aircraft daily, should receive warning from Ringway Air Control of aircraft in trouble over the area

8. that research be undertaken into the practicability of the issue of fire proof or fire resisting suits to police forces situated in heavy density glide in areas

9. that research be undertaken into the possibility of increasing protection against fire within the plane itself

Recommendation no. 9 deals with an intractable problem which has been under consideration by the appropriate authorities for very many years. Recommendations nos. 1 and 2 seem to us to be useful practical and easy to put into force. As to recommendation no. 8, the occasions on which police equipped with fireproof suits could arrive on the scene of a crash early enough to be of any real value for rescue are probably few. It was because Hotel Golf crashed within some 100 yards of police headquarters that so many officers were on the spot so soon.

### B. The Fire Services

1. The Manchester Airport Fire Service crash crews were alerted at 1008 hours BST when the Approach Controller initiated the emergency procedure, but the first call to the fire service itself came at 1012 hours BST, some 3 minutes after the crash. The first appliance, a water tender, arrived at the crash site at 1017 hours, and by 1025 local resources had been reinforced from the Cheshire County Council brigade and from the Manchester brigade, and foam tenders were arriving from the airport.

2. In addition to the major fire in the aircraft itself the fire services had to deal with fire in two transformers in an electricity substation which had been struck, with fires in other buildings involved, and with the exploding petrol tanks of the burning garage. They

prevented two 500 gallon petrol tanks in the garage forecourt, which were nearly full, from becoming involved. A number of firemen joined the police, Civil Defence workers, and ordinary civilians in the rescue efforts. The fire services functioned promptly and efficiently, and it was in no way through any delay on their part that more of the passengers were not rescued.

## C. The Medical Aspect

1. A medical investigation was made by Group Capt. Mason and S/Ldr. Tarlton, of the R.A.F. Institute of Pathology and Tropical Medicine, Halton, with the following objects:

(i) to see whether there was anything in the physical state of the pilots which might have caused or contributed to the accident.

(ii) to assist in the reconstruction of the accident by assessing the directions of maximum force.

(iii) to assess the survivability of the accident.

(iv) to disclose any reasons for the failure of many passengers to escape from the crash environment before being overcome by fire.

2. There was no evidence of ill health or abnormality found which suggests that physical incapacity of the First Officer or Engineer were a contributory cause of the accident.

3. The passengers who survived were with one exception seated on the starboard side of the forward end of the cabin. There was a heavy preponderance of typical deceleration injuries among the dead in the first nine rows of seats. Those of them who were unburned were probably thrown clear through the rent in the fuselage caused by the crash, as was the stewardess who survived, or brought out dead by rescuers. Those who were rescued survived because although they were in the area subjected to the maximum deceleration forces they were in way of the rent in the fuselage and so accessible to rescuers before the fire. Their survival was thus fortuitous and unconnected with special seating, escape hatches, or other safety devices. The medical evidence was that the crash forces in the rear part of the aircraft were less than further forward, and were potentially survivable. Most of the passengers there died because they were unable to escape, and could not be rescued, in the period of some 10 minutes before the fire took hold.

4. There was no medical evidence that the design of the seat belts caused difficulty in escape or hindered rescue. The only difficulty which can have arisen was from unfamiliarity of those trying to rescue unconscious passengers with the operation of the belt releases. The significant medical evidence was that again and again among the dead there were lower leg injuries consisting of massive soft tissue damages with underlying fractures of the tibia or tibia and fibula. Five out of the 10 surviving passengers had fractures of the lower leg.

5. The seats in the Argonaut aircraft have two strengthening metal bars across between the uprights at the back, some 9 inches above the floor. The bar nearest the passenger behind is comparatively thin, the inner bar is massive. The wreckage of 66 seats was examined at the Royal Aircraft Establishment, Farnborough. Of these, the thin outer bar was bent inwards or fractured in 38 cases, and the inference is inescapable that this was caused by the legs of the passenger behind as the whole of the seating concertinaed forward during the deceleration. This was the major factor which resulted in failure of conscious passengers to escape from death by fire in what was a potentially survivable accident.

6. The seats and their anchorage to the floor were stressed to 9 g fore and aft, and complied with air safety requirements. The main disintegrating force appears to have been not the fore and aft but vertical deceleration and to have been considerably greater than 9 g. The seats concertinaed because of the collapse of the structure to which they were attached, namely the cabin floor.

7. As a result of a communication to the Attorney-General evidence was given directed to whether backward facing seats would have reduced the casualty rate in this accident. In this accident the real cause of the trouble was the disintegration by reason of vertical g of the cabin floor to which the seats were attached, and the result as far as the passengers were concerned, and particularly the lower limb injuries, would have been much the same if the seats had been facing aft.

8. In this report Group Captain Mason recommended that the consideration should be given to the question whether it was necessary to provide athwartship strengthening bars at the back of passenger seats at all, even though they may only be dangerous in case of accidents which cause the seating to concertina by reason of disintegration of the floor. He suggested that seats might be designed on the hammock principle, or at least that any athwartship back bars which might be needed to retain cushions might be made of frangible material such as bamboo, and any strengthening bars so placed as to avoid the lower limbs in case of seat failure or severe limb flailing.

