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FOREWORD

General

1. The purpose of the Aircraft Accident Digest is to disseminate accident report information to all Contracting States. Publication of the Digest began in 1951. A study of the problems associated with the publication of the Digest was carried out in 1964. The main conclusion of that study was that States should submit to ICAO a summary of the final report, with the information presented in a standardized format. After consideration by the Third Session of the Accident Investigation Division in 1965 and approval by the Council, the necessary specifications were introduced in the Second Edition of Annex 13 (March 1966).

ADREP

2. In 1970 the Secretariat initiated another study on possible arrangements for the statistical and other analysis of the available accident information. This study was submitted to a Panel which made recommendations to the Accident Investigation and Prevention Divisional Meeting (1974). After approval by the Council the necessary specifications for the Accident/Incident Data Reporting (ADREP) system were introduced in Chapter 6 of the Fourth Edition of Annex 13 (April 1976). As a result, a Digest of Accident Statistics will be published annually and the Aircraft Accident Digest will only contain Summaries of Final Reports sent to ICAO by States, when they consider "that the international dissemination of the information contained in the Final Reports is of exceptional value to the promotion of aviation safety, because of the successful employment of new investigative techniques or the disclosure of the need for significant preventive action".

Interim Period

3. This Digest covers the interim period 1972 - 1976, when a major effort was made to implement the ADREP system and when no Digests were published. It contains a limited number of accidents selected by the Secretariat on the basis of their:

a) high fatality rate; or

b) technical interest; or

c) impact on the promotion of safety

Accordingly, this Aircraft Accident Digest should not be seen as being statistically representative of the world distribution of accidents.

Abbreviated Reports

4. In a few cases the information submitted by States was sufficiently brief to constitute an actual "Summary of Final Report". These Summaries have been published as received. However, in most cases the information, although in the format of the "Summary of Final Report", was much too extensive to be reproduced as received. Indeed

some States had sent what amounted to Final Reports. The work involved in summarizing these reports would have considerably delayed the publication of this Digest. Therefore, since most of the "Factual information" in a report is discussed and summarized in the "Analysis" and the "Conclusions" sections, these long reports have been abbreviated by limiting the factual information to "History of the flight", "Injuries to persons" and "Damage to aircraft".

Future Digests

5. The introduction of the Accident/Incident Data Reporting system has significantly reduced the requirement for sending "Summaries of Final Report" to ICAO. The reason is that only those accidents that are "of exceptional value to the promotion of aviation safety" need be summarized by States for inclusion in the Digest. Thus the number of Summaries to be prepared by States and the related workload will be reduced.

It is hoped that all States will continue to co-operate to the fullest extent possible by sending to ICAO actual "Summaries of Final Report", rather than Final Reports. This will enable ICAO to publish the Aircraft Accident Digest without undue delay and without having to resort to the kind of abbreviation used in this Digest.

SUMMARIES OF AIRCRAFT ACCIDENT REPORTS AS PREPARED BY ICAO

No. 1

East African Airways, Super VC-10, 5X-UVA, accident at Addis Ababa, Ethiopia, on 18 April 1972. Report No. AI 11/72, dated 1 February 1973, released by the Imperial Ethiopian Government, Civil Aviation Administration.

1.- Investigation

1.1 History of the flight

The aircraft was operating East African Airways Flight EC-720 to London via Addis Ababa and Rome. It had departed from Nairobi at 0655 hours on 18 April 1972 in the charge of the crew later concerned in the accident. The flight to Addis Ababa was uneventful and the aircraft landed there at 0823 hours, at an all-up weight of 103 394 kg. On landing, the aircraft was observed to roll the whole length of Runway 07, in order to make use of the turning pad at the end.

During the transit stop at Addis Ababa, a quantity of freight was off-loaded together with 40 passengers. Fifteen passengers joined the flight, bringing the total on board at departure to 107 persons, including 11 crew members. The aircraft was refuelled to 50 000 kg of fuel, resulting in an all-up weight (at the time of taxi) of 132 738 kg. Whilst the aircraft was on the ramp at Addis Ababa the attention of the flight engineer was drawn to a leak of hydraulic fluid from the No. 1 rear main wheel (that is, the left outer rear position). After the system had been pressurized, the flight engineer considered that the leak was small enough to be acceptable for the flight to London, where the defect could be rectified. No other unserviceabilities were reported.

Start up clearance was given at 0921 hours and the aircraft taxied out at 0927 hours via the eastern taxiway for take-off on Runway 07. The tower advised the aircraft that the wind was 5 knots and variable in direction.

At 0932 hours, as the aircraft was backtracking to the take-off point, the pilot advised the tower that there was a number of dead birds on the runway, and that the aircraft had hit one of them on landing. It was requested that these birds be removed before the aircraft took off.

The tower agreed to do this and accordingly dispatched a fire truck (call sign Addis One) at 0935 hours.

The aircraft continued to backtrack down the runway and turned in the pad at the end. It then lined up on the runway and stopped a short distance from the threshold. At 0938:40 hours, the tower cleared the aircraft for take-off. The pilot acknowledged and shortly afterwards at 0939:15 hours, he called "rolling".

The ground run appeared to outside observers to be normal for just over half the runway length, though two of the surviving passengers stated afterwards that they thought the initial acceleration was poor.

Shortly after the aircraft had passed the mid-point of the runway and was near where it would normally have been expected to take-off, a loud bang was heard. This was subsequently established as being caused by the right hand nose wheel tire bursting. The effect of this was to cause a severe vibration to be felt on the flight deck and a "loss of control" according to a brief statement made by the flight engineer after the accident shortly before he died.

Almost immediately after the nose wheel tire had been heard to burst, the nose of the aircraft was seen to rise momentarily and then come down. The engines were also throttled back at about this time, and were subsequently heard to go into reverse thrust.

The aircraft continued down the runway, veering slightly to the right as it did so. White smoke was observed to be emanating from the wheels at this stage. A few seconds later, a second bang was heard, and this was subsequently found to be due to the failure of No. 1 rear main tire. Just before the aircraft reached the end of the runway, it veered slightly to the left and ran approximately parallel to the centre line. After crossing a storm drain located at the end of the runway at right angles to the centre line, the aircraft became momentarily airborne as it left the lip of the embankment on which the 60 m stopway was laid. As it did so, the left outer wing of the aircraft struck a steel lattice tower forming part of the approach lighting system to Runway 25. This ruptured No. 1A fuel tank and the released fuel promptly ignited. Sixty metres beyond the end of the runway the aircraft fell heavily on to the lower ground 10.6 m below the runway level. It broke up immediately on impact and after sliding a short distance, came to rest and caught fire.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	8	35	-
Non-fatal	2	13	-
None	1	48	

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

The top section of a steel approach lighting tower near the threshold of Runway 25 was damaged.

1.5 Crew information

a) Flight crew

The Pilot-in-command, aged 42, held a valid East African Airline Transport Pilot's licence, endorsed for the command of Super VC-10 aircraft.

His latest available record of flying hours, dated 28 October 1971, showed that up to that time he had flown a total of 8 769 hours, of which 752 hours were on the Super VC-10 aircraft. It is not known how much of this was in command time, as official records did not show. His personal flying log book is presumed to have been destroyed at the time of the accident. The Pilot-in-command underwent a competency check ("B" Check) on 14 April 1972, in the VC-10 simulator and was assessed as "Very Good". This check included an Abandoned Take-Off procedure.

The Pilot-in-command was last medically examined on 27 October 1971 and pronounced as fit for the renewal of his ALTP licence. During the 30 days preceding the accident, he had flown a total of 31 hours. His rest period prior to the flight to Addis Ababa was 26 hours.

The First Officer, aged 26, held a valid East African Senior Commercial Pilot's licence (SCPL), endorsed in Group 2 for the Super VC-10. He had flown a total of 2 744 hours as at 12 January 1972, the latest date for which records were available, and of this, 640 hours were on the SVC-10. He passed a combined instrument rating and competency check ("A" Check) on 12 January 1972.

He was last medically examined on 11 January 1972 and pronounced fit for the renewal of his SCP licence. During the 30 days preceding the accident, he had flown a total of 62 hours. His rest period prior to the flight to Addis Ababa was 4 days and 8 hours.

The Navigation Officer, aged 45, held an East African Flight Navigator's licence, which was valid for all types of aircraft. On 5 March 1972, records showed that he had flown a total of 20 653 hours. He was last medically examined on 3 March 1972 and pronounced fit. He passed a competency check on 24 March 1972. He had been off duty for 7 days prior to the flight to Addis Ababa.

The Flight Engineer, aged 34, held a valid East African Flight Engineer's licence endorsed for the Super VC-10 aircraft. His total flying time when it was last officially rendered valid on 11 October 1971 was 3 577 hours, of which 1 513 hours were on the SVC-10. He was last checked in emergency procedures on the VC-10 simulator on 5 January 1972, and was assessed as "Very Good". His last flight check on the route was in August 1971. In addition to his Flight Engineer's licence, he also held a valid East African Commercial Pilot's licence, endorsed for the Piper PA-28 aircraft. He was last medically examined for this licence on 23 March 1972 and for his Flight Engineer's licence on 11 October 1971, and in both cases he was pronounced fit. He had been off duty for 5 days and 22 hours prior to the flight to Addis Ababa.

b) Cabin crew

Competency checks were carried out on the cabin staff on the following dates:

Purser:	25 March 1972
Chief Steward:	8 February 1972
Senior Stewardess:	26 January 1972
Stewardess:	4 April 1972
Steward:	14 March 1972
Steward:	9 October 1971
Steward:	21 October 1971

1.6 Aircraft information

a) The aircraft was constructed by the British Aircraft Corporation during the year 1966. It went into service with the East African Airways Corporation that same year, having been issued with both a United Kingdom and an East African Certificate of Airworthiness. At the time of the accident the latter Certificate was valid until 29 September 1972.

The aircraft had been maintained in accordance with an approved maintenance schedule. It was last inspected on 9 March 1972 and a Certificate of Maintenance was issued, which was valid at the time of the accident.

The aircraft had flown a total of 18 586 hours, 409 of which were since the issue of the Certificate of Maintenance and 2 003 since the renewal of the Certificate of Airworthiness.

b) Weight and balance

The load sheet for the flight to Rome was examined together with the passenger and cargo manifests. These had been prepared by the Ethiopian Airlines on behalf of the operator in accordance with normal practice. The Basic Weight and Index figures used on the load sheet were checked against company records and found to be correct. It was also noted that the aircraft was last weighed on 29 September 1969. A revision was made on 26 January 1971, increasing the Basic Empty Weight by 149 kg.

The number of passengers on the load sheet was 97 as against the actual total of 96. This was due to the off-loading of one passenger after the load sheet had been prepared.

The weight of the 97 passengers recorded on the load sheet had been incorrectly calculated as 6 466 kg, whereas, the correct figure was 6 531 kg. This was a negligible error and in any case was compensated for by the off-loading of one passenger.

According to the refuelling record, 9 641 gallons of fuel were uplifted at Addis Ababa, bringing the total fuel on board to 50 000 kg, including an allowance of 600 kg for taxi fuel. Allowing for two small errors in the computation of passenger baggage and cargo weight together with the passenger weight error referred to above, the actual weight at take-off was calculated to have been 132 138 kg as opposed to 132 043 kg as recorded on the load sheet.

This excess of 95 kg is considered to have been a negligible amount and of no significance in the context of the accident.

The distribution of load was checked against the Company's Balance Chart and the centre of gravity was found to be within limits. From the same chart it was determined that the tailplane setting required for take-off was minus 5.2; this had been correctly recorded on the load sheet.

c) Replacement of brake system components

On 5 April 1972, a hydraulic leak from the left rear axle was noted, in consequence of which the associated hydraulic transfer coupling was changed, together with the anti-skid units. On 7 April, the No. 1 rear tire burst on landing following brake application. This was thought at the time to be due to a defect in the No. 1 rear anti-skid unit and it was accordingly changed. There is no record of any further changes having been made to this part of the braking system.

1.7 Meteorological information

A weather observation made shortly after the accident gave the following information:

Surface wind	170 degrees, 9 knots
Temperature	21°C
Dew point	9°C
Weather	Nil
Cloud	1/8 cumulonimbus base 750 m
	6/8 cumulus base 900 m
Visibility	7-10 km
QNH	1023.9 mb

Since 0800 hours the surface wind as measured at the airport meteorological station had been reported at half-hourly intervals as follows:

0800	190 degrees, 8 knots
0830	Calm
0900	170 degrees, 5 knots
0930	170 degrees, 8 knots

At the time the aircraft called for taxi-clearance, the tower reported that the surface wind was 5 knots and variable in direction.

The accident occurred during daylight hours.

1.8 Navigation aids

Navigation aids were not a factor in this accident.

1.9 Communications

All the recorded tapes in the Air Traffic Control were played back after the accident for the relevant period and it was confirmed that the local tower frequency of 118.1 MHz was the only one used by the aircraft. All communications between the aircraft and the tower were normal. The aircraft first called at 0921 hours, requesting taxi-clearance, and the last transmissions from the aircraft were identified as being made by the Pilot-in-command.

Communications between the tower and the fire truck, Addis One, were made on 121.9 MHz. The crew of this fire truck, who had been engaged in clearing the dead birds from the runway, saw the aircraft abandon its take-off and disappear off the end of the runway. As it did so they called ATC for assistance. The time of this call was established to be 0940:23 hours.

1.10 Aerodrome and ground facilities

The Haile Selassie 1st International Airport has a single runway, 07/25. Over a period of months, the runway had been resurfaced with asphalt and extended to 3 700 m with additional 60 m stopways at each end. This work was completed by 7 April 1972, when it was announced by NOTAM HAAB A053 that the runway was fully operational. However, the NOTAM did not give any details regarding the revised runway length, and up to the time of the accident, this information had not been officially promulgated.

In order to accommodate the additional length, it had been necessary to raise the level of the ground at each end of the runway, where it otherwise slopes down. In the case of Runway 07, the up-wind end had been built up to a height of approximately 10.6 m and at the foot of this embankment and on the extended centre line of the runway, had been erected a steel lattice tower forming part of the approach lighting system to Runway 25. The top of this tower was level with the surface of the runway and it was positioned approximately 24 m off the end.

The overall slope of Runway 07 was 0.1 per cent downhill, though in fact it sloped up slightly to the mid-point and then sloped down 0.29 per cent to the runway end.

At the time of the accident the runway surface was dry. The runway surface is normally inspected once each day at 0300 hours, and records showed this inspection to have been carried out on the morning of 18 April.

The air traffic control log showed that there had been 37 aircraft movements prior to the departure from the ramp of 5X-UVA. One of these movements involved a locally based Cessna 185 aircraft which took off at 0455 hours. It was subsequently established that it was from this aircraft that the jacking pad probably fell.

1.11 Flight recorder

a) The flight recorder, located in the rear of the ventral freight compartment, was recovered intact and dispatched to the British Aircraft Corporation for read-out under the supervision of the UK Accidents Investigation Branch. It was a United Data Control unit, Model FB-542. part number 100550-1, serial number 2361.

b) Examination of the foil showed that all parameters had been recorded and could be clearly read with the exception of the datum line which was faint, and the airspeed trace, which was unusually thick. All the parameter data were found to be within specified tolerances. The initial read out of the flight recorder traces was made using nominal calibrations. It was found that the accuracy of the magnetic heading and normal acceleration traces were good and needed no further correction. The accuracy of the pitch trace was also good but a correction of 1 degree had to be applied to compensate for the aircraft's ground attitude. The altitude trace was found to be inaccurate and it was suspected that the recording mechanism itself was faulty. No reliance could therefore be placed on the altitude plot.

Considerable difficulty was experienced with obtaining a credible airspeed plot from the recorder read out. The initial read out showed unusually low speeds and this together with the poor quality of the trace itself led to an attempt being made to check the accuracy of the read out against previous flights where the conditions were known. This work showed that the recorded speeds were generally 10 knots too low at the low speed end.

A detailed calibration was then made which showed that there had been a change since the previous calibration made in August 1971. There were also signs of hysteresis in the recording mechanism. A further calibration was accordingly made using a constantly varying input of pressure to simulate as closely as possible the accelerate-stop case. This calibration was successful in showing up the amount of hysteresis.

When this calibration was applied to the recorded airspeed values, the results were found to be more credible than hitherto and it was felt that they were the most accurate that could be achieved in the circumstances.

However, it is still possible that the final speed plot may be in error due to unknown changes that may have occurred in the flight recorder itself as a result of the accident. Nevertheless, though the absolute accuracy of the recorder airspeed values must always remain in doubt, there was no evidence to justify its outright rejection. It is considered, therefore, that the airspeed trace as plotted, represents a fair though approximate record of the aircraft's indicated airspeed above 80 knots. This is the minimum speed on which reliance can be placed with this type of recorder.

All five parameters are shown plotted against time in seconds at Appendix A.

The start of the take-off run was identified as occurring during the first 8 seconds as given by activity on the pitch and heading traces and more precisely by activity on the airspeed trace after 4 seconds.

Abnormal activity between 51 and 51 1/2 seconds on the magnetic heading trace on the recorder foil itself (not reproduced on the plot) suggested that the unit was subjected to heavy vibration at that point. It is considered that this was most probably coincident with the nose wheel tire burst.

The period for which the nose of the aircraft was raised is shown clearly by the pitch trace, though the precise interval of time that the nose wheel itself was clear off the ground could not be established due to uncertainty as to the exact amount of oleo extension involved.

At 74 seconds, the pitch trace shows the nose wheel leaving the end of the runway followed 1/2 a second later by the main wheels. Impact with the lower ground occurred at 76 seconds as given by normal acceleration and pitch attitude.

1.12 Wreckage

1.12.1 Distribution of wreckage and marks on the runway (see Appendix B)*

The first tire marks attributable to 5X-UVA were found on the runway surface 2 159 m from the commencement of the runway and 0.7 m to the right of the centre line. These marks clearly indicated that the right hand nose wheel tire had burst at that point. Lying nearby was found a steel component of channel section 9 by 4 by 8 cm, which was subsequently identified as a jacking pad used on Cessna 185 aircraft. A clear impression on the runway surface to a depth of 2.3 cm exactly matched the profile of the jacking pad and this impression could be seen 11.5 m before the tire burst point and in line with it. Subsequently, an examination was made of the remnants of the right hand nose wheel tire of 5X-UVA, and one of these was found to have a cut in the tread which also exactly matched the profile of the jacking pad.

Marks made by the burst tire as it revolved could be seen to run parallel to the centre line for a distance of 131 m, where they ceased momentarily before reappearing 15 m further on. The marks then continued for a further 15 m when they again ceased and they did not reappear for another 295 m. Marks made by both nose wheel tires could then be seen in one continuous line until the end of the runway. The marks made by the left hand nose wheel tire indicated that a severe nose wheel shimmy had occurred from the time that the nose wheel tires had last remade contact with the runway.

* ICAO Note: Appendix B not reproduced.

The first marks attributable to the main wheels could be seen 333 m down the runway from the point of nose wheel burst, and these marks had been made whilst the nose wheel was clear of the runway surface and 108 m before it remade contact. The marks made by the main wheels were light in intensity for the first 68 m but thereafter became heavy and continuous for the remaining 1 200 m of runway and stopway.

Some 183 m beyond the point where the mainwheel tracks first became apparent, there was an increase in intensity of the marks made by the left main gear and at this point there were signs of a tire having burst. This was later established as being the No. 1 rear tire.

The main landing gear tracks showed that the aircraft had continued parallel to the centre line for a short distance and then had veered slowly to the right. When it was approximately 300 m from the end of the runway and on the right hand edge, the aircraft had turned slightly left so as to parallel the centre line of the runway once more and it continued on this heading until it passed over the end.

As the aircraft passed the end of the runway it crossed a stone-lined drain, 1 m wide and 0.5 m deep, located at right angles to the runway centre line. Both undercarriage bogies were damaged on impact with the drain and No. 2 rear and No. 3 front tires burst at this point, the former becoming detached from its wheel in the process.

The aircraft became momentarily airborne as it left the end of the runway where the ground drops steeply away. As it did so, the left outer mainplane struck the steel lattice approach lighting tower, breaking off the outer slat and leading edge section. It also ruptured No. 1A fuel tank and severed electric cable looms in the leading edge of the wing. Pieces of structure from this portion of the wing and tank were found between the base of the tower and where the left mainplane finally came to rest. There was also evidence from scorch marks on the ground that fuel released from the ruptured tank was on fire and this had trailed the aircraft to the final impact area.

The aircraft fell heavily on the soft lower ground 60 m beyond and 10.59 m below the end of the runway, the initial impact being taken by the main landing gear. The aircraft broke up immediately into three major portions, namely the tail empennage with the engines attached; the centre section and wings; and the forward part of the fuselage. The tail section came to rest 44 m beyond the initial impact point whilst the remainder of the aircraft slid a further 44 m down the slope. In the latter stages of the ground slide, the nose section swung round to the right and came to rest facing back towards the airfield. A severe fire broke out almost immediately and this eventually consumed the forward and centre fuselage sections together with the left wing and right wing root. The tail unit was extensively scorched but was otherwise relatively undamaged.

1.12.2 Examination of the wreckage

With the exception of the braking system, no evidence was found of pre-impact mechanical or technical malfunction nor were there any signs of pre-impact structural damage. A detailed examination of the wreckage was made and the results of this are summarized below.

a) Configuration:

Nose and main langing gear - down and locked.
Flaps - 20 degrees (take-off position)
Slats - Out (take-off position)
Spoilers - Out to fullest extent.
Tailplane incidence - Between 5 and 6 degrees nose up.
Nos. 1 and 4 engine thrust reversers - Reverse thrust position.

b) Aircraft attitude at impact:

Laterally level with no slip or skid, and slightly nose down.

c) Main landing gear - Both legs had been torn from the structure on impact. The left gear was subsequently damaged severely during the ground fire. The right gear was undamaged by fire, having been thrown clear of the main wreckage by the force of the impact. The condition of the tires on this gear were good. The No. 3 front tire had burst on contact with the storm drain and the remaining tires had deflated due to the operation of the fusible plugs.

d) Flight deck - This area had been completely burnt out and yielded no useful evidence.

e) Engines - Nos. 2, 3 and 4 engines were relatively undamaged but were extensively blackened by smoke from the ground fire. All three could still be freely rotated and it was considered that each of them would have been capable of delivering full power up to the moment of impact. No. 1 engine had ingested some hard object which had severely damaged the LP compressor. It was apparent that this had occurred during the break-up of the aircraft on impact. There was no other evidence to suggest that this engine would not have been capable of delivering full power before the accident.

1.12.3 Examination of the brake system

The brake assemblies and associated anti-skid units were examined initially at the Company's maintenance base at Nairobi and then later sent to the United Kingdom for detailed examination by the manufacturer under the supervision of the U.K. Accident Investigation Branch. It was found in the course of this latter examination that all eight brakes had been serviceable during the aircraft's attempted take-off but, that only five of them had been used to their individual maximum energy limit of 42 million ft/lb during the deceleration phase. The remaining three brakes were found to have absorbed lesser amounts of energy, as follows:

No. 4 front	-	29 million ft/lb
No. 1 rear	-	less than 19 million ft/lb
No. 2 rear	-	less than 19 million ft/lb

Thus the total energy which had been absorbed by the brakes during the deceleration phase of the accident sequence was between 239 and 277 million ft/lb that is, between 70-80 per cent of the design maximum.

A further examination was therefore made of the three brakes which had absorbed less energy than the other five to account for the loss in braking efficiency.

In the servo unit serving No. 4 front brake, it was found that a restrictor pack had been incorrectly assembled, with the result that the flow of fluid to the brake could have been less than normal. In incipient skid conditions, this reduced flow would have resulted in a slower recovery of brake pressure after it had been relieved by the anti-skid unit. In consequence, the brake would have been off for a longer period than would normally have been the case. It is considered that it was at least partly for this reason that the No. 4 front brake absorbed less than maximum energy.

The No. 1 rear brake had absorbed negligible kinetic energy due to the locking of the wheel and bursting of the tire early in the accident sequence. The reason for this was twofold. Firstly, it was found that the transfer unit in the left rear axle had been installed in the reverse of its correct position. The effect of this was to cross couple the anti-skid units and brakes in the left rear axle, so that the No. 1 rear brake was being controlled by No. 2 rear anti-skid unit and the No. 2 brake was being controlled by No. 1 rear anti-skid unit. This in itself would not have been significant, provided that both anti-skid units were serviceable. However, it was found that the No. 2 rear anti-skid had been totally inhibited by the installation of a rubber ring at the point where a hydraulic coupling was fitted to one end of the transfer unit. From marks on the ring (which was not part of the installation), it could be seen that it had blocked the four ports of the anti-skid valve block. This would have prevented the No. 2 rear anti-skid unit from relieving No. 1 rear brake pressure in a skid situation, thus causing the No. 1 rear wheel to lock and its tire to burst.

When the No. 1 rear wheel locked, the No. 1 rear anti-skid unit would have sensed the skid but, in this instance (because of the cross coupling) would have caused the brake pressure to No. 2 rear brake to be relieved. The pressure should have been restored automatically after 4 to 5 seconds. Had it been so, the energy absorbed by No. 2 rear brake would have been considerably more than in fact was the case. It would appear, therefore, that after the pressure to this brake had been relieved by No. 1 anti-skid unit, maximum pressure was not re-applied for the remainder of the accident sequence. No reason for this could be found. Not all components of this particular braking system were recovered.

1.13 Fire

a) Fire initially broke out when the left outer wing struck the approach lighting tower just after the aircraft left the runway. The effect of this impact was to rupture No. 1A fuel tank and the released fuel was ignited either by sparks generated as a result of the wing hitting the tower or by arcing due to the disruption of electric cable looms in the leading edge of the wing. There was evidence of burning on the ground from the point of impact with the tower to the final position of the left wing on the ground, indicating that the fire had trailed behind the aircraft for the whole distance. The left wing was subsequently almost entirely consumed by fire.

On impact with the ground, the aircraft broke into three major components, releasing most of the 50 000 kg of fuel on board. According to the statements of survivors, fire appears to have started almost immediately after impact towards the rear and underside of the main cabin. There the heat was described as being intense at floor level. Fire also broke out immediately after impact on the right side by the wing root. This prevented the emergency exits on that side being used. Fire eventually consumed the main cabin area, the forward fuselage, the left wing and the right wing root. The tail unit together with the engines were unburnt though extensively scorched.

b) The first fire truck on the scene was Addis One, which had been previously engaged in removing the dead birds from the runway prior to the aircraft's take-off. This reached the scene at 0942 hours. Other airport fire vehicles were dispatched, the first arriving at 0944 hours and the others at some undetermined time later. From 1025 hours onwards, units of the city fire service participated in fighting the fire. The last practice by the Airport Fire Services was on 4 March 1972, during which the Fire Crews practiced fire extinguishing and rescue drills. The Fire Service equipment was inspected on the day of the accident at 0300 hours. The part played by the Airport and City Fire Services and the type and quantity of extinguishing agents applied to the fire is the subject of specialist investigation.

1.14 Survival aspects

a) Rescue

In the main, the evacuation from the aircraft by the passengers and crew was self-effected. Considerable selfless assistance was rendered by members of the cabin staff and also some of the passengers, some of whom died as a result of their efforts in this respect when they would have otherwise survived. The evacuation was facilitated considerably by the fortuitous fracture of the left forward fuselage, allowing relatively easy egress. Had it not been for this fracture casualties may well have been greater, as the left emergency exits were jammed by impact damage and the right side exits were blocked by fire.

b) Survival

It appears that the majority of those on board survived the impact, but some subsequently succumbed to the effects of fire. Those who managed to get clear of the aircraft to the left side found their way blocked by a barbed wire fence. This forced most passengers and surviving members of the crew to walk down the slope alongside two main streams of fuel flowing from the aircraft. This fuel subsequently caught fire, trapping a number of people, believed to be about ten in number.

1.15 Performance calculations

a) Scheduled performance

The Operator's airfield Regulated Take-Off Weight (RTOW) chart for Addis Ababa was no longer valid at the time of the accident since it related to the former length of the runway. The Generalized Take-Off Chart was therefore used to check the aircraft's RTOW and field requirements appropriate to its last take-off.

In making these calculations, the following airfield data were utilized:

Runway 07

Take-Off Run Available (TORA)	-	3 700 m
Take-Off Distance Available (TODA)	-	3 760 m
Emergency Distance Available (EMDA)	-	3 760 m
Slope Down	-	0.29 per cent
Elevation (AMSL)	-	7 625 ft
Temperature	-	21 degrees C
Wind component at the time of take-off	-	1 1/2 knots Tail

From this data the Balanced Field Length required for the aircraft's actual take-off weight of 132 138 kg was found to be 3 300 m and the maximum permitted take-off weight (RTOW) was found to be 135 800 kg.

It should be emphasized that the above calculations, which were post accident, were based on the actual wind and temperature conditions prevailing at the time of take-off and merely serve to confirm that the aircraft was not overweight for operation using the full length of Runway 07. Since the crew would not have known the precise values of wind and temperature that they would encounter on take-off, their pre-take-off calculation of RTOW would have had to be based on assumed or predicted values. Thus, it could be expected that there would normally be a difference between the two values of RTOW. Such is the case in this instance, where the pre-take-off RTOW recorded on the load sheet was 132 400 kg i.e. 3 400 kg less than the RTOW based on actual values.

However, this is a large discrepancy and it is considered that it cannot be wholly explained in terms of differences between predicted and actual values of wind and temperature. It is more likely that the difference was due to the crew basing their calculations of RTOW on a runway length which was less than the actual length of 07 but more than the old length. Consideration of the Balanced Field Length required for the RTOW recorded on the Load Sheet suggests that the crew may have allowed for only half the actual runway extension in the interests of erring on the safe side since no revised runway length had been promulgated.

As regards the runway slope the crew may have used in their calculations, it appears most unlikely that they would have used the value of 0.29 per cent. This is because they would have assumed most probably that the slope of the new 07 runway was close to the slope of the old one, and may have used the value of 0.15 per cent as indicated on the Company's RTOW chart for Addis Ababa. In fact the slope of the old Runway 07 was 0.296 per cent as calculated in accordance with the provisions of Annex 14 of the ICAO Convention. The resulting difference in RTOW and V_1 due to the use of a 0.15 per cent slope would have been approximately 400 kg and 2 knots, which for all practical purposes was negligible and had no bearing on the cause of the accident.