9. Any tall person who has travelled as a tourist class passenger in the most modern jet aircraft, let alone propeller-driven aircraft of the Argonaut era, will be in sympathy with this recommendation. It is difficult to imagine the horror of being trapped by broken legs in the cabin of a crashed aircraft which you know is very likely to take fire at any moment. We wholeheartedly endorse Group Captain Mason's recommendation that this aspect of seat design should be given consideration. It may be that it has already been considered. As he was careful to point out, these were seats in an aircraft of a type which came into service over 20 years ago. There was no evidence before us of the design of seats in modern aircraft in this respect, and whether a similar type of accident leading to disintegration of the seat platform would be likely to result in similar injuries and place similar difficulties in the way of rescue and escape from death by fire. If they share this design characteristic of the seats in Hotel Golf others may share the appalling fate suffered by some of the Hotel Golf passengers.

## Part IV. THE FLIGHT CREW

### A. Experience and Qualifications

1. *Captain Marlow*

Captain Marlow was 41 years old at the time of the accident. He qualified as a pilot in 1943 while serving in the R.A.F. as a non-commissioned officer, served from 1950 to 1954 as a pilot in the R.A.F., and obtained his Senior Commercial Pilots' Licence on 10th June 1955. After 6 months with Skyways Limited he joined British Midland, then Derby Aviation Limited, on 1st January 1956 as first officer. In 1957 he was promoted to Junior Captain on C47 (Dakota) and Marathon aircraft, and was promoted to Captain on C47s next year. On 14th October 1964 he had a heavy landing accident at Derby Airport as a result of which he was demoted to First Officer, but he was reinstated as Captain in June 1965. At the time of the accident to Hotel Golf he had flown 10,197 hours in all. Of these 2009 were in Argonaut aircraft, 1900 of them in command. His current Air Transport Pilots Licence with Instrument Rating had been issued in May 1959 and was endorsed for command on Argonauts, Viscounts, Dakota C47s, and DHC1s. He holds a Flight Radio Telephony operators' licence. His last medical examination was on 18th April 1967.

2. Captain Marlow had duly passed all his pilots' mandatory checks. His instrument rating was renewed on 3rd March 1967 and he had an instrument approach proficiency check on 11th January 1967. He had Line checks and route competence checks on 15th April and 15th January 1967 respectively. He was checked in asymmetric flying, including three engine take offs and two engine landings, on four occasions during 1966. On the last occasion, with Captain Fenton on 25th October, his base check on the Argonaut included take-off, instrument approach, instrument overshoot, and approach and landing, all with no. 4 engine shut down, and cross feed drill. Captain Marlow was properly licensed and experienced to command Hotel Golf on the flight on which she crashed.

3. *First Officer Pollard*

Mr. Pollard was 21 years of age. He had started to fly at the age of 13 at Plymouth Aero Club and his Private Pilot's Licence was issued in 1963 when he was only 17. At 18 he began flying training for his Commercial Pilot's Licence and Instrument Rating at the London School of Flying, Elstree. In 1965 he got his Commercial Pilot's Licence and instrument rating, with the DC3 included in part II, and joined British Midland as second officer. On 26th October 1966 the Argonaut and in 1967 the Viscount were included in part II of his licence. He had flown 1,001 hours in all, including 136 hours on Argonauts all since October 1966. His current licence was endorsed for command in Auster Variants and as co-pilot in Dakotas, Argonauts and Viscounts, with instrument rating, and he held a Flight Radio Telephony Licence. He graduated from the London School of Flying as an above average standard student who had completed his training very satisfactorily. His last medical was on 15th December 1966.

4. Mr. Pollard had duly performed all his mandatory flying checks, and had flown with Captain Marlow before on 21 flights, for a total of 30 hours 25 minutes. He was tested for asymmetric flying on the Argonaut on 20th October 1966 with no. 2 engine shut down and on 12th April 1967 with no. 4 shut down. He was properly licensed and experienced to be First Officer of Hotel Golf on the flight on which she crashed. He was clearly a professional pilot of considerable promise.

5. *Mr. Lloyd*

Mr, Lloyd was an experienced although not certificated ground engineer. After service in the Fleet Air Arm he joined British Midland's predecessors in 1962 and had served with them ever since. He flew in Hotel Golf in order to perform ground engineers duties when the aircraft was away from its home station. He had no duties to perform in the air, but in order to help out, not as a matter of duty, he filled in instrument readings in the technical log and instrument and fuel logs, and if asked to do so by the Captain or First Officer would move control levers or switches in flight, for example the radiator shutter controls, and the fuel booster pump switches during the approach check.

## B. Division of Duties

1. Apart from such very limited help in flight as they might request and receive from the ground engineers the Captain and First Officer on Argonaut aircraft in British Midland shared the whole workload of flying, navigation, radio communication, engine handling and system management. The normal division of duties was that one pilot should handle the aircraft while the other fulfilled the other tasks.

2. In normal conditions this division of duties was perfectly satisfactory. However the result of flight tests carried out after the accident both by Captain Fenton the British Midland Chief Pilot, and Mr. Davies, the Air Registration Board Chief Test Pilot, demonstrated clearly that in an emergency such as that which overtook Hotel Golf, while one pilot would be fully occupied in keeping the aircraft under control and on the desired flight path, the work load on the other, particularly in the performance of drills and maintenance of communications, would be altogether excessive.