The V_1 and V_R values that were most probably calculated by the crew using the Generalized Take-Off Chart and a slope of 0.15 per cent would have been 135 and 145 knots respectively. With the 0.29 per cent slope applied, the V_1 as given by the Flight Manual would have been between 128-140 knots and V_R would have been 144 knots for the aircraft's actual take-off weight.

b) Calculation of the speed envelope and maximum speed attained

Calculations were made to check the extent to which the evidence obtained from runway marks, brake examination and the flight recorder were mutually consistent. In making these calculations, certificated Flight Manual data were used, together with other relevant aircraft and runway data, and the fact that full reverse thrust was available was taken into account. Also taken into account was the fact that the total load of the aircraft was taken on only seven wheels during the greater part of the deceleration phase following the failure of the No. 1 rear tire early in the sequence.

It was found, as a result of these calculations, that the various parts of the evidence were mutually consistent with the exception of the speed as given by the flight recorder, which was shown to have been generally 10 knots too low. The results of the performance calculations are shown graphically at Appendix C* and are summarized as follows:

1. The take-off roll was commenced 123 m in from the beginning of the runway.

2. The nose wheel burst occurred at an airspeed equivalent to 135 knots when the aircraft had travelled a distance of 2 013 m.

3. The decision to abandon the take-off was most probably taken 1.9 seconds later when the airspeed was equivalent to 140 knots and the distance gone was 2 170 m.

* ICAO Note: Appendix C not reproduced.

4. The maximum airspeed reached by the aircraft was equivalent to 143 knots.

5. The airspeed of the aircraft as it left the end of the runway was equivalent to 67.6 knots (assuming zero wind).

From these calculations, it was also deduced that the maximum braking effort was approximately 61 000 lb, that is approximately 70 per cent of the established Flight Manual certificated value. To achieve the performance calculated, it would appear that the brakes would have absorbed 215 million ft/lb of kinetic energy against certificated maximum of 340 million. Allowing for most adverse factors, calculations show that had full braking been available, the aircraft could have been stopped within the distance remaining at the time the decision to abandon the take-off was implemented.

1.16 Other information

1.16.1 Relevant extracts from the company flight manual

a) Abandon take-off procedures

When the ATC tape recording of the R/T conversation on 118.1 MHz was played back, the voice of the pilot making the transmission from the aircraft was positively identified as that of the Pilot-in-command.

Assuming that normal Company procedures were being followed, this indicated that the co-pilot was handling the aircraft from the right hand seat from the time it left the ramp until at least when the emergency occurred, if not beyond that point. The relevant sections of the Flight Manual supporting this conclusion were contained in Section 3-2-1 page 8, paragraph 12 and on page 2 of the same section, paragraph 2 4).

In the event of an emergency, the Manual states that control will remain with the co-pilot unless the pilot-in-command decides to take over control. In this event, the co-pilot reverts to his normal duties.

In the event of the take-off being discontinued whilst under the control of the co-pilot, the executive order "Abandon" may be given by either the pilot-in-command or the co-pilot. The co-pilot will close the throttles and apply full brakes. The pilot-in-command will select full spoilers and apply reverse thrust as necessary. The pilot-in-command will then call, "I have control" and take over control of the nose wheel steering and the brakes. (Reference Section 3-2-1 page 5, paragraph C.)

The following paragraph D states that in the event of an emergency at or after V_1, no action will be taken until the pilot-in-command gives the command which will not be below 400 ft.

In Section 3-5-1 page 5, paragraph I entitled "ABANDONED TAKE-OFF", it is stated, the basis of calculation of stopping distances from V_1 includes the assumption that only one thrust reverser will be available. The paragraph goes on to say that maximum retardation can be effected by continuous application of anti-skid braking and the use of reverse thrust, which should be applied as soon as possible. The brakes must be considered as the primary means of retardation.

b) Brake cooling times

In Section 2-4-1 page 2, under the heading BRAKE COOLING TIMES, it is stated that "if the scheduled stopping distances are to be achieved in the event of an abandoned take-off, the brakes must be cool enough at the start to absorb the required amount of energy". The information as to the correct cooling time assumes two cases, one of which is relevant to this accident, namely, "To allow the next take-off to be abandoned at maximum V_1 after a normal landing".

In the accompanying table, the longest brake cooling time was given as 57 minutes and this relates to a higher landing weight and higher take-off weight than was the case with 5X-UVA. The time interval between the aircraft landing and commencing taxi was in fact 64 minutes.

c) Dispatch of aircraft with unserviceable equipment

Part 5 of the Company Flight Manual details those items of equipment which can be accepted as unserviceable at the commencement of a flight, subject to the pilot-in-command's discretion. One of the items so listed was any one of the eight anti-skid units with which the aircraft was fitted.

1.16.2 Relevant extracts from the Super VC-10 Maintenance Manual

Instructions for the installation of an anti-skid unit were contained in section 32-40-35 of the Super VC-10 Maintenance Manual current at the time of the accident. These instructions did not include any explicit provision for the functional testing of the equipment following installation.

2.- Analysis and Conclusions

2.1 Analysis

The aim of this analysis is to consider the most significant features of the evidence that has been obtained with a view to establishing the following:

1. The maximum speed attained by the aircraft as registered on the pilot's instruments and how this related to the actual speed of the aircraft over the ground.

2. The distance remaining to the end of the runway from the point where the aircraft reached its maximum speed.

3. The effect of deficiencies in the braking system.

The analysis will then examine the actions of the crew in dealing with the emergency.

a) Speed of the aircraft

In considering the maximum speed reached by the aircraft, a clear distinction has to be made between the speed as registered on the pilot's instruments (and on the flight recorder) and the actual speed of the aircraft over the ground. Normally the two speeds can be directly related after due allowance has been made for the effects of altitude, temperature and surface wind, together with position and instrument error corrections.

In the case of 5X-UVA, it was found that the speed as given by the flight recorder (which would normally be the same as that registered on the pilots' instruments) was substantially less than that which the aircraft had undoubtedly achieved according to performance and other calculations. Though initially this was thought to be due to errors within the recorder itself, it was found that the disparity still existed after further calibration work had ironed out most of the errors. Though a small residual error may still remain, no adequate reason could be found to explain the discrepancy between recorded and predicted speeds. It was of interest to note, however, that the 8 knot differential between the two maximum speeds was equivalent to a 10 knot tailwind component for a period of approximately 20 seconds. It was not impossible, in the meteorological conditions prevailing at the time, that there was a gust of this magnitude and duration at the relevant time. Certainly, an indication of mildly gusty conditions was given by the jerky quality of the airspeed trace throughout the take-off run. However, as there was no positive evidence as to the actual behaviour of the wind over the runway, the difference between recorded and predicted speed cannot be ascribed to these effects with certainty.

In conclusion therefore, it is considered that the best assumption that can be made as regards the speed history of the aircraft is that the flight recorder speed plot represents the minimum airspeed that the pilots could have read on their instruments during the acceleration phase and that the predicted performance line at Appendix C* represents the maximum. On this basis, the indicated airspeed when the nose wheel burst must have been between 120 and 135 knots, and the decision to abandon the take-off was taken when the indicated airspeed was between 125 and 140 knots. Subsequently, the speed rose to a peak value of between 135 and 143 knots, which was equal to a ground speed of between 156-166 knots.

b) Position at which maximum speed was attained

The difficulty in establishing where on the runway the maximum speed was attained by the aircraft has already been mentioned. Logically, the aircraft must have reached its maximum speed somewhere between the point where the nose wheel burst, when it was still accelerating and the point where heavy braking marks were apparent on the runway, when the aircraft was decelerating. These distances were 2 158 and 2 560 m respectively from the beginning of the runway. Between these two points, it was positively established from marks on the runway that the nose wheel was off the ground, and that it had not come down again by the time heavy braking occurred. Though it was not known precisely where on the pitch trace of the flight recorder plot the nose wheel regained the runway, it must have been somewhere between 56 and 57 seconds. If the application of brakes was instrumental in pitching the nose wheel back on the runway, then (relative to the pitch trace) heavy braking most likely occurred at 56.2 seconds. If this is accepted, then it follows that if the indicated airspeed at that time was 143 knots (assuming the higher value) then this was most probably the speed of the aircraft when it was 1 200 m from the end of the runway (i.e. 2 560 m from the beginning). Calculations have shown that it should have been possible to bring the aircraft to rest from this speed and within this distance given fully serviceable brakes and reverse thrust.

c) Condition of the braking system

The available braking effort shortly after the abandon take-off procedure had been implemented was approximately 70 per cent of the certificated value. This was established separately by both performance calculations and detailed brake examination. Calculations positively established that this amount of braking effort was insufficient to bring the aircraft to rest within the runway and stopway distance remaining from the

* ICAO Note: Appendix C not reproduced.

speed it was travelling at the time. The loss of braking effort was due to the bursting of the No. 1 rear tire early in the accident sequence, the unexplained failure of the No. 2 rear brake to operate effectively and the partially reduced operation of the No. 4 front brake. The reasons for at least part of the loss of braking effort could be directly attributable to the presence of an alien seal found within No. 2 rear anti-skid system, reversed fitting of the left rear transfer tube and possibly from blockage arising from mis-assembly of part of the restrictor valve in No. 4 front brake system. In the event, however, the installation of the transfer coupling in the reversed sense together with the presence of an alien seal in the No. 2 anti-skid system was significant only when braking to the level of anti-skid operation took place. Such a situation existed during a landing on 7 April 1972 when No. 1 rear tire burst. The diagnosis was a faulty No. 1 rear anti-skid unit which was changed and the aircraft returned to service with both defects still present. There were no functional checks for the system specified in the Maintenance Manual following the change of an anti-skid unit.

d) Nose wheel tire failure

The reason for the nose wheel tire failure was positively established as being due to penetration by the piece of steel channel section lying in the path of the aircraft 2 147 m from the beginning of the runway. It was also established that this object, identified as a jacking pad used on Cessna 185 type aircraft, had been deposited on the runway 4 hours 40 minutes before 5X-UVA began its take-off run and had lain there unnoticed. This was not altogether surprising as the object itself was relatively small and unlikely to be seen other than by pure chance. The pad had been deposited long after the daily runway inspection and there was, therefore, no possibility of it being discovered in the normal way. The area covered by the crew of the fire truck sent to clear the dead birds in the runway prior to the take-off of 5X-UVA did not include that in which the jacking pad lay.

e) Decision to abandon take-off

There would seem to be no doubt that the decision to abandon take-off was taken solely as a result of the nose wheel burst and for no other reason. There was no evidence that the failure of the nose wheel tire resulted in any other damage which could have given rise to a decision to abandon take-off. Whether or not the crew fully appreciated the true nature of the emergency is not known. The flight engineer stated that the vibration was severe and that there was also a "loss of control". It was not possible to clarify precisely what he meant by this but clearly it suggests an alarming and confusing situation from which the crew could well have presumed the aircraft to be in a non-airworthy condition. In fact, as is now known, the aircraft could have been taken off and flown away safely, but this is not to imply the crew acted incorrectly, or even considered that they had a choice in the matter.

So far as can be ascertained, the nose wheel burst before the maximum V_1 (Decision) Speed of 140 knots was attained as given by the Flight Manual, and the decision to abandon the take-off was taken almost immediately. This was a perfectly proper decision for the crew to make, if they considered that the nature of the emergency was sufficiently serious. All the evidence points to the crew having implemented the decision to abandon the take-off very quickly. The distance between the nose wheel burst mark and the point where light braking was apparent was 333 m. At the ground speed the aircraft was travelling, say approximately 80 m/sec, this distance would have been covered in about 4 seconds. Within this time, the crew obviously recognized the emergency, took the decision to abandon take-off and had taken the necessary actions by the end of the 4 second period. This indicates fairly positively that the crew's reaction time was well within that allowed for by scheduled performance criteria.

f) Dispatch of aircraft with one unserviceable anti-skid unit

There is no doubt that the crew were quite unaware of the actual condition of the brake system prior to the aircraft's departure from the ramp at Addis Ababa, particularly as regards to the state of the No. 2 rear anti-skid system. Therefore, the provisions of Part 5 of the Company Flight Manual which allows a flight to be commenced with one unserviceable anti-skid unit were not applicable in this case. However, the wider implications of allowing the dispatch of an aircraft with an unserviceable anti-skid unit are clearly relevant in the light of what happened to 5X-UVA. It would appear that the aircraft could have been dispatched quite properly with the No. 2 rear anti-skid unit deliberately blanked off and in the event still been unable to stop from an abandoned take-off at V_1. It would seem that further consideration should be given to the question of permitting the deliberate dispatch of aircraft with less than fully serviceable brake systems, particularly from airfields where the consequences of an overrun area are severe.

2.2 Conclusions

a) Findings

1. The documentation of the aircraft was in order.

2. The aircraft had been properly loaded.

3. The crew were properly licensed and qualified to conduct the flight.

4. The aircraft was most probably being handled by the co-pilot from the right hand seat. This was in accordance with the provisions of the Company Flight Manual.

5. The right hand nose wheel tire was punctured by a steel jacking pad lying in the path of the aircraft on the runway surface.

6. The crew took the decision to abandon the take-off when the speed of the aircraft was at or below the maximum V_1 and this decision was properly implemented.

7. The emergency distance available at the time the crew commenced the abandon take-off procedure was sufficient in which to stop the aircraft, given a fully serviceable braking system.

8. The No. 1 rear tire burst shortly after brake application due to the lack of anti-skid protection. This was because the No. 2 anti-skid unit, to which the No. 1 brake had been inadvertently connected, had been inhibited by the presence of an alien seal.

9. The No. 4 front brake did not operate to the fullest extent possibly due to reduced hydraulic flow through an incorrectly assembled restrictor valve.

10. The reason that the No. 2 rear brake did not achieve full braking effort could not be determined due to fire damage and non-recovery of certain components of the system.

11. The resultant braking effort was insufficient to stop the aircraft within the emergency distance remaining at the time that the take-off was abandoned.

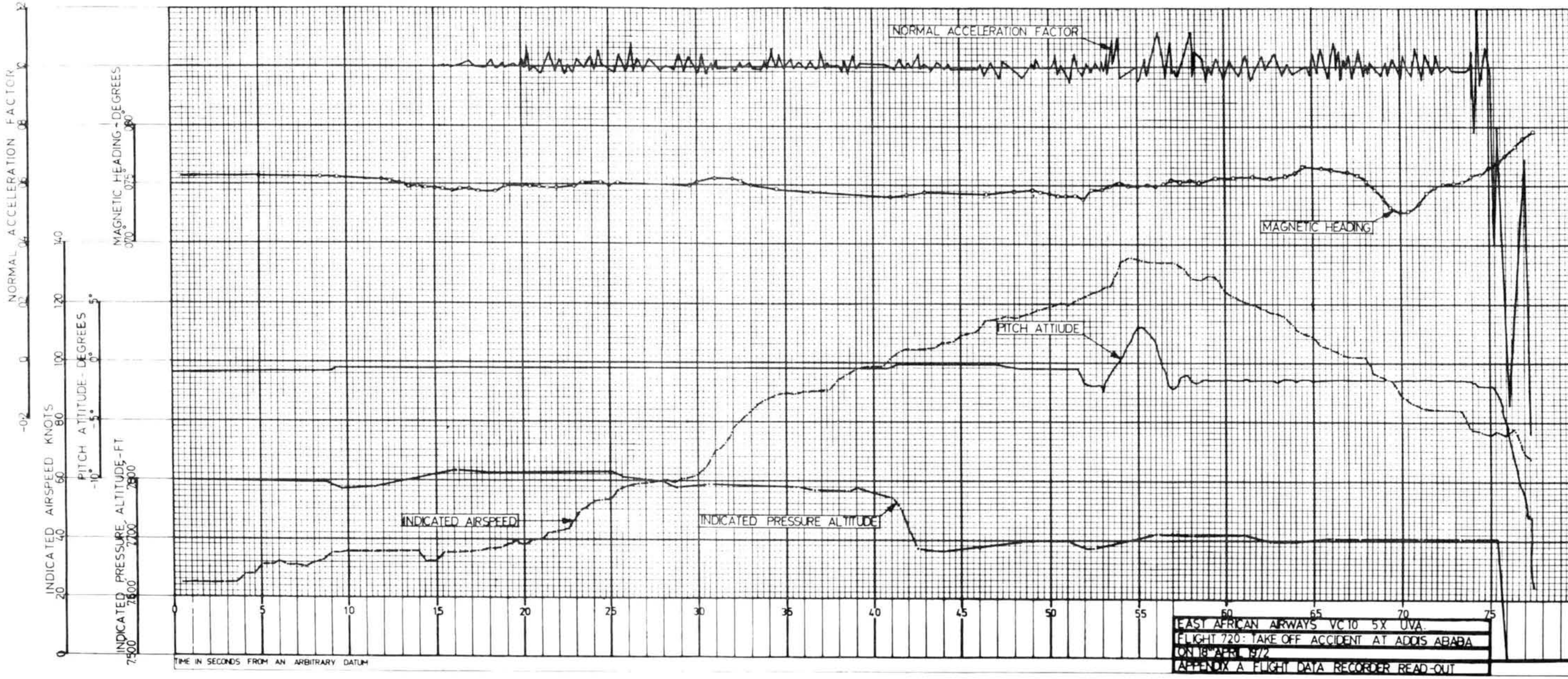
12. The aircraft had been maintained in accordance with an approved maintenance schedule. However, the functional test procedures specified in the maintenance manual in force at the time were insufficiently comprehensive for the purposes of checking the correct operation of the braking system following component changes.

b) Cause or Probable cause(s)

The accident was due to a partial loss of braking effort arising from incorrect re-assembly of part of the braking system, as a result of which the aircraft could not be stopped within the emergency distance remaining following a properly executed abandoned take-off procedure.

ICAO Ref.: AIG/128/72

APPENDIX A


NORMAL ACCELERATION FACTOR
MAGNETIC HEADING - DEGREES
PITCH ATTITUDE - DEGREES
INDICATED AIRSPEED KNOTS
INDICATED PRESSURE ALTITUDE - FT
NORMAL ACCELERATION FACTOR
MAGNETIC HEADING
PITCH ATTIUDE
INDICATED AIRSPEED
INDICATED PRESSURE ALTITUDE
TIME IN SECONDS FROM AN ARBITRARY DATUM
EAST AFRICAN AIRWAYS VC10 5X UVA.
FLIGHT 720: TAKE OFF ACCIDENT AT ADDIS ABABA
ON 18th APRIL 1972
APPENDIX A FLIGHT DATA RECORDER READ-OUT

No. 2

Japan Air Lines, DC-8-62, JA-8040, accident at Moskva/Sheremetievo, USSR, on 28 November 1972. Report not dated, released by the Deputy Minister of Civil Aviation of the USSR

1.- Investigation

1.1 History of the flight

The DC-8-62 JA-8040 of the Company JAL was on flight JAL-446 Copenhagen - Moscow (Sheremetievo) - Tokyo on 28 November 1972.

At 1817 hours local time the aircraft landed at Sheremetievo airport.

Technical servicing of the aircraft at Sheremetievo prior to take-off was performed by the staff of JAL.

Pre-flight briefing of the crew in conformity with current JAL instructions took place on board the aircraft.

All the necessary weather data and meteorological documentation were obtained for the crew by JAL officials.

The flight plan for the route Moscow-Tokyo was signed by the Pilot-in-command.

The meteorological conditions (forecast and present weather), on the basis of which the crew decided to take-off from Sheremetievo, corresponded to the aerodrome minima and the crew minima prescribed by JAL.

The taxiways and runway were in a state of normal serviceability. The adherence factor was within the limits 0.32 - 0.37.

The radio aids, lighting facilities and communication systems at Sheremetievo airport, required for the flight, were functioning in accordance with current regulations and no observations were made concerning them on 27 November 1972.

At 1938 hours the crew requested start-up clearance. This was given together with the taxi sequence and take-off heading (248°).

At 1949:49 hours the crew was cleared to take-off position and received the take-off conditions.

At 1950:30 hours the aircraft started take-off roll and, after lifting off and climbing to approximately 100 m, lost height abruptly, collided with the ground, broke up and caught fire.

The accident to JAL DC-8-62 JA-8040 took place at 1951:42 hours Moscow time (1651:42 hours GMT) in night flight conditions.

The aircraft struck the ground at a point 150 m from the end of the runway and 50 m to the left of its extended centre line. Elevation above sea level at the accident site is 185 m.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	9	52	-
Non-fatal	5	10	-
None			

1.3 Damage to aircraft

The first contact with the ground was made with the tail part of the fuselage, the left landing gear, both left-side engines and the left wing tip.

In its further progress along the ground the aircraft broke up and caught fire.

ICAO Note: Paragraphs 1.4 to 1.16 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

In the final stage of the flight the aircraft was at supercritical angles of attack. This was indicated by the following:

- the initial contact with the ground made by the tail section of the fuselage and the nature of the ensuing disintegration of the aircraft;
- the characteristics of the parameters recorded by the flight recorder (high-frequency g-load fluctuations, scatter of the height and air speed readings);
- testimony of witnesses on the flight concerning heavy vibration experienced in the air;
- computation of the recorded motion parameters of the aircraft, which point to a level of drag which could only arise in the presence of supercritical angles of attack.

The take-off roll and lift-off up to V_2 proceeded normally. The parameters of the take-off path were virtually identical with those that would be normal for the prevailing conditions.

In the portion of the flight subsequent to V_2 anomalies took place in the functioning the engines. This was evidenced by:

- the statement captured by the voice recorder prior to the impact, in which a crew member reported irregularities in the functioning of No. 2 engine;

- the sounds captured by the voice recorder at the end of the flight which were suggestive of the typical noise of an engine surge;

- the testimony of an air hostess who saw a flame in the vicinity of the engines (No. 1 or No. 2) issuing from under the left wing;

- the testimony of passengers who felt the aircraft decelerate several times in flight;

- the presence of a dense layer of soot on the blades of the third stage turbine of No. 1 engine;

- the bending of the tips of three blades located in different sectors of the first stage fan of No. 4 engine, combined with the absence of any defects in the air intake and straightening devices.

Based on the results of research into the technical condition of the engines after dismantling, which showed that there was no damage, burn-holes or other flaws in the structural elements which might have caused outage of the engines in flight, and having regard to the nature of the damage to all the power plants, it can be assumed that total outage of one or more engines in flight did not take place.

The anomalies observed in the functioning of the engines could have been caused by stall phenomena accompanied by loss of thrust in one or more engines consequent upon ice formation on the engine intakes. Ice formation could have occurred in the prevailing weather conditions, since the valves of the de-icing system tubes to the engines and the intakes were closed during take-off. Moreover, the bends observed on the blades of No. 4 engine fan were characteristic of damage produced by the impact of ice particles.

Owing to the supercritical angle of attack of the aircraft during the final portion of the flight, engine surge may also have occurred. It is possible that the soot deposit on the third stage turbine of No. 1 engine was provoked by the leakage of flame into the turbine during engine surge or by flame-out and deposition of fuel on the hot blades.

Approximately 11 seconds after V_2 had been reached the voice recorder captured the words "spoiler" (or the Japanese expression for "what was that?") followed by "I am sorry" spoken by a crew member at a time when the computations of the investigators showed a marked increase in the aircraft drag.

Supercritical angles of attack could have been caused by a malfunction of the pitch control system. This, however, is precluded inasmuch as:

- no evidence of failure was discovered when the surviving components of the aircraft control system were examined;

- at the time of impact the stabilizer was in the normal take-off position;

- the cockpit voice recorder did not record any conversation between the crew that might suggest defects or difficulties in controlling the aircraft.

A substantial rise in drag could result from an inadvertent extension of the spoilers. At the time of impact with the ground the spoilers were almost completely retracted. However, even brief extension of the spoilers would suffice to explain the abrupt rise in drag and create a possibility of a stall situation arising as a result of the sudden decrease in lift at relatively small take-off speeds.

Malfunctioning of the engines and the accompanying loss of thrust could lead the pilots to try and maintain the climb-out regime by pulling on the control column: this would result in the aircraft assuming angles of attack characteristic of the so-called second flight regime, with a resultant increase in drag, followed by a loss of vertical speed. Irregularities of this sort in the piloting of the aircraft, which was already complicated by the night-time conditions, could lead to the assumption of large angles of attack, loss of air speed and stall.

To say unequivocally which of the two possibilities referred to in 2.1.6 and 2.1.7 led to the supercritical angles of attack was not possible owing to the limited information provided by the aircraft's flight recorder (4-track tape).

The conversations of the crew, as recorded by the cockpit voice recorder before the start of roll, during the roll and in the air, showed that none of the crew lost his capacity to act prior to the moment of impact.

2.2 Conclusions

a) Findings

The preparation, training and flying experience of the pilot-in-command and other crew members, the crews' qualifications and capacity to execute flights on the DC-8-62, particularly on the Moscow - Tokyo route, satisfied the requirements of the Japanese Government and the JAL Company for this type of aircraft.

The medical fitness of the crew, their duty and rest periods accorded with the current requirements of the Japanese Government and the JAL Company and should not have had an adverse influence on the course of the flight.

Aircraft JA-8040 was airworthy and its technical condition prior to the flight, as well as its certification, cannot be cited as grounds for the accident.

The take-off weight and centre of gravity of the aircraft were within the prescribed limits.

The aircraft was serviceable prior to flight, according to its technical documents. Ground servicing prior to the flight, including refuelling at Sheremetievo airport, took place in conformity with current requirements.

The meteorological conditions in the area of Sheremetievo airport at the time of take-off corresponded to the airport minima and the crew minima prescribed by JAL.

The take-off runway and taxiways were in normal operating condition.

The radio and lighting aids for the flight, as well as the airport communication systems, were functioning correctly in accordance with current regulations.

These was no fire, explosion or damage to the aircraft during ground roll or in the air prior to impact.

No member of the crew lost his capacity to act during the flight up to the moment of impact.

The take-off took place in an ambient air temperature of -5°C, with 96 per cent relative humidity and with the engine de-icing systems switched off.

The ground roll and take-off up to V_2 took place normally.

After V_2, anomalies occurred in the functioning of No. 1 or No. 2 engine.

In the initial climb-out the aircraft assumed supercritical angles of attack, after which it began to lose speed and height until it struck the ground.

Neither the technical investigation nor the analysis of conversations which took place on the flight deck revealed any signs of failure or malfunctioning of the pilot's instruments or aircraft control system.

Up to the time of impact the aircraft was in take-off configuration, with the landing gear extended and all engines functioning.

After the accident occurred, all the essential action was immediately taken to rescue those on board the aircraft. All the survivors were immediately admitted to hospital.

b) Cause or Probable cause(s)

The cause of the disaster to aircraft DC-8-62 JA-8040 resided in the fact that, during take-off and following attainment of the safety speed V_2, the crew put the aircraft into a supercritical angle of attack, which resulted in loss of speed and altitude.

The aircraft's assumption of supercritical angles of attack was the consequence of one of the following circumstances:

a) inadvertent extension of the spoilers in flight, leading to a fall in the maximum value of the lift ratio and an increase in drag;

b) loss of control of the aircraft by the crew in conditions associated with malfunctioning of the No. 1 or No. 2 engine consequent upon possible ice formation on the engine intake at a time when the de-icing system was switched off.

The anomalies in the functioning of the engines observed by the crew and other witnesses may have arisen after the aircraft had assumed a supercritical angle of attack with the spoilers extended.

3.- Recommendations

The Commission recommends to Japan Airlines and the Flight Safety Service of the Japanese Ministry of Transport that steps be taken to enhance the safety of flights with special reference to strict observance by crews of the prescribed rules of operating aircraft systems.

The Commission asks to be informed of the steps taken pursuant to the foregoing.

ICAO Ref.: AIG/510/72

No. 3

North Central Airlines, DC-9-31, N-954N and Delta Air Lines, CV-880, N-8807E, collision at Chicago/O'Hare, U.S.A., on 20 December 1972. Report No. NTSB-AAR-73-15, dated 5 July 1973, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flights

a) Delta Air Lines Flight 954

Flight 954, a CV-880, N-8807E, was a regularly scheduled passenger flight from Tampa, Florida, to O'Hare International Airport, Chicago, Illinois. On 20 December 1972, the flight departed from Tampa at 1541[1/] eastern standard time with 86 passengers and 7 crew members aboard. The en-route portion of the flight was completed without reported incident.

Flight 954 established radiocommunication with Chicago Approach Control (CAC) at 1723:10. The flight had heard Automatic Terminal Information Service (ATIS)[2/] "Golf" announce that Runway 14R was being used for landings and Runways 14R and 14L for departures. The local weather was reported, in part, to be: ceiling indefinite 200 ft, sky obscured, visibility 1/4 mile in fog.

At 1739:10, the CAC controller informed all flights under his control that parallel Instrument Landing System approaches would be conducted to Runways 14L and 14R, and that all aircraft under his control would be vectored for the ILS approach to Runway 14L. The Runway Visual Range (RVR) for 14L was 3 000 ft.

After receiving a clearance for the approach, Flight 954 contacted the O'Hare tower local controller at 1746:10. At 1752:30, the local controller cleared the flight to land on Runway 14L and advised the flight crew that the RVR was 1 800 ft.

At 1755:05, the O'Hare local controller requested Flight 954 to report when clear of Runway 14L. The flight crew reported clear of the runway at 1756:18; 2 seconds later, the local controller cleared the flight to the ground control frequency. Simultaneously, the ground controller attempted to contact the flight, without success.

At 1757:29, the co-pilot of Flight 954 established radio communications with the O'Hare ground controller with the transmission, "Delta nine fifty four is with you inside the bridge and we gotta go to the box".[3/] The controller replied, "... OK if you can just pull over to (the) thirty two pad". The co-pilot replied, "Okay we'll do it".

1/ Unless otherwise specified, all times herein are central standard time, based on the 24-hour clock.

2/ A sequential automatic radio transmission of weather and airport traffic information. Each new message is given an identifying letter designator.

3/ The "box" is a holding area on the airport, officially designated as the Penalty Box. (See Appendix D)

There were no further communications between the ground controller and Flight 954. The controller made an entry on a scratch sheet which he later stated was to remind him that he had sent the CV-880 to the 32R pad to hold awaiting a gate assignment.

The pilot-in-command of Flight 954 taxied the aircraft via the Bridge, the Outer Circular, and the North-South taxiways4/ en route to the Runway 32L run-up pad.

The ground controller later stated that he did not hear the words "inside the bridge" in the co-pilot's initial transmission. The ground controller also stated that he thought that the flight was taxiing clear of the runway when he was contacted and in replying, it was his intention to determine whether the flight could hold on the Runway 32R run-up pad.