3. As a result the Air Registration Board now require that as part of its minimum crew the Argonaut shall carry a third pilot or qualified flight engineer, and British Midland have operated their remaining Argonaut with a three pilot crew.

## C. Flight Time Limitations and Fatigue

1. At the time of the accident to Hotel Golf the maximum permissible flight and duty times for the crew were contained in Articles 45 to 52 in Part VI of the Air Navigation Order 1966, which also charge operators with the duty to ensure that their flight crews do not fly when excessively fatigued. British Midland's operations manual contained a limit of 14 hours on the scheduled flying duty period to be undertaken by two-pilot flight crews. This was within the statutory limit of 15 hours and the statutory overall maximum duty period of 16 hours.

2. The scheduled flying duty period for Hotel Golf's flight from Manchester to Palma and return on the night of 3-4th June 1967 was in fact 12 hours and 5 minutes and the crew's time on duty was 12 hours 55 minutes to the moment of the crash, which took place slightly later than the time at which the aircraft should have landed.

3. Throughout 1967 fresh proposals for new time limits were under consideration between the Directorate of Flight Safety, Board of Trade, the aircraft operators including BOAC and BEA, the Air Registration Board and the Ministry of Defence. It was considered that the general tempo and complexity of modern public transport operations together with increasing medical knowledge justified a review of limits laid down ten years before. The proposals had they been in force at the date of the accident would in fact have restricted the flying duty period of Hotel Golf's crew to 12 hours. The new proposals, which represent a consensus of medical opinion over a wide field, did not come into force until 1st January 1968.

4. British Midland's operating instructions at the time of the accident provided that flight crews must have 10 hours clear of duty before beginning flying duty. Arrangements were made for them to be taken by company's transport to the airport of departure, and hotel rooms reserved by the company were available near the airport of departure in which the 10 hours clear of duty could be spent. The terms of a letter from British Midland to the Accident Investigation Branch dated 4th August 1967 naturally led to the suggestion before us by the Crown that there was a company rule that the 10 hours clear of duty must be spent in a hotel room, but we are satisfied that there was no such rule, and that it was for pilots to decide whether to take advantage of the hotel facilities laid on by the company or whether to rest in their own way.

5. On Saturday 3rd June 1967 First Officer Pollard, together with Miss Partleton and Mr. Taylor the cabin crew left by company transport for Manchester at about 0800 BST and spent the day resting in the rooms at the Excelsior Hotel at Manchester Airport which had been provided by the company. Captain Marlow, who had not flown since Tuesday 30th May when he came off duty at 2055 BST, on Friday cancelled his hotel room at Manchester through British Midland and arranged to collect some documents on Saturday from British Midland Airport, Castle Donington, which is on the way from his home to Manchester. It has been Captain Marlow's usual practice to rest at home rather than in a hotel near the airfield of departure.

6. On Saturday 3rd June Captain Marlow played a round of golf in the morning, lunched at home, had a sleep, and at 1800 BST got up, had a shower, changed into uniform, and drove to Castle Donington only to find the documents which he had arranged to collect had already been sent to Manchester. He reached Manchester Airport at about 2100 BST and reported to the Operations Room.

7. It is perhaps obvious that pilots at the end of a tour of flying duty which means they have been up all night will be more tired than when they took off, however they have spent their rest period before starting on the tour of duty. Because he is tired, a pilot may find it more difficult to cope with an unusual emergency. There is however no evidence that Captain Marlow or First Officer Pollard were unduly tired after what had been up to the moment of their emergency a normal and uneventful tour of night duty performed in good weather. In particular the playback of the tape of the R/T traffic between Hotel Golf and the Approach Controller contains no indication that Captain Marlow or First Officer Pollard were suffering from fatigue. Wing Commander Whiteside, consultant in aviation physiology at the R.A.F. Institute of Aviation Medicine at Farnborough, considered it a perfectly reasonable practice that pilots should choose between hotel or home for their rest, depending on their personal preference.

## D. Summary

Hotel Golf's flight crew was properly licensed, trained and experienced. British Midland's operational arrangements complied with the statutory requirements in force at the time. The period of duty actually performed by the flight crew on the night of 3-4th June was slightly in excess of the new limitations then under discussion and now in force, but was well within the then existing limitations. There was no defect in the training or experience of Captain Marlow or First Officer Pollard, and no element of undue fatigue, which caused or contributed to their inability in the event to cope with the emergency with which they were faced.

## Part V. THE AIRCRAFT

### A. History of Certification of the Argonaut in England

1. The Argonaut (Canadair C4) is a derivative of the Douglas DC4 built by Canadair Limited upon the basis of the DC4 design but with Rolls Royce Merlin instead of American engines. The DC4 was designed in the mid 1940s. In all according to the evidence before us some 3,000 of the DC4 and its derivatives the DC6, DC7, North Star, Canadair and Carvair have been certified in the transport fleets of the world. In October 1967 there were still in operation all over the world some 230 DC4s, 9 Canadair or North Stars, and 19 Carvairs. There were a further 660 aircraft still in operation all over the world with fuel systems very similar to the Canadair fuel system, including DC6s, DC7s and Constellations.