The pilot-in-command and co-pilot both stated that they thought the controller wanted them to hold on the Runway 32L run-up pad and cleared them to do so. The collision occurred as Flight 954 was crossing Runway 27L en route to the 32L run-up pad.

b) North Central Airlines Flight 575

Flight 575, a DC-9, N-954N, was a regularly scheduled passenger flight between Chicago, Illinois, and Duluth, Minnesota, with an intermediate stop at Madison, Wisconsin. Forty-one passengers and four crew members were aboard. At 1750, the O'Hare ground controller cleared the flight to taxi to Runway 27L for departure.

At 1758:52.3, the O'Hare local controller cleared Flight 575 into the take-off position on Runway 27L and advised the crew the visibility was one-fourth mile. Twenty-six seconds later, the local controller cleared the flight for take-off; at 1759:24.3, the pilot-in-command reported that he was beginning his take-off roll.

The co-pilot made the take-off. The pilot-in-command stated that the take-off roll was normal until he called "Rotate."5/

At that moment, the pilot-in-command saw another aircraft ahead on the runway, and he immediately assisted the co-pilot in applying additional control pressure to gain altitude in an attempt to clear the other aircraft. The attempt was unsuccessful. After the collision, the pilot-in-command decided that his aircraft could not maintain flight, at which time he took control, and flew the aircraft back onto the runway.

The collision occurred at 1800:08.7, 20 December 1972. The geographic coordinates of the accident site are 41°58'9" N and 87°54'4" W. The accident occurred at night at an elevation of approximately 667 ft above mean sea level.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	10	-
Non-fatal	2	15	-
None	9	102	

4/ See Appendix D for the airport taxi chart and taxiway nomenclature.
5/ V_R (rotate) the indicated airspeed at which elevator control is applied to establish the angle of attack for lift-off.

1.3 Damage to aircraft

The DC-9 was destroyed. The CV-880 was substantially damaged.

ICAO Note: Paragraphs 1.4 to 1.16 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

Both the DC-9 and the CV-880 were equipped, certificated, and maintained in accordance with company procedures and FAA requirements. Both aircraft were capable of normal operation.

All crew members of both flights were qualified and certificated for their respective duties. Each had received the training prescribed in the FAA-approved company training programmes. All flight crew members had received the crew rest opportunities specified in the regulations.

All the involved air traffic controllers were qualified and certificated for their respective duties. Each had received the training prescribed in the FAA training programmes.

The pilot-in-command of the DC-9 was operating the aeroplane within the scope of a valid clearance, and, under the circumstances, he did all that could be reasonably expected of a pilot to avoid the collision. Because of the restricted visibility and the short time interval available after they saw the CV-880, the flight crew of the DC-9 was unable to take any other course of action to avoid the collision. Although the exact visibility in the accident area could not be determined, the recorded RVR nearest the accident site was about 2 000 ft or more than one-fourth mile. A review of the recorded visibilities at various points on the airport indicates that the fog was homogeneous, with little variation in visibility at any specific time.

With 1/4 mile visibility, the flight crew of the DC-9 could not have seen the CV-880 until they were approximately 1 600 ft from the collision point. The co-pilot was making an instrument take-off which the pilot-in-command was monitoring, with particular attention to the airspeed. The pilot-in-command looked outside the aircraft after he called "Rotate" at 1800:03.4. When he saw the CV-880 at 1800:07.2, the pilot-in-command reacted with the order, "Pull 'er up!" In the 5.3-second interval between "Rotate" and the impact, the pilot-in-command first had to see the CV-880, next evaluate the probability of a collision, then decide on a course of action, and finally initiate an action; the aircraft had to respond to the control inputs. There was insufficient time for the flight crew of the DC-9 to avoid the collision; and there was no other reasonable course of action that the pilot-in-command could have taken in the time and distance available to him.

The attention of the flight crew of the CV-880 was divided between taxiing the aircraft and intracockpit conversations. They did not see the DC-9 in time to take any action to avoid the collision.

The investigation confirmed that after the collision occurred, the DC-9 was incapable of sustaining flight. The flight crew's skill in maintaining control of the aircraft most likely averted more serious consequences.

The principal causal area in this accident involved the exchange of communications between the O'Hare ground controller and the flight crew of the CV-880. However, the sequence of events that established the conditions for the accident probably began when the CV-880 crew listened to ATIS broadcast "Golf".

That broadcast announced to the flight crew that Runway 14R and Runway 14L were being used for departures. When the O'Hare operation was subsequently changed to use Runways 14R and 14L for approaches, the flight crew was not informed that departures had been started on Runway 27L. Consequently, the flight crew was unaware that Runway 27L had become an active runway, and the information they subsequently received contained nothing to indicate that the runway was being used for take-offs.

After the CV-880 had landed on Runway 14L, the local controller requested the flight to report when it was clear of the departure end of the runway. The flight crew acknowledged and complied with that request. While the local controller was clearing the flight to the ground control frequency, the ground controller was attempting simultaneously to contact the flight. Consequently, the ground controller was aware of the flight's arrival and anticipated radio contact with the flight crew.

Meanwhile, the ground controller was also occupied with another Delta flight, which was having difficulty locating the Penalty Box. Immediately after the other flight appeared to have located the Penalty Box, the co-pilot of the CV-880 established contact with the ground controller by transmitting "Delta nine fifty four is with you inside the bridge and we gotta go to the box".

The Board is of the opinion that the controller did not hear the words "inside the bridge" in that transmission, but is unable to determine why he failed to hear those words. Had he heard the position given by the CV-880 crew, he would not have directed the crew to the 32R pad, his stated intention. From their reported position, the CV-880 crew would have had to turn the areoplane around and taxi against the flow of traffic from 14L toward the terminal. Had the controller intended to direct the CV-880 to the 32L pad, he would have had to co-ordinate the clearance with the local controller before he could allow the flight to cross Runway 27L. This co-ordination was not effected. It is significant that when the ground controller directed the CV-880 crew to the 32 pad, he entered on a scratch sheet a written notation that the flight was holding at the 32R pad. For these reasons, the Board concludes that the controller did not hear the full transmission from the CV-880 and that he intended to clear the flight to the 32R pad. The CV-880 crew's response "Okay we'll do it" satisfied the controller and reinforced his belief that the CV-880 was going to the 32R pad.

The controller should have been particularly alert to the position report from the CV-880 because of the limited visibility which prevented him from seeing the aeroplane. There was no evidence of a physical reason for his not hearing the complete transmission. The transmission was recorded, and a review of the recording showed that the transmission was both audible and intelligible. If the controller did not hear the crew report their position, he should have immediately requested a position report, rather than issuing what constituted a clearance to taxi to a holding point. The controller stated that had he heard the phrase "inside the bridge", he would have asked for additional information regarding the position of the aeroplane. The transmission without the position report was incomplete in that it did not contain information the controller needed to control the ground movement of the aeroplane. It is the Board's opinion that if any transmission is unclear or ambiguous, the recipient should immediately request clarification.

The controller stated that at the time he received the initial transmission from the CV-880 crew, he believed that the aeroplane was just clear of Runway 14L near the 32R pad. Since the crew had notified the local controller that they were clear of the runway more than a minute before the initial transmission to the ground controller, the Board can find no valid reason for such an assumption. Pilots testified that the normal procedure after clearing a runway was to continue to taxi and call ground control as soon as possible for taxi clearance. Delta aircraft clearing Runway 14L normally taxied via the Bridge taxi route to the terminal. The initial call from an aeroplane to ground control normally contained the position of the flight and its destination on the airport. The crew of the CV-880 experienced a delay in getting their destination on the airport from the station agent and did not call the ground controller until more than 1 minute after they were clear of the runway. Controllers testified that they commonly received initial radio contact from flight crews at various points on taxiways. The handling of the flight that followed the CV-880 is an example. The flight crew contacted the ground controller and, in response to the controller's request for their position, reported that "... just getting ready to cross the bridge".

The flight crew of the CV-880 stated that since they had reported their position "inside the bridge", they believed that the controller was referring to the 32L pad in his transmission. They said it would have been impractical to go to the 32R pad from their position. However, since the controller's transmission was not clear in that it did not specify which 32 pad was to be used as a holding point, the crew should have requested clarification of the transmission before taxiing approximately 1 mile in limited visibility. Separation of aircraft on the ground, as well as in the air, is a joint responsibility of controllers and flight crews. Each has a duty in the interest of safe operations to request either additional information or clarification when transmissions are ambiguous, unclear, or incomplete. In this case, there was a need for a request for additional information and for clarification on the part of both the flight crew and the controller.

The manner in which the ASDE equipment in the O'Hare tower was used by the controllers did not comply with the provisions of Section 20[9/] of the Terminal Air Traffic Control Handbook and the provisions of O'Hare Tower Order 7110.26.[10/] The ground controllers were not required to be qualified in the use of the ASDE, nor were they encouraged to use it. Although the display in the tower cab did not provide a clear picture of the airport environment, it is the Board's conclusion that the use of the ASDE equipment was mandatory and that it should have been used by the controller. The Board recognizes that the difficulties with the tower cab display might lead to controller reluctance to rely on the equipment, but the Board is also cognizant of the manner in which other facilities use similar equipment to control ground traffic effectively. Consequently, the Board believes that to overcome the limited and discretionary use of the ASDE, and to improve the effectiveness of the equipment, standard operating procedures should be established for all ASDE-equipped facilities.

Fire broke out almost immediately, and smoke developed very rapidly in the DC-9 after it came to a stop. This reduced the time available to effect an evacuation and made a co-ordinated crew response extremely important in this accident.

9/ Airport Surface Detection Procedures -- 1680, Equipment Usage -- Use ASDE to observe aircraft movement on runways and taxiways during low visibility conditions or to supplement information obtained by visual observations and pilot reports.

10/ Policy - ASDE shall be turned on and used whenever any area of the airport is not visible due to reduced visibility. It shall also be on and available for use at night whenever the operation is such that the exact position of aircraft cannot be determined by visual reference.

The Board concluded that the DC-9 cabin emergency lights did come on. However, because the aircraft battery ground lead was severed, the power was supplied by the 2.5-volt batteries, which resulted in low intensity illumination. This made the emergency lights difficult to see in the concentration of smoke near the ceiling of the aircraft.

The emergency evacuation of the DC-9 was impeded by dense smoke and inadequate cabin illumination. Also, the supervision of the evacuation by the flight and cabin crew members from a position outside the aircraft delayed the egress of some of the passengers.

The Safety Board concludes that individual crew member actions and crew co-ordination during the evacuation were less than adequate and probably detracted from the success of the evacuation. All of the North Central DC-9 crew members received FAA-approved emergency evacuation training, which was conducted in much the same manner as many other air carriers train their crew members. Such training emphasizes that crew members must take control of an evacuation, open all usable exits, direct passengers expeditiously through those exits, and ensure that all passengers are out of the aircraft before they themselves exit.

An individual crew member's response to an emergency situation is almost wholly a product of his training, particularly when time is critical. The assessment and response must be swift and accurate, and the crew member's actions must be co-ordinated with little or no direction. In addition, because of the possibility of disabling injuries or unusual circumstances, each crew member must be prepared to assume command of the evacuation.

Each crew member must have a firm understanding of the duties of the others so that his efforts will complement theirs. Crew members must understand that they are the leaders of the evacuation, and that most passengers will immediately seek their aid and guidance. Passengers also may experience negative panic and may need to be physically aroused to action. To achieve maximum effectiveness, the crew members must remain inside the aircraft as long as possible.

Crew members must be familiar with the location and operation of the installed evacuation aids, such as voice amplifiers, portable emergency lights, flashlights, and smoke goggles.

To achieve this degree of efficiency, crew member evacuation training must be such that individual reaction to an emergency situation will be reflexive. Ideally, such training should be conducted in an environment approximating that of an actual aircraft evacuation. Environmental factors such as lighting, smoke, and confusion should be introduced into evacuation training. Training should be conducted in facilities which simulate an aircraft as closely as possible and should be conducted on a crew basis, rather than on an individual basis, so that each crew member can become familiar with the duties and responsibilities of the others.

Prior accident experience shows that crew members who have received approved emergency evacuation training often exhibit exemplary performance when faced with an emergency situation. This leads the Board to believe that this crew's performance was the result of an inadequate training programme. If the evacuation training of this crew had been oriented toward co-ordinated activities and had been conducted under emergency conditions, simulated more realistically, crew performance during the actual evacuation could have been more effective. The corrective action taken by the FAA regarding the carrier's training programme is outlined in section 3 of this report.

A discrepancy was found in the maintenance of the evacuation slide at the main entry door. Examination of the slide after the accident showed that the slide would not have inflated when the inflation lanyard was pulled because the lanyard was wrapped around the neck of the inflation bottle. An evaluation of the effect of not inflating the slide indicates that the escape of those persons who used the main entry door might have been expedited. Had the slide been inflated, it would have extended at a shallow angle because of the attitude of the aeroplane. Therefore, the evacuees would not have been able to slide out of the aircraft, but rather, they would have had to walk or run out on an unstable slide. This would have increased the possibility of a fall and subsequent injury. On the other hand, had the slide been inflated, it would have been easier for crew members to return to the cabin when the flow of passengers slowed or stopped.

There was a 3-minute lapse between the time of the collision and the first communication from the Chicago Fire Department (CFD) which indicated that they arrived at the DC-9. This delay occurred because the tower personnel did not know at first that an accident had occurred. About 1:50 minutes were required for the controllers to learn that the DC-9 was not visible as a radar target, that the DC-9 flight crew did not respond to radio calls, and for the pilots on the ground to report a fire on the ground south of the Penalty Box. This fire was not visible from the tower. The CFD response to the alarm was prompt, and the first unit reported "on scene" within 1 minute of the time the alarm was sounded.

2.2 Conclusions

a) Findings

1. The visibility at O'Hare at the time of the accident was one-fourth mile in fog.

2. Airport traffic beyond the confines of the main terminal area could not be observed visually from the control tower.

3. The ASDE "BRITE" equipment at the O'Hare tower provided indistinct displays of airport ground traffic.

4. The ground controller's transmission to the CV-880 was ambiguous because he did not specify which of two similarly numbered run-up pads was to be used as a holding point.

5. The flight crew of the CV-880 did not request clarification of the ground controller's ambiguous transmission.

6. Flight crews and controllers in the Chicago terminal area both deviated from the prescribed ATC communication procedures.

7. The pilot-in-command of the DC-9 was operating under a valid clearance.

8. Neither the local controller nor the flight crew of the DC-9 was aware of the proximity of the CV-880 to Runway 27L.

b) Cause or
Probable cause(s)

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the traffic control system to ensure separation of aircraft during a period of restricted visibility. This failure included the following: 1) the controller omitted a critical word which made his transmission to the flight crew of the Delta CV-880 ambiguous; 2) the controller did not use all the available information to determine the location of the CV-880; and 3) the CV-880 flight crew did not request clarification of the controller's communications.

3.- Recommendations

On 20 March 1973, the Federal Aviation Administration issued Air Carrier Operations Bulletin 73-1. This bulletin requested that each Principal Operations Inspector review his assigned carrier's emergency evacuation training programme to ensure compliance with 14 CFR 121.417. The bulletin recommended that the initial and recurrent training programmes provide for operation of each emergency exit by individual crew members either on the aircraft or on a suitable mock-up.