2. In 1949 the Canadair C4 aircraft type was approved for transport use by the Air Services Branch of the Canadian Department of Transport. The applicable airworthiness requirements were in part the United States Civil Air Regulations CAR 4a and in part CAR 4b up to and including amendment CAR 4b-10. BOAC bought a number of the aircraft in 1948, and it was at the time urgently necessary that the Canadian export certificates of airworthiness issued with each aircraft should be validated by the UK Ministry of Civil Aviation so that BOAC could fly the aircraft for delivery and for preparation for transport use. By August 1949 the Canadian certificates were being fully validated in the UK for transport use of the aircraft, and in 1952 the Canadian certificates with their UK validations were replaced by UK certificates of airworthiness issued by the Ministry of Transport and Civil Aviation.

3. The process of validation, which was a matter of urgency, was facilitated by the fact that the Air Registration Board knew that the Canadair C4 was a derivative of the DC4 which had been in wide and successful service as a transport aeroplane. The Rolls Royce Engines with which the aircraft were fitted were constructed in England and approved by the Air Registration Board. The Hamilton Standard propellers were well proven in service and were accepted on the basis of their USA type approval. By the time of validation of the Canadair the DC4, M2 and its variants already had 1,000 successful Transatlantic crossings to their name.

4. Because of the urgency of the matter the Air Registration Board did not make a full survey of the aircraft in Canada, but invited BOAC to bring to its attention any respects in which the Canadair in its opinion did not comply with contemporary British airworthiness requirements. Following upon correspondence a meeting was held in London on 28th October 1948 between BOAC and the Air Registration Board to discuss the respects in which BOAC then believed the Canadair to deviate from British civil airworthiness requirements. The only matter discussed relevant to the Hotel Golf crash was the British fuel system requirement that 'The arrangement of the system and the design of the cocks shall be such that it is not possible for any pump to draw fuel from 2 or more tanks simultaneously unless means are provided to prevent the introduction of air into the system.'

5. It is clear that at that time BOAC believed, and the Air Registration Board apparently accepted, that the Canadair fuel system did not comply with this British requirement. BOAC comment, according to the minutes of the meeting, suggested that 'the only practicable action is to ensure that the fuel system diagram in the crew compartment bears a warning notice that the supply lines from 2 tanks must not be opened when they are connected by an open cross feed valve.' The Air Registration Board is recorded to have stated that in view of the past satisfactory demonstration, in operational experience, of airworthiness in regard to this among other items, there was no question as to airworthiness.

6. In fact what became the British airworthiness requirement had originated for the first time in the US in 1945 when it was proposed by the Americans to PICAO, the provisional organisation preceding ICAO. It was incorporated into British national requirements in 1946. Since the Canadair had already been certificated as complying with US requirements it follows that in the eyes of the US and Canadian airworthiness authorities the fuel system was not a deviation but a compliance with a requirement identical with the British requirement, whatever in 1948 BOAC thought and the Air Registration Board accepted.

7. Whether or not the Canadair C4 fuel system as a matter of construction of the wording complies with either the original United States or subsequent British requirement, the fact

is that according to the Air Registration Board the only available 'means' which could prevent air being drawn into the system then or now is in the case of a non-pressurised system the pilot-operated cock which shuts off the empty main tank; and in the case of a pressurised system the pilot-operated booster pump in the tank which is not empty, which has the same effect. The Canadair system is non-pressurised when the booster pumps are off, pressurised when they are switched on. No automatic device is yet available at any rate in civil aircraft which will automatically provide a 'means which will prevent introduction of air into the system' without the intervention of the pilot.

8. It follows that the Air Registration Board was not only justified in accepting the Canadair fuel system in 1948 as it stood, but that it had no real alternative. The fact that it did so did not cause or contribute to the accident to Hotel Golf.

## B. Airworthiness at the date of the accident

1. Before World War 2, commercial aircraft underwent an annual overhaul and major inspection followed by a flight test before the renewal of their annual Certificate of Airworthiness. The aeroplane was torn down, thoroughly inspected and put together again, and after such a tear down the flight test was very desirable if not a necessity.

2. After the end of World War 2 this practice was restarted. Very shortly however it was found that it was really inappropriate to the modern postwar sophisticated transport with a variety of equipment requiring overhaul and inspection at different periods, measured sometimes by the calendar and sometimes by flying hours. Maintenance schedules were therefore planned so that the work could be done at the specified intervals calculated for the various systems to achieve maximum use consistent with safety and by 1952 the Air Registration Board had agreed with operators that there should be some flexibility about the 'annual' flight test, and that within limits this should be carried out to fit in with major inspections or work programmes which would require the aircraft to be flight tested in any case.

3. Later when operators started to use big fleets of aircraft of the same type the Air Registration Board came to the conclusion that since the real object of its 'annual' flight test in modern conditions was to check that aircraft of a certain type were not suffering from unnoticed deterioration in performance in service with advancing age, an annual flight test of each aircraft in the large fleets was not necessary. Accordingly in about 1959 a sample check system was introduced.

4. The present position is that where an operator operates only a small fleet, like British Midland's Argonaut fleet of three only, each aircraft has to be flight tested every year plus or minus three months to fit in with major inspections. In a fleet of up to twelve of a type three aeroplanes a year have to be flight tested, so that each may only be flight tested once in four years. In this way in large fleets the periodic flight test has become completely divorced from the annual renewal of the Certificate of Airworthiness. In small fleets the flight test is still loosely tied to the annual renewal of the Certificate of Airworthiness.

5. The object of the flight test as defined in *BCAR* section A chap. A5-2 para. 5.1 is not to see that the individual aeroplane is serviceable following a major overhaul but 'To ensure that the aircraft flight characteristics and the functioning in flight of the aircraft do not differ significantly in an adverse sense from those acceptable to the Board in respect of the aircraft'. The maintenance of the modern aircraft and its complex systems is carried out not periodically but continuously and progressively in accordance with the maintenance schedule. In these circumstances there is no longer any purpose to be served by associating the periodic flight tests with the annual renewal of the Certificate of Airworthiness. Nor indeed is there any functional significance in the renewal of the Certificate of Airworthiness itself on a strictly twelve months calendar basis, though it is administratively convenient that it should be renewed at that interval. In the United States after the original issue of the Certificate of Airworthiness there is no provision for periodic flight tests or periodic renewals. The Certificate runs on until the aircraft is declared unairworthy.

6. The Canadair 4 is one of the few aircraft which has been found to have a performance deterioration during its life. As a result of flight tests during its service with BOAC the Air Registration Board altered its performance schedules to make allowance for this, although of course the new performance was still wholly satisfactory from the airworthiness point of view. Flight test records show that there was no further deterioration, and the revised performance schedules have been met with a margin to spare ever since.

There was therefore no reason to treat flight test requirements on the Canadair in spite of its age any differently from any other aircraft. Its accident record bears this out. In their 18 years of life the fatal accident rate of the DC4, M2 and Canadair C4 was only 2.66 deaths per million hours flown.

7. Hotel Golf herself was built in 1949. After service with BOAC she was bought ultimately by British Midland and registered on 14th November 1961. Her Certificate of Airworthiness current at the time of the accident was valid until 20th December 1967, and her current maintenance certificate, issued on completion of a Check 1 inspection on 19th May 1967 and signed by the appropriate and duly certificated engineers certifying that she had been maintained according to the approved maintenance schedule, was valid for 42 days or a further 250 flying hours.

8. On 14th October 1965 Hotel Golf was flight tested in connection with the renewal of her Certificate of Airworthiness, and it was then agreed between British Midland and the Air Registration Board, in pursuance of the Board's small fleet practice, that the next flight test should be carried out within 15 months of that date or at the completion of the next Check 4 major inspection. That inspection began on 26th December 1966 and Hotel Golf did not fly again until it was complete, when she was flight tested by Captain Austin on 26th February 1967. *BCAR* chapter A5-2 section 5 para. 5.5 requires the operator to conduct the test without participation by the Board unless the Board wishes to participate, and to furnish the flight test report to the Board in a form acceptable to the Board.

9. It was the practice of Captain Fenton, British Midland's Chief Pilot, to satisfy himself that the flight test had been satisfactorily flown and reported on before sending the report to the Engineering Section for transmission by them to the Air Registration Board. He examined Captain Austin's report, and was not satisfied with the record of the section dealing with three engine en route climb. He endorsed this section of the report with the words 'Climb not accepted - too erratic'. This was not intended as a reflection either on the performance of Hotel Golf or of Captain Austin in flying the test, because the total climb was satisfactory: but Captain Fenton intended the climb to be done again in weather conditions which would enable the pilot to avoid the large variations shown in the report. Captain Fenton's approach to the problem was more exacting than that of the Board who when the test report finally reached them in its original form were satisfied with the test performance which it recorded.

10. Captain Fenton passed the report to the Engineering Section of British Midland. The Engineering Section did not send it on to the Board until after the accident. Hotel Golf on 6th March was damaged by the collapse of her nose wheel at the end of the radio flight test following her Check 4. As a result further work was carried out, and she was functionally flight tested on 12th April by Captain Marlow. Because of this both the further test climb intended by Captain Fenton and the forwarding of the 26th February flight test report to the Air Registration Board were overlooked by British Midland.

11. When the flight test report ultimately reached the Board it was found that the test climb performance with which Captain Fenton had not been satisfied was in fact satisfactory for the Board's purposes. However the Board was, to use the words of Mr. Pardoe its Deputy Chief Technical Officer, shaken when it was found it had not had the flight test report until nearly 6 months after the event. It was also found that the Board had no organisation for chasing flight test reports, because its experience had been that this was unnecessary, and that British Midland and other operators had always sent in reports promptly. Steps have now been taken to make sure that the Board's area offices keep a running record of when tests are due and ask operators for reports if they are not forthcoming.

12. We are satisfied that the current divorce of periodic flight tests from the annual renewal of the Certificate of Airworthiness is in accordance with the requirements of the post World War 2 transport aeroplane, and that the Air Registration Board's practice in this respect both for small and large fleets is sound. At the time of the accident Hotel Golf had been properly maintained and tested, and the failure of the report on the 26th February flight test to reach the Board was purely accidental. Nothing emerged in the evidence given before us to suggest that any alteration is desirable in the present practise that operators have the primary responsibility for conducting flight tests and furnishing the Board with flight test reports. The Board is obviously wise to have instituted its organisation for chasing reports that do not turn up when they should. No evidence before us suggests that the age of Hotel Golf or the way in which her maintenance was required to be carried out and tested or was actually carried out and tested caused or contributed to the emergency on the morning of 4th June 1967 which led to the disaster.