On 21 March 1973, the FAA advised North Central Airlines that the portion of its emergency evacuation training programme which authorized training by demonstration on the operation and use of emergency exits was cancelled. Also, provisions were set forth that required: 1) all crew members individually to operate each type of emergency exit during initial and recurrent training; 2) all DC-9 crew members, except those who had done so in the preceding 12 months, to operate the DC-9 tail cone exit within the succeeding 90 days; and 3) North Central Airlines to demonstrate an emergency evacuation of a DC-9 within the succeeding 30 days.

The Board has submitted six recommendations (A-73-21 to 26) to the FAA concerning air traffic control procedures. Correspondence related to these recommendations is included in Appendix E.*

Five recommendations (A-73-39 to 43) concerning the crash survival aspects of this accident and two other recent accidents were submitted to the Federal Aviation Administration in a letter issued 25 June 1973. (See Appendix F.)*

*ICAO Note: Appendices E and F not reproduced. The specific recommendations concerning the crash survival aspects were:

"The Safety Board recommends that the Federal Aviation Administration:

1. Take the necessary steps to ensure that all air carrier before-landing and take-off checklists contain a "Fasten Shoulder Harnesses" item.

2. Amend 14 CFR 25.785(h) to require provisions for a shoulder harness at each cabin attendant seat, and amend 14 CFR 121.321 to require that shoulder harnesses be installed at each cabin attendant seat.

3. Amend 14 CFR 25.812 to require provisions for the stowage of a portable, high-intensity light at cabin attendant stations; and amend 14 CFR 121.310 to require the installation of such portable, high-intensity lights at cabin attendant stations.

4. Amend 14 CFR 25.812 to require exit sign brightness and general illumination levels in the passenger cabin that are consistent with those necessary to provide adequate visibility in conditions of dense smoke.

5. Amend 14 CFR 25.812 to provide an additional means for activating the main emergency lighting system to provide redundancy and thereby improve its reliability."

An additional survival aspect, a need for improved emergency evacuation capability in darkness and smoke conditions, was illustrated by this accident. In the darkness and smoke, the passengers had extreme difficulty in finding their way to the main exit and in locating exits. Four passengers left their seats and apparently attempted to find an exit but were unable to do so under the conditions that existed.

In January 1968, a study entitled, "New Concepts for Emergency Evacuation of Transport Aircraft Following Survivable Accidents" was prepared by North American Rockwell Corp., Aerospace and Systems Group. This study discussed a number of concepts to improve egress from aircraft involved in survivable accidents. These concepts included among others, sonic indicators at emergency exits; "chemical light" to outline aisles, exits and egress devices; revised cabin lighting; floor level lighting; and tactile indicators for exit routes.

Our evaluation of this accident as well as other recent survivable accidents indicates that egress from the aircraft would have been easier and faster if some or all of the above listed items had been available in the aircraft.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Amend the existing certification and operating rules for air carrier and air taxi aircraft to include provisions requiring tactile guidance and improved visual guidance to emergency exits, as well as more efficient methods of indicating the location of emergency exits in a dark or smoke environment. (Recommendation A-73-53)

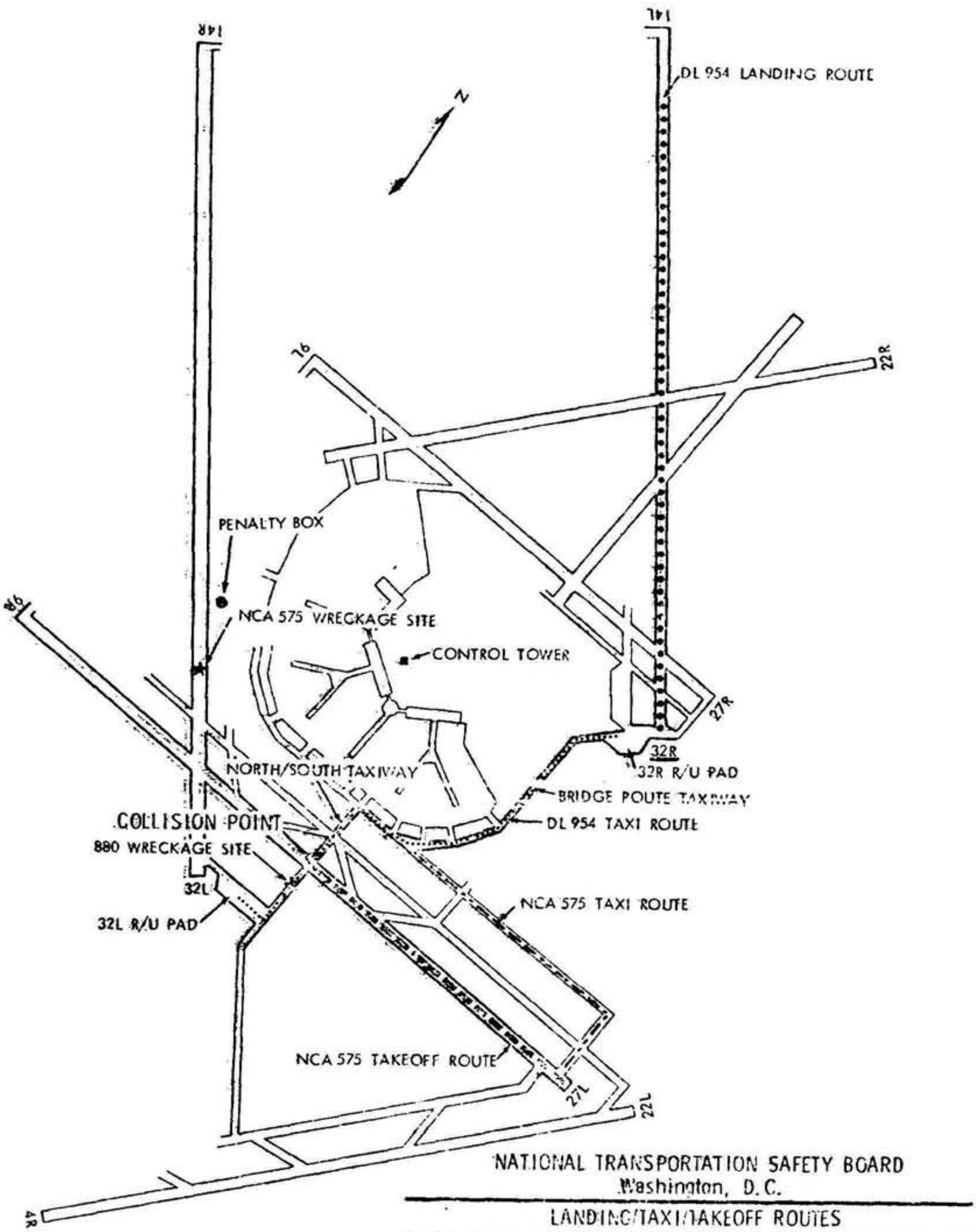
A major factor in this accident was that the ground controller did not know the position of the CV-880 following initial radio contact because he did not hear the position given by the flight crew. Additionally, the controller did not use the ASDE to verify or determine the position of the aircraft, the controller did not issue instructions to taxi via a specific route to a specific destination, and the flight crew did not request additional clarifying information from the controller. To eliminate these problems, the Board recommends that the Federal Aviation Administration:

2. Require flight crews to report their aircraft position on the airport when establishing radio communications with controllers, and require the controllers to read back the reported aircraft position when it cannot be verified either visually or by means of radar. (Recommendation A-73-54)

3. Require flight crews to read back taxi clearances when operating in visibilities of less than one-half mile. (Recommendation A-73-55)

ICAO Ref.: AIG/540/72

APPENDIX D



NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D.C.

LANDING/TAXI/TAKEOFF ROUTES
DELTA AIRLINES FLT. 954/NORTH CENTRAL AIRLINES FLT. 575
CONVAIR 880 N8807E/McDONNEL DOUGLAS DC-9-31 N954N
Collision at Chicago-O'Hare International Airport
December 20, 1972

No. 4

Eastern Air Lines, L-1011, N-310EA, accident near Miami, U.S.A., on 29 December 1972. Report No. NTSB-AAR-73-14, dated 14 June 1973, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

Eastern Air Lines, Inc., Lockheed L-1011, N-310EA, operating as Flight 401 (EAL 401), was a scheduled passenger flight from the John F. Kennedy International Airport (JFK), Jamaica, New York, to the Miami International Airport (MIA), Miami, Florida.

On 29 December 1972, the flight departed from JFK at 2120[1/] with 163 passengers and 13 crew members on board and was cleared to MIA in accordance with an instrument flight rules flight plan.

The flight was uneventful until the approach to MIA. The landing gear handle was placed in the "down" position during the preparation for landing, and the green light, which would have indicated to the flight crew that the nose landing gear was fully extended and locked, failed to illuminate. The pilot-in-command recycled the landing gear, but the green light still failed to illuminate.

At 2334:05, EAL 401 called the MIA tower and stated, "Ah, tower this is Eastern, ah, four zero one, it looks like we're gonna have to circle, we don't have a light on our nose gear yet."

At 2334:14, the tower advised, "Eastern four oh one heavy, roger, pull up, climb straight ahead to two thousand, go back to approach control, one twenty eight six."

At 2334:21, the flight acknowledged, "Okay, going up to two thousand, one twenty eight six."

At 2335:09, EAL 401 contacted MIA approach control and reported, "All right, ah, approach control, Eastern four zero one, we're right over the airport here and climbing to two thousand feet, in fact, we've just reached two thousand feet and we've got to get a green light on our nose gear."

At 2335:20, approach control acknowledged the flight's transmission and instructed EAL 401 to maintain 2 000 ft mean sea level and turn to a heading of 360° magnetic. The new heading was acknowledged by EAL 401 at 2335:28.

At 2336:04, the pilot-in-command instructed the co-pilot, who was flying the aircraft, to engage the autopilot. The co-pilot acknowledged the instruction.

At 2336:27, MIA approach control requested, "Eastern four oh one, turn left heading three zero zero." EAL 401 acknowledged the request and complied.

1/ All times herein are eastern standard, based on the 24-hour clock.

The co-pilot successfully removed the nose gear light lens assembly, but it jammed when he attempted to replace it.

At 2337:08, the pilot-in-command instructed the second officer to enter the forward electronics bay, below the flight deck, to check visually the alignment of the nose gear indices.2/

At 2337:24, a downward vertical acceleration transient of 0.04 g caused the aircraft to descend 100 ft; the loss in altitude was arrested by a pitchup input.

At 2337:48, approach control requested the flight to turn left to a heading of 270° magnetic. EAL 401 acknowledged the request and turned to the new heading.

Meanwhile, the flight crew continued their attempts to free the nose gear position light lens from its retainer, without success. At 2338:34, the pilot-in-command again directed the second officer to descend into the forward electronics bay and check the alignment of the nose gear indices.

At 2338:46, EAL 401 called MIA approach control and said, "Eastern four oh one'll go ah, out west just a little further if we can here and, ah, see if we can get this light to come on here." MIA approach control granted the request.

From 2338:56 until 2341:05, the pilot-in-command and the co-pilot discussed the faulty nose gear position light lens assembly and how it might have been reinserted incorrectly.

At 2340:38, a half-second C-chord, which indicated a deviation of ±250 ft from the selected altitude, sounded in the cockpit. No crew member commented on the C-chord. No pitch change to correct for the loss of altitude was recorded.

Shortly after 2341, the second officer raised his head into the cockpit and stated, "I can't see it, it's pitch dark and I throw the little light, I get, ah, nothing."

The flight crew and an Eastern Air Lines maintenance specialist who was occupying the forward observer seat then discussed the operation of the nose wheel well light. Afterward, the specialist went into the electronics bay to assist the second officer.

At 2341:40, MIA approach control asked, "Eastern, ah, four oh one how are things commin' along out there?"

This query was made a few seconds after the MIA controller noted an altitude reading of 900 ft in the EAL 401 alphanumeric data block on his radar display. The controller testified that he contacted EAL 401 because the flight was nearing the airspace boundary within his jurisdiction. He further stated that he had no doubt at that moment about the safety of the aircraft. Momentary deviations in altitude information on the radar display, he said, are not uncommon; and more than one scan on the display would be required to verify a deviation requiring controller action.

2/ Proper nose gear extension is indicated by the physical alignment of two rods on the landing gear linkage. With the nose wheel well light illuminated, these rods may be viewed by means of an optical sight which is located in the forward electronics bay, just forward of the nose wheel well.

At 2341:44, EAL 401 replied to the controller's query with, "Okay, we'd like to turn around and come, come back in", and at 2341:47, approach control granted the request with, "Eastern four oh one turn left heading one eight zero". EAL 401 acknowledged and started the turn.

At 2342:05, the co-pilot said, "We did something to the altitude". The pilot-in-command reply was, "What?"

At 2342:07, the co-pilot asked, "We're still at two thousand, right?" and the pilot-in-command immediately exclaimed, "Hey, what's happening here?"

At 2342:10, the first of six radio altimeter warning "beep" sounds began; they ceased immediately before the sound of the initial ground impact.

At 2342:12, while the aircraft was in a left bank of 28°, it crashed into the Everglades at a point 18.7 statute miles west-northwest of MIA (latitude 25°52' N, longitude 80°36' W). The aircraft was destroyed by the impact.3/

Local weather at the time of the accident was clear, with unrestricted visibility. The accident occurred in darkness, and there was no moon.

Two ground witnesses had observed the aircraft shortly before impact to be at an altitude that appeared low.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	5	94	-
Non-fatal	10*	67	-
None	-	-	

*Includes two non-revenue passengers, one occupying an observer seat in the cockpit and the other seated in the first-class section of the cabin.

The accident survivors sustained various injuries; the most prevalent were fractures of the ribs, spine, pelvis, and lower extremities. Fourteen persons had various degrees of burns. Seventeen persons received only minor injuries and did not require hospitalization.

Post-mortem examination of the pilot-in-command revealed a tumour which emanated from the right side of the tentorium in the cranial cavity. The tumour displaced and thinned the adjacent right occipital lobe of the brain. The lesser portion of this meningioma extended downward into the superior portion of the right cerebellar hemisphere. The tumour measured 4.3 cm laterally, 5.7 cm vertically, and 4.0 cm in an anterior-posterior direction.

3/ ICAO Note: Reconstruction of the flight path appears at Appendix F.

4/ One non-revenue passenger and one other passenger succumbed to their injuries more than 7 days subsequent to the accident. 14 CFR 430, section 430.2, requires that these deaths be classified herein as "non-fatal".

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.16 not reproduced.

2.- Analysis and Conclusions

2.1 Analysis

It was concluded from the investigation and the data obtained from tests, that the aircraft powerplants, airframe, electrical and Pitot static instruments, flight controls, and hydraulic and electrical systems were not factors contributing to this accident.

Investigation of the Air Traffic Control responsibilities in this accident revealed another instance where the ARTS III system conceivably could have aided the approach controller in his ability to detect an altitude deviation of a transponder-equipped aircraft, analyse the situation, and take timely action in an effort to assist the flight crew. In this instance, the controller, after noticing on his radar that the alphanumeric block representing Flight 401 indicated an altitude of 900 ft, immediately queried the flight as to its progress. An immediate positive response from the flight crew, and the knowledge that the ARTS III equipment, at times, indicates incorrect information for up to three scans, led the controller to believe that Flight 401 was in no immediate danger. The controller continued with his responsibilities to the five other flights within his jurisdiction.

The Board recognizes that the ARTS III system was not designed to provide terrain clearance information and that the FAA has no procedures which require the controller to provide such a service. However, it would appear that everyone in the over-all aircraft control system has an inherent responsibility to alert others to apparent hazardous situations, even though it is not his primary duty to effect the corrective action.

The destruction of the fuselage, with the possible exception of the cockpit area, was to such an extent that the generally accepted factors which affect occupant survivability could not be applied. Survivability in accidents generally is determined by these factors: a relatively intact environment for the occupants, crash forces which do not exceed the limits of human tolerance, adequate occupant restraints, and sufficient escape provisions. A useful distinction may, therefore, be made between impact survival and post-crash survival. Impact survival implies that the crash forces generated by the impact were of a nature which did not exceed the limits of the occupant's structural environment nor the occupant's physiological limits. Post-crash survival is determined by the occupant's successful escape from his environment before conditions become intolerable as a result of fire, water immersion, or other post-crash conditions. This requires non-incapacitation and adequate exit provisions.

From the above, it is evident that two important factors affecting impact survival were exceeded in this accident: loss of environmental protection and loss of restraint. The injuries of most of the fatalities can be attributed directly to these factors. Therefore, despite the fact that 77 occupants survived, the Board cannot place this accident in the survivable category.

The high survival rate is difficult to explain. The location of the majority of survivors near the larger fuselage sections would indicate that they remained with these sections until the velocity was considerably reduced or until these sections came to a stop. Although the fuselage shell was torn away, thereby exposing the occupants to external hazards, the fuselage structure apparently did not impinge on these survivors. The Board believes, therefore, that the 76 cabin occupants survived because either their seats remained attached to large floor sections or the occupants were thrown clear of the wreckage at considerably reduced velocities.

A final survival factor which deserves attention is the design of the passenger seats in this aircraft. These seats incorporated energy absorbers in the support structure. Additionally, in contrast with the conventional floor tiedown arrangement of aircraft seats, each of the seat units in this aircraft was bolted to a platform, which in turn was fitted to tracks attached to basic aircraft structure. It was noted that many of the seat units remained attached to these platforms and that failures occurred because the basic aircraft structure was compromised, rather than the platform attachments. Although many seat leg failures also were noted, these failures occurred because forces were applied in an aft direction; the seats are stressed to withstand much lower loads in the aft direction than in a forward direction. In fact, the Federal Aviation Regulations do not have a stress requirement in the aft direction for aircraft seats. The Board is of the opinion that the design of the passenger seats in this aircraft materially contributed to the survival of many occupants.

The thrust of the investigation was focussed on ascertaining the reasons for the unexpected descent. The areas considered were:

1. Subtle incapacitation of the pilot.
2. The auto-flight system operation.
3. Flight crew training.
4. Flight crew distractions.

Subtle incapacitation had to be considered in view of the finding of a tumour in the cranial cavity of the pilot-in-command. The medical examiner suggested that the space-occupying lesion could have affected the pilot-in-command's vision particularly where peripheral vision was concerned. Additionally, in the public hearing held in connexion with this accident, expert testimony revealed that the onset of this type of tumour is slow enough to allow an individual to adapt, by compensation, to the lack of peripheral vision so that neither he nor other close associates would be aware of any changed behaviour. It was also noted that, based on the size and location of the tumour in the cranial cavity, the extent of peripheral vision loss could not, in this case, be predicated with any degree of accuracy.

It was hypothesized that if the pilot-in-command's peripheral vision was severely impaired, he might not have detected movements in the altimeter and vertical speed indicators while he watched the co-pilot remove and replace the nose gear light lens. However, the pilot-in-command's family, close friends, and fellow pilots advised that he showed no signs of visual difficulties in the performance of his duties and in other activities requiring peripheral vision. In the absence of any indications to the contrary, the Board believes that the presence of this tumour in the pilot-in-command was not a causal factor in this accident.

In considering the use of the auto-flight system, it was noted that the go-around was flown manually by the co-pilot until 2336:04 when the pilot-in-command ordered engagement of the autopilot. The affirmative reply by the co-pilot implies that the autopilot was engaged at this time. Verification of such action was provided by the aircraft performance group analysis of the DFDR readout which showed pitch control surface motions indicative of autopilot control in either altitude hold or pitch CWS.5/ Which of the autopilots was engaged, i.e. system "A" or system "B", could not be determined. Testimony by pilots at the public hearing indicated that the co-pilot would have probably engaged system "B" to the command position with the altitude hold and heading select functions selected, in accordance with general practices. At the same time, the co-pilot probably selected 2 000 ft into the altitude select/alert panel.

At approximately 2337, some 288 seconds prior to impact, the DFDR readout indicates a vertical acceleration transient of 0.04 g causing a 200 fpm rate of descent. For a pilot to induce such a transient, he would have to intentionally or inadvertently disengage the altitude hold function. It is conceivable that such a transient could have been produced by an inadvertent action on the part of the pilot which caused a force to be applied to the control column. Such a force would have been sufficient to disengage the altitude hold mode. It was noted that the pitch transient occurred at the same time the pilot-in-command commented to the second officer to "Get down there and see if the ... nose wheel's down". If the pilot-in-command had applied a force to the control wheel while turning to talk to the second officer, the altitude hold function might have been accidentally disengaged. Such an occurrence could have been evident to both the pilot-in-command and co-pilot by the change on the annunciator panel and the extinguishing of the altitude mode select light. If autopilot system "A" were engaged, however, the discrepancy in the disengage force comparators, i.e. the mismatch between computers "A" and "B" would become a significant factor in this analysis. Because of this mismatch and the system design, a force exerted on the pilot-in-command's control wheel in excess of 15 lb, but less than 20 lb, could result in disengagement of the altitude hold function without the occurrence of a corresponding indication of the co-pilot's annunciator panel. This would lead to a situation in which the co-pilot, unaware that altitude hold had been disengaged, would not be alerted to the aircraft altitude deviation. If the autopilot system "B" was engaged, as is believed to have happened, such a situation could not have occurred since a force in excess of 20 lb would have been required to disengage the altitude hold function and both annunciator panels would have indicated correctly. Therefore, the Board concludes that the mismatched pitch computers in the auto-flight system were not a critical factor in this accident.

5/ It was concluded that the autopilot was engaged at various times throughout the flight from JFK. A complete mode assessment summary for the pertinent portions of the 27-minute period preceding impact is contained in Appendix G. In attempts to distinguish between autopilot "ON" and "OFF", considerable reliance was placed on DFDR data which showed the ratio between pilot and co-pilot control cable system input motion in the roll axis, since the ratio varies between manual and autopilot operation. This characteristic of the L-1011 lateral control system, verified by ground and flight tests, was used to distinguish between autopilot "ON" and "OFF" whenever there was appreciable roll activity. During lateral manoeuvring with CWS, this ratio becomes less definitive, and, although autopilot "ON" and "OFF" status can be determined, positive identification of the selected mode becomes more difficult.

However, it is significant that recognition of the aforementioned 100 ft loss took 30 seconds after the 0.04 g pitch transient occurred, and after a heading change was requested by approach control. The DFDR readout indicates a 0.9° pitchup manoeuvre coincident with a change of heading. It was concluded from the DFDR analysis of lateral control system motions that the heading select mode was used for the last 255 seconds of flight to control the aircraft to a heading of 270°. Since selection of the new heading would have required action by the co-pilot, which included attention to the autopilot control panel, it is reasonable to assume that he should have been aware of the selected heading select functions at this time. It is also reasonable to assume that the autopilot was set up to provide pitch attitude stabilization sensitive to control wheel inputs and heading select, wherein lateral guidance signals were provided to achieve and maintain the 270° heading.

In the pitch attitude stabilization mode, the aircraft will respond to intentional or unintentional movements of the control wheel. Furthermore, while the aircraft is operating in this mode, the effect of aircraft thrust changes, without compensating pitch attitude control inputs, will be directly related to changes in vertical speed.

A series of reductions in power began 160 seconds before impact. The power reductions and slight nosedown pitch control movements together were responsible for the unrecognized descent which followed. Extensive flight testing and simulation studies of N-310EA's entire Speed Control System (SCS) (autothrottle) were conducted to identify the reason for the series of reductions in thrust during the last few minutes of the flight. Thrust reductions generated by the N-310EA auto-throttle components installed in the test aircraft were dissimilar to those reductions recorded on the DFDR from the accident aircraft. In one series of flight tests, the auto-throttle speed reference was set to 175 kt indicated airspeed (IAS), and a descent rate of 200 fpm was established. The airspeed was maintained to within ±3 kt of the reference speed by the SCS, until the auto-throttle authority limits were reached (flight idle thrust). Such control during the flight of N-301EA was not evident; a 15 kt increase in airspeed did occur, with throttle authority still available. Comparison of the auto-throttle system simulation data with Flight 401's airspeed and acceleration data confirmed that the throttles would have been retarded to the flight idle position relatively quickly.

Reference to the DFDR shows that power on the No. 3 engine was increased slightly, 1 minute before reduction of power on the Nos. 2 and 3 engines (the initiation of the descent profile). This is a normal manual adjustment typically made by a pilot, and cannot be accomplished by the auto-throttle system. Additionally, the speed found set on the auto-throttle selector dial was 160 kt, a speed well below that attained or maintained during the last 4 minutes of flight.

An indication that the throttles were not retarded by a properly operating auto-throttle system is the sequence in which the power was reduced. The first power reduction occurred on the Nos. 2 and 3 engines 160 seconds before impact. In the second reduction, the power on the No. 1 engine was matched with the power on the Nos. 2 and 3 engines. Finally, the power on the No. 1 engine was retarded for more than 10 seconds before reduction of power in the two other engines. The throttles were clutched together and driven simultaneously by one servo. If the auto-throttle system was "on", only intermittent and random failures in the clutch system would have produced asymmetrical reduction of power similar to that typical of manual throttle movement. Since the auto-throttle system of N-310EA was found to have been functional, the Board does not believe that this system was involved in the reduction of thrust.

Another explanation of the thrust reductions would seem to be one of two alternatives -- either an inadvertent or an intentional action by one or both of the pilots. The pilot-in-command might have inadvertently bumped the throttles with his right arm when he leaned over the control pedestal to assist the co-pilot. Similarly, the co-pilot's left arm might have accidentally bumped the throttles while he was occupied with the nose gear indicating system. Because the EPR reductions reflected by the DFDR do even out, at times, one of the pilots might have noted an uneven EPR display (which usually accompanies movement of a throttle), and his reaction might have been to reposition the throttle without reference to the flight instruments.

The other alternative is that one of the pilots intentionally reduced thrust power when he noted that the speed of the aircraft was exceeding the desired speed (160-170 kt) for the flight regime involved. The intentional adjustment, similarly, most probably was made with reference to the airspeed indicators only. If the crew relied on the auto-flight system to maintain the aircraft's altitude, it is conceivable that a correction in airspeed might have been made without reference to other instruments. Of the two possibilities, the Board believes that the throttles were intentionally retarded by one or both of the pilots.

Regardless of the way in which the status of the auto-flight system was indicated to the flight crew, or the manner in which the thrust reduction occurred, the flight instruments (altimeters, vertical speed indicators, airspeed indicators, pitch attitude indicators, and the autopilot vertical speed selector) would have indicated abnormally for a level-flight condition. Together with the altitude-alerting, 1/2 second, C-chord signal, the flight instrument indications should have alerted the crew to the undesired descent.

The throttle reductions and control column force inputs which were made by the crew, and which caused the aircraft to descend, suggest that crew members were not aware of the low force gradient input required to effect a change in aircraft attitude while in CWS. The Board learned that this lack of knowledge about the capabilities of the new autopilot was not limited to the flight crew of Flight 401. Pilot training and autopilot operational policies were studied extensively during the field phase of the investigation, and were discussed, at great length, in the public hearing connected with this accident. Although formal training provided adequate opportunity to become familiar with this new concept of aircraft control, operational experience with the autopilot was limited by company policy. Company operational procedures did not permit operation of the aircraft in CWS; they required all operations to be conducted in the command modes. This restriction might have compromised the ability of pilots to use and understand the unique CWS feature of the new autopilot.

However, the Board believes that the present Eastern Air Lines training programme is adequate but is in need of more frequent quality control progress checks of the student during the ground school phase of the training and an early operational proficiency follow-up check in the flight simulator after the pilot has flown the L-1011 in scheduled passenger service.

Another problem concerns the new automatic systems which are coming into service with newer aircraft and being added to older aircraft. Flight crews become more reliant upon the functioning of sophisticated avionics systems, and their associated automation, to fly the aeroplane. This is increasingly so as the reliability of such equipment improves. Basic control of the aircraft and supervision of the flight's progress by instrument indications diminish as other more pressing tasks in the cockpit attract attention because of the overreliance on such automatic equipment.

Pilots' testimony indicated that dependence on the reliability and capability of the autopilot is actually greater than anticipated in its early design and its certification. This is particularly true in the cruise phase of flight. However, in this phase of flight, the autopilot is not designed to remain correctly and safely operational, without performance degradation, after a significant failure occurs.

In any event, good pilot practices and company training dictate that one pilot will monitor the progress of the aircraft at all times and under all circumstances.

The Board is aware of the distractions that can interrupt the routine of flight. Such distractions usually do not affect other flight requirements because of their short duration or their routine integration into the flying task. However, the following took place in this accident:

1. The approach and landing routine was interrupted by an abnormal gear indication.

2. The aircraft was flown to a safe altitude, and the autopilot was engaged to reduce workload, but positive delegation of aircraft control was not accomplished.

3. The nose gear position light lens assembly was removed and incorrectly reinstalled.

4. The co-pilot became preoccupied with his attempts to remove the jammed light assembly.

5. The pilot-in-command divided his attention between attempts to help the co-pilot and orders to other crew members to try other approaches to the problem.

6. The flight crew devoted approximately 4 minutes to the distraction, with minimal regard for other flight requirements.

It is obvious that this accident, as well as others, was not the final consequence of a single error, but was the cumulative result of several minor deviations from normal operating procedures which triggered a sequence of events with disastrous results.

2.2 Conclusions

a) Findings

1. The crew was trained, qualified, and certificated for the operation.

2. The aircraft was certificated, equipped, and maintained in accordance with applicable regulations.

3. There was no failure or malfunction of the structure, powerplants, systems, or components of the aircraft before impact, except that both bulbs in the nose landing gear position indicating system were burned out.

4. The aircraft struck the ground in a 28° left bank with a high rate of sink.

5. There was no fire until the integrity of the left wing fuel tanks was destroyed after the impact.

6. The tumour in the cranial cavity of the pilot-in-command did not contribute to the accident.

7. The autopilot was utilized in basic CWS.

8. The flight crew was unaware of the low force gradient input required to effect a change in aircraft attitude while in CWS.

9. The company training programme met the requirements of the Federal Aviation Administration.

10. The three flight crew members were preoccupied in an attempt to ascertain the position of the nose landing gear.

11. The second officer, followed later by the jump seat occupant, went into the forward electronics bay to check the nose gear down position indices.