## C. Loading

1. The Argonauts were exported by Canadair to England with no passenger seats. They were used by BOAC for long haul operations, at first with 40 first class seats only. While still in use by BOAC the seating was increased to 54. When the aircraft were acquired by Overseas Aviation they were modified to carry 72 passengers, and Hotel Golf and her sister aircraft were so equipped when acquired from Overseas Aviation by British Midland in 1961. In 1962 they were modified to take 75 seats, and in 1964 the passenger seating was brought up to 78. The small number of seats when they were used on long haul operations by BOAC was dictated by the heavy petrol loads which had to be carried. All the modifications referred to had proper airworthiness approval from the Air Registration Board. In its final configuration the seating provided an average seat pitch of 31 inches, greater than certain modern aircraft in current use.

2. In fact at the time of the accident there were 79, not 78 passengers on board. Two of the 79 however were small children. Arrowsmith Holidays Ltd. who had chartered Hotel Golf for the flight arranged with the family concerned that one of these should not occupy a seat but should be carried on his parents' knee at the appropriate fare rebate, and this was accepted by British Midland. This arrangement produced no overload by weight of the aircraft, which was at all times on the flight within its total permitted load and centre of gravity limits. There is no question of the loading having caused or contributed to the accident.

## D. The Engines

1. After the accident the Merlin engines were removed to Prestwick and examined to determine whether there had been any pre-crash malfunction, mechanical defect or failure, any lack of or restriction in oil supply, particularly to the propellers, or any overspeeding. The examination showed that nos. 1 and 2 engines were rotating at the time of impact, but the damage to nos. 3 and 4 was such that it was not possible to say whether they were rotating at impact or not. There was no evidence of overspeeding. The integrity of the oil supply to all engines and to the propellers as far as the transfer housing at the rear of the propeller shaft was absolutely established.

2. The only mechanical defects found were both in no. 4 engine. There was fatigue failure of one tooth on the A side camshaft drive bevel pinion, and scoring of the B side no. 4 cylinder liner bore. Neither of these pre-crash defects would have had any effect on the operation of no. 4 engine. They would not have been apparent to the flight crew, nor would British Midland's engineering staff have discovered them. The condition of the plugs on no. 3 engine when examined could have caused rough running apparent to the flight crew, but it was not possible to decide to what extent this was due to the environment to which they were exposed as a result of the crash. Miss Partleton the stewardess noticed no abnormal engine noise, neither overspeeding nor rough running, before the impact, and this coupled with the other evidence leads to the conclusion that there was no mechanical failure or malfunction of the engines which caused the power failure leading to the crash.

## E. The Propellers

1. The propellers were examined by Hawker Siddeley Dynamics Limited at Stevenage to determine the blade pitch angles at impact and to ascertain whether there was any evidence of pre-crash defect or failure which might have affected control or governing of rpm. The examination showed that propellers nos. 1, 2, and 3 had been within a $27^{o}$ to $28^{o}$ pitch band, which approximates to the flight fine position. No. 4 had been at the feathered angle of $94^{o}$. The damage to the blades of no. 4 propeller which had very heavy bending of the two lower blades and very slight bending of the upper blade, suggests that no. 4 was not rotating at impact. There was no evidence of pre-crash failure or malfunction of any of the propellers.

2. None of the eyewitnesses who saw Hotel Golf during the last few minutes before the crash speak of having seen any of the propellers stationary. There were nine such witnesses in all, and of the nine four had served in the R.A.F and one in the Fleet Air Arm. The only common denominator of their evidence is that none of them speak of any propeller, not even no. 4, as having been stationary.

3. As against this there is the undisputable evidence that no. 4 was feathered at the time of the impact, supported by the nature of the damage to its blades. Further the analysis of the flight recorder read-out, as will be seen, strongly suggests that the only

configuration of the aircraft which makes sense and which is consistent with the flight path followed after the emergency is that two engines were not delivering power, that the propeller of one was feathered, and that the propeller of the other was windmilling.

4. Our conclusion is that we must regard the subjective evidence of the eyewitnesses about the propellers as unreliable. We do not regard this as surprising, since they were all presented, some more suddenly than others, with the astonishing sight of a large aeroplane flying very low and noisily over the densely built-up area in which they were. There can be no real doubt that no. 4 propeller was stationary at impact, and there is no sensible reason why Captain Marlow should have feathered just before impact rather than at the stage of the initial power failure in cloud when the flight recorder read-out analysis suggests that he did. We are satisfied that a propeller was in fact feathered shortly after the onset of the emergency and at about the time when Captain Marlow first told the Controller that Hotel Golf was overshooting and had a little bit of trouble with rpm.

F. The flight and engine instruments

1. The instrumentation of the Argonaut cockpit is typical of the complex and sophisticated 4 piston engined pressurised transport aeroplane of its epoch. The only characteristic of the instrumentation which has any bearing on the accident to Hotel Golf is that the engine rpm, manifold pressure, fuel flow, fuel pressure, oil temperature and oil pressure gauges are all dual pointer instruments, each serving two port or two starboard engines. The first three namely rpm, manifold pressure and fuel flow indicate by means of concentric pointers for each engine.

2. Investigations have shown that multi-pointer instruments are open to misinterpretation. Most of the evidence is in respect of three pointer instruments, particularly the altimeter, but there is also evidence which shows that instruments using two pointers on the same dial are also susceptible to being misread, particularly if the pointers are oscillating at the time at which their indicator, have to be appreciated. This could be the situation of the dual pointer engine rpm indicator, manifold pressure indicator, or fuel flowmeter if one or both of the engines to which they relate is misbehaving.

3. In this connection evidence was given before us of an incident which occurred on 21st July 1950 to a BOAC Argonaut over the South Atlantic on a flight from Daker to Natal. At 20,000 feet in darkness and smooth weather an engine which the pilot identified as no. 4 overspeeded to 3,500 rpm. He feathered no. 4, and almost immediately after no. 3 overspeeded to 4,000 rpm and was seen to be completely on fire. The pilot managed to extinguish the fire at the second shot when he had reduced the speed to 120 knots, but could not feather the propeller. He was unable to maintain height on nos. 1 and 2 only with no. 3 propeller windmilling, and as nos. 1 and 2 showed signs of overheating he decided to restart no. 4 which he did successfully. No. 4 ran without trouble for some 4 hours until he made a successful landing at Fernando de Noronha.

4. Subsequent examination of no. 4 engine showed it to be serviceable for reinstallation, and subsequent examination of no. 4 constant speed unit showed no signs that it had overspeeded. One of the conclusions of the BOAC investigation of the incident was that the pilot may have misinterpreted the warning of overspeeding due to the dual pointer tachometer and feathered no. 4 when it was really no. 3 which was overspeeding all the time, but no definite conclusion in this connection was reached.

5. In a supercharged piston engined aeroplane with constant speed propellers it may be difficult to recognise immediately which engine has ceased to deliver power, especially if the good engines are set to deliver no more than low cruising power. The constant speed unit will ensure that the rpm on the failed engine remain at the same speed as before failure. The supercharger will continue to turn at the same speed because the propeller does, and so the manifold pressure will remain the same, although if the engine failure is due to fuel starvation what is being compressed is not the fuel air mixture but only air. The only reliable instrument indication of which engine is not delivering power is the fuel pressure gauge coupled with the flowmeter. It is because of this problem that aircraft of the generation which succeeded the Argonaut were fitted with power failure indicators.

6. Dual pointer fuel pressure gauges and flowmeters may well have aggravated the problem with which Captain Marlow was faced on the initial power failure, and his observation in hospital on the day after the crash, 'Which engine was it', suggests they did so, and so must be regarded as being to a small extent a contributory cause of the Hotel Golf crash. It is however only right to say that dual pointer instruments similar to those installed in the Argonauts were standard equipment on American aircraft of the time, were accepted

by the Air Registration Board for certification purposes, and are still in large scale service all over the world. They have not been used on British built aircraft at any rate since 1950.

7. When the tachometers installed in Hotel Golf were examined after the accident it was found that the instrument serving nos. 3 and 4 engines had been wrongly assembled at some stage when sent away by British Midland for overhaul, so that no. 3 pointer would indicate the rpm of no. 4 engine. This had been corrected by connecting the lead from no. 4 engine to the terminal on the instrument for no. 3, and vice versa, so that in the result, with the leads transposed in this way, the tachometer functioned as it should. Apart from this oddity, which had no bearing on the accident, there was no evidence to suggest malfunction of any of the flight or engine instruments with the exception of the fuel contents gauges, with which we will deal later.

## G. The fuel system

### 1. *Description*

The Argonaut fuel system comprises four main tanks and four auxiliary tanks. Numbering from port to starboard, no. 1 main tank and no. 1 auxiliary tank in the port wing supply no. 1 engine, no. 2 main and no. 2 auxiliary supply no. 2 engine, in the starboard wing no. 3 main and no. 3 auxiliary supply no. 3 engine, no. 4 main and no. 4 auxiliary supply no. 4 engine. There are booster pumps in or at the outlet of each tank. Cross feed lines are provided so that either engine of each pair can be fed from the tank supplying the other, 'inter engine cross feed', or any tank in one wing can be used to supply engines on the other wing, 'cross ship cross feed'.

2. The tank selector valves and cross feed valves are similar in design. The four control levers for the tank selector valves are situated in the cockpit in front of and below the engine throttles for the port pilot's seat, normally occupied by the Captain. The two control levers for the cross feed valves are situated in front of and below the throttles for the starboard pilot's seat, normally occupied by the co-pilot. In figure 1, the general view of the Argonaut cockpit, both the tank selector and cross feed valves are concealed by the throttles. Figure 2 shows the tank selector levers, easily seen by reason of the camera angle and the fact that the throttles are in the fully closed position. Figure 3 shows the cross feed levers from a similar camera angle and with the co-pilot's throttle levers in the fully closed position. The tank selector levers have three positions. In the fully forward and down position the respective main tank is on and auxiliary tank is off. In the midway position the main tank is off and the auxiliary tank is on. In the fully aft and up position both tanks are off. Similarly the cross feed levers each have three positions. In the fully forward and down position the cross feed system is off. When either is in the midway position it provides 'inter engine cross feed' between the engines on the wing to which it refers. In the fully aft and up position 'cross ship cross feed' is provided. It is very difficult to reach the cross feed levers from the port hand seat or the tank selectors from the starboard seat. For a pilot wearing the shoulder harness provided it is not possible.

3. Figure 4 is a diagram of the fuel system and valves to illustrate its working, with all the elements which do not affect the accident to Hotel Golf omitted. It shows:

(a) no. 1 main tank off, no. 1 auxiliary tank on, no. 2 main and auxiliary tanks both off, and the port cross feed valve in the 'inter engine cross feed' position. nos. 1 and 2 engines are being supplied by no. 1 auxiliary tank (the red lines)

(b) no. 3 main tank on, no. 3 auxiliary tank off, no. 4 main tank on, no. 4 auxiliary tank off, the starboard cross feed valve closed in the 'no cross feed' position, no. 3 engine being supplied by no. 3 main tank (the green lines) and no. 4 engine by no. 4 main tank (the ~~brown~~ blue lines).

If both cross feed valves were turned to the 'cross ship cross feed' position and nos. 3 and 4 selector valves were turned to the off position, all four engines would be being supplied from no. 1 auxiliary tank. Owing to the wing dihedral, if the aircraft was laterally level and the main tank selector valves and cross feed valves were open either in the 'inter engine' or 'cross ship cross feed' position fuel would run by gravity from nos. 1 and 4 tanks inwards towards nos. 2 and 3 tanks.

FIGURE 1. ARGONAUT COCKPIT; GENERAL VIEW

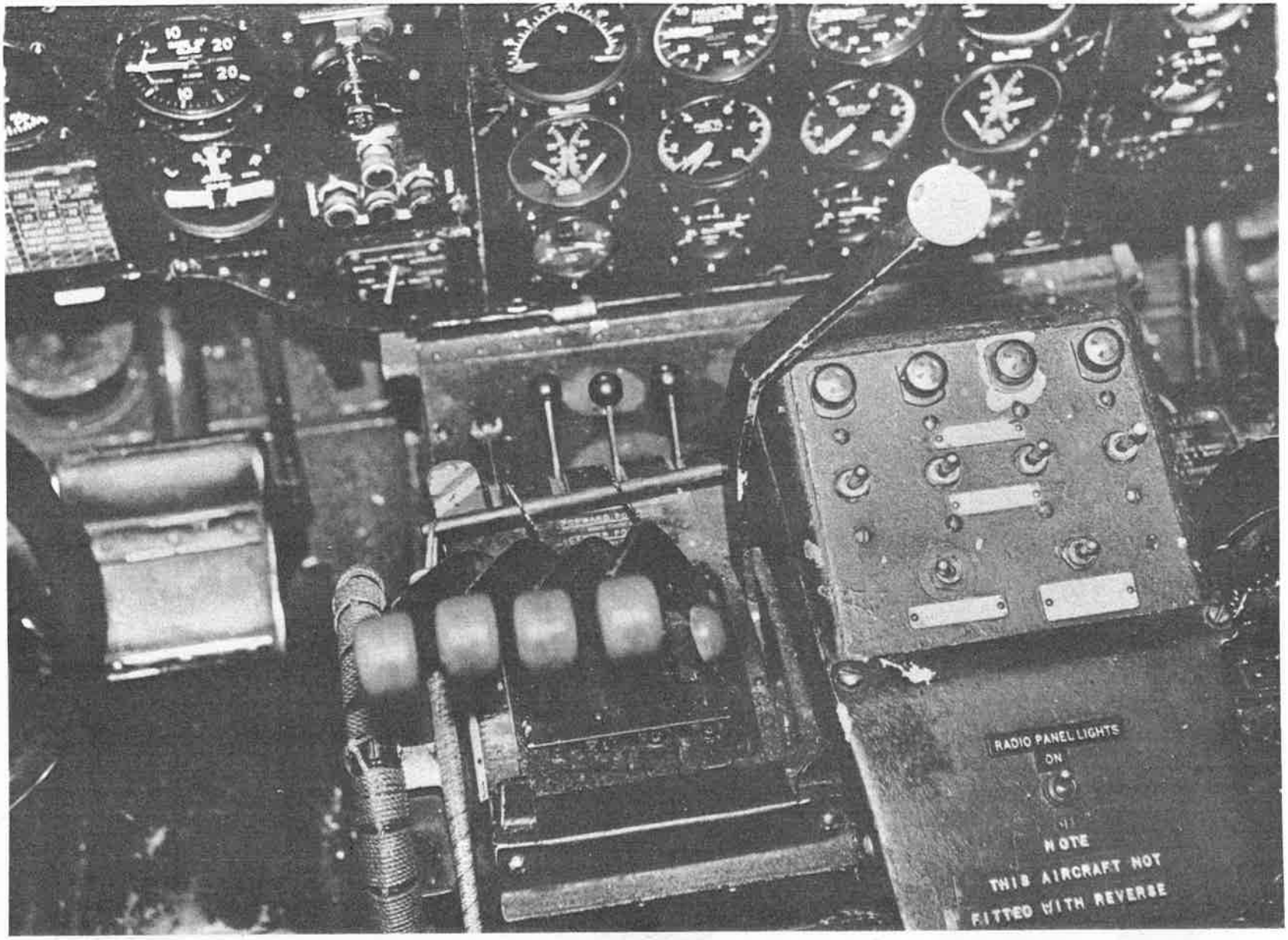


FIGURE 2. FUEL TANK SELECTOR COCKS