12. The second officer was unable visually to determine the position of the nose gear.

13. The flight crew did not hear the aural altitude alert which sounded as the aircraft descended through 1 750 ft msl.

14. There were several manual thrust reductions during the final descent.

15. The speed control system did not affect the reduction in thrust.

16. The flight crew did not monitor the flight instruments during the final descent until seconds before impact.

17. The pilot-in-command failed to assure that a pilot was monitoring the progress of the aircraft at all times.

b) Cause or Probable cause(s)

The National Transportation Safety Board determines that the probable cause of this accident was the failure of the flight crew to monitor the flight instruments during the final 4 minutes of flight, and to detect an unexpected descent soon enough to prevent impact with the ground. Preoccupation with a malfunction of the nose landing gear position indicating system distracted the crew's attention from the instruments and allowed the descent to go unnoticed.

3.- Recommendations

As a result of the investigation of this accident, the Safety Board on 23 April 1973, submitted three recommendations (A-73-11 through 13) to the Administrator of the Federal Aviation Administration. Copies of the recommendation letter and the Administrator's response thereto are included in Appendix H.*

Recommendations concerning the crash survival aspects of this accident have been combined with those of two other recent accidents and were submitted to the FAA on 15 June 1973. (See Appendix I.*)

*ICAO Note: Appendices H and I not reproduced. The specific recommendations A-73-11 to 13 were:

"The Safety Board recommends that the Federal Aviation Administration:

1. Require the installation of a switch for the L-1011 nose wheel well light near the nose gear indicator optical sight.

2. Require, near the optical sight, the installation of a placard which explains the use of the system.

3. Require that the altitude select alert light system on Eastern Air Lines-configured L-1011 airplanes be modified to provide a flashing light warning to the crew whenever an aeroplane departs any selected altitude by ±250 ft, including operations below 2 500 ft radar altitude."

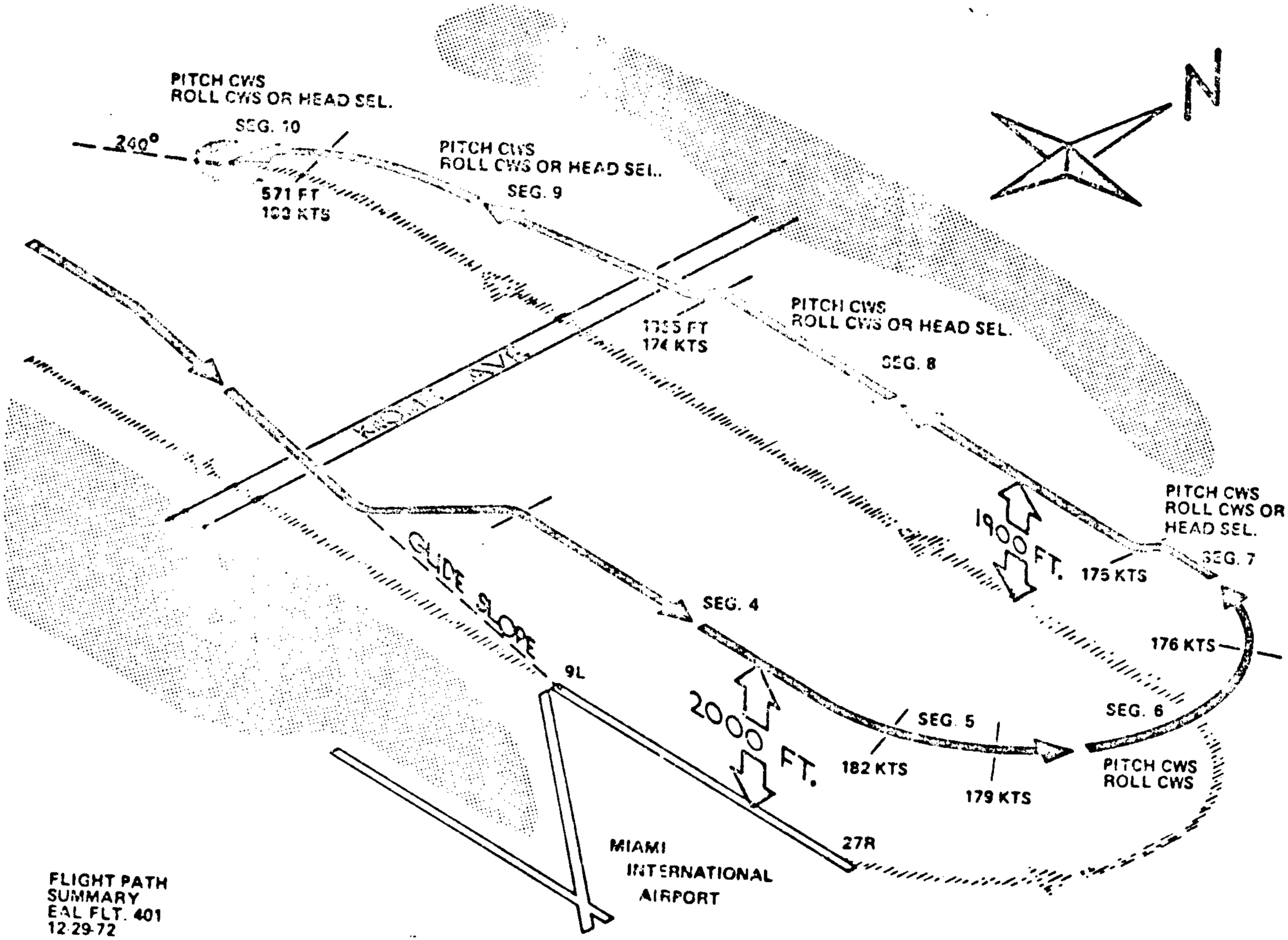
The specific recommendations concerning the crash survival aspects have been reproduced at the end of Summary No. 3.

The Board further recommends that the Federal Aviation Administration:

Review the ARTS III programme for the possible development of procedures to aid flight crews when marked deviations in altitude are noticed by an Air Traffic Controller. (Recommendation A-73-46.)

The Board is aware of the present rule-making proceedings initiated by the Flight Standards Service on 18 April concerning the required installation of Ground Proximity Warning Devices. However, in view of this accident and of previous recommendations on this subject made by this Board, we urge that the Federal Aviation Administration expedite its rule-making proceedings.

ICAO Ref.: AIG/557/72



FLIGHT PATH
SUMMARY
EAL FLT. 401
12-29-72

APPENDIX G

MODE ASSESSMENT SUMMARY

SEGMENT	TIME BEFORE IMPACT	MANOEUVRE	AUTOPILOT ENGAGE STATUS[a/]					
			OFF	PITCH CWS	ALTITUDE CAPT/HOLD	VERTICAL SPEED	ROLL CWS	HEADING SELECT
1	27 min to 20.6 min	Descent to 9 700 ft altitude		X			*	*
2	20.6 min to 19.3 min	Altitude capture at 9 700 ft altitude			X		*	*
3	19.3 min to 16.3 min	Level flight at 9 700 ft altitude	X					
4	420 sec to 373 sec	Level out at 2 000 ft altitude	#	#			#	
5	373 sec to 355 sec	Period before autopilot engage order	#	#	#	#	#	
6	355 sec to 270 sec	Period after autopilot engage order; left turn with 12° roll angle		*pre Xafter 288 sec	*pre 288 sec		X	
7	270 sec to 220 sec	Acquire heading of 270°		X			Xpre *after 256 sec	*after 256 sec
8	220 sec to 140 sec	None - constant heading		X			*	*
9	140 sec to 20 sec	Pitch over and descent		X			*	*
10	20 to 0 sec	Left turn toward 180°; Impact		X			*	*

[a/] X Denotes the mode engaged as indicated by the performance analysis.
* Denotes either of two modes indicated.
\# Denotes possible modes when more than two are possible.

No. 5

Aeroflot, Tu-154, CCCP-85023, accident at Praha/Ruzyne, Czechoslovak Socialist Republic, on 19 February 1973. Report not dated, released by the Federal Ministry of Transport of the Czechoslovak Socialist Republic.

1.- Investigation

1.1 History of the flight

The aircraft took off at 0650 GMT on a scheduled flight Moscow - Prague. Over the territory of the USSR the flight proceeded at 10 000 m, and this altitude was increased over the Romanian People's Republic to 10 650 m. Over Warsaw the aircraft was cleared to descend to 9 400 m, and near the Czechoslovak frontier it was cleared again to 8 850. The frontier was crossed at 6 700 m, the crew complying with all instructions. At 0854 GMT the aircraft reported overhead OKX that it had descended from 7 200 m to 6 700 m. Prague ACC cleared it to continue descent to 2 450 m and tune to Rodnice (RCE) VOR. At 0856 GMT the aircraft was instructed to maintain a track which would keep it in the middle of the airway. At 0900 GMT the aircraft reported overhead Rodnice at 2 450 m and was instructed to change over to the approach frequency 121.4 MHz.

The aircraft at once contacted approach control and was cleared to fly via EHO until it intercepted the approach beacon, then to descend to 1 200 m and report when crossing 1 500 m. The crew complied with these instructions. At 0902 GMT the aircraft reported descending through 1 500 m on a 135° heading and was instructed to change over to the ATC radar frequency.

On this frequency it was cleared to continue flying to the ILS approach beacon, was given priority to land on Runway 25 and instructed to descend to 500 m on QFE 730.1 mm. At 0904 GMT the aircraft was cleared to descend to 350 m on QFE and was informed that it was 2 km off the course line. After 40 seconds the radar controller informed the aircraft that it was correctly aligned and 15 km from the aerodrome, and at 0905 GMT he instructed the aircraft to switch over to the TWR frequency. After changeover the aircraft reported to TWR that it was approaching to land. TWR cleared it to land on Runway 25 and reported a change in the wind direction and speed to 250° - 4 m/s. At 0906 GMT, at its own request, the aircraft was given runway braking coefficient 5 and again cleared to land. This data was acknowledged by the aircraft at 0906.30 GMT, and this was the last contact with it.

The aircraft flew the correct heights and headings and did not report any defects or trouble on the ATC frequencies. The descent to land proceeded normally along the ILS glide path up to the vicinity of the "L" marker.

Near this aid the aircraft suddenly ducked under the glide path, continued to descend at an average angle of 4.62° to the glide path and struck the ground with the nose-wheel at a point 467 m before the threshold of Runway 25.

Calculations showed that in its descent to the ground the aircraft's attitude was:

- flight path angle = -4.12^{o}
- longitudinal inclination of the aircraft = -3.5^{o}
- tilt of the aircraft to the right = 3.6^{o}
- angle of attack = 3.62^{o}

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	62	-
Non-fatal	3	15	-
None	6	10	

1.3 Damage to aircraft

The aircraft was completely destroyed.

1.4 Other damage

Approach lights to Runway 25.

1.5 Crew information

Pilot-in-command, age 41, First Class Pilot's Licence No. UI R 0301, valid till 13 March 1973, annual medical check 16 March 1972, last quarterly medical check 21 December 1972, pre-flight medical check at 0820 hours on 19 February 1973.

Total flight time 12 650 hours, including 236 hours on Tu-154, 48 of these at night. Was off duty the day before flight and slept 7 hours 45 minutes before the flight. Last pilotage check on Tu-154 on 16 February 1973, at night in aerodrome conditions. Previous accidents: None.

Co-pilot, age 44, Second Class Pilot's Licence No. 1X P 3361, valid until 23 February 1973, annual medical examination 23 February 1972, last quarterly medical examination 23 November 1972, pre-flight medical check 19 February 1973 at 0820 hours.

Total flight time 14 650 hours, including 247 hours on Tu-154, of which 53 hours at night. Was off duty the day before the accident, pre-flight rest (sleep) 9 hours. Last pilotage check 2 January 1973. Previous accidents: None.

Navigator instructor, age 35, First Class Navigator Licence No. X1 SH 0396, valid until 24 March 1973, annual medical check 24 March 1972, last quarterly medical check 4 January 1973, pre-flight medical check 19 February 1973 at 0831 hours.

Total flight time 7 280 hours, including 310 hours on Tu-154 of which 60 hours at night. Was on a flight to Rome on 18 February 1973. Returned at 1640 hours. Total time of the flight 6 hours 35 minutes. Pre-flight rest (sleep) 10.40 hours. Last in-flight proficiency check 8 June 1972.

Trainee navigator, age 47, First Class Navigator Licence No. 11 SH 1026, valid until 15 December 1973, annual medical check 15 December 1972, last quarterly medical check (date missing), pre-flight medical check on 19 February 1973 at 0752 hours.

Total flight time 4 630 hours, including 124 on Tu-154, of which 25 hours at night. Was off duty the day before the flight, pre-flight rest (sleep) 9 hours.

Flight Engineer Instructor, age 47, First Class Flight Engineer Licence No. 4 BM 0498, valid until 19 December 1973. Annual medical check 19 February 1972, pre-flight medical check 19 February 1973 at 0750 hours.

Total flight time 9 515 hours, including 674 on Tu-154 and 230 at night. On 18 February he flew to Rome and returned at 1 640 hours. Total time of the flight 6 hours 35 minutes. Pre-flight rest (sleep) 8 hours.

Flight Engineer, age 34, Flight Engineer Licence First Class No. UP BM 2923 valid until 13 September 1973. Annual medical check 13 September 1972, pre-flight medical check on 19 February 1973 at 0742 hours.

Total flight time 3 710 hours, including 957 on Tu-154 of which 323 at night. Was off duty the day before the flight, pre-flight rest (sleep) 8 hours.

Flight Radio Operator Instructor, age 44, First Class Flight Radio Operator Licence No. PBR 0035 valid until 6 February 1974, annual medical check 6 February 1973, pre-flight medical check on 19 February 1973 at 0846 hours.

Total flight time 9 987 hours, including 602 on Tu-154 of which 156 hours at night. Was off duty on the day before the flight, pre-flight rest (sleep) 8 hours.

Radio Operator Trainee, age 42, Flight Radio Operator Licence First Class No. PBR 0084 valid until 24 March 1973. Annual medical check 24 March 1972, pre-flight medical check on 19 February 1973 at 0825 hours.

Total flight time 10 460, including two hours as trainee on Tu-154. Was off duty on the day before the flight, pre-flight rest (sleep) 8 hours.

1.6 Aircraft information

a) Airworthiness and maintenance

The Tu-154, serial No. 72A023, was manufactured by the Ministry of the Aviation Industry of the USSR in September 1972. The owner of the aircraft was Aeroflot, Moscow, USSR.

The aircraft carried a valid Certificate of Airworthiness No. 2806, issued on 30 October 1972 by the USSR Ministry of Civil Aviation, valid until 19 September 1973.

The aircraft was entered in the USSR Aeronautical Register under No. 10135 with effect from 30 October 1972 and carried the identification mark "CCCP - 85023".

At the time of the accident the airframe had flown:

since manufacture:	459.10 hours
since last overhaul:	4.10 hours
number of landings since entry into service:	261

The aircraft was fitted with series 1 HK-8-2 engines as follows:

left - serial No. A8214044

central - serial No. A8214038

right - serial No. A8214040

Engine No. A8214044 had flown 472.53 hours since manufacture

Engine No. A8214038 had flown 472.49 hours since manufacture

Engine No. A8214040 had flown 472.49 hours since manufacture

According to the documents produced, the aircraft had been maintained in conformity with the instruction and technology applicable to the Tu-154.

No modifications were made either to the aircraft or its powerplant during its period of operation. Only defects of a more serious character, and the replacement of major components of the aircraft, have been extracted from the aircraft's repair log book for the last month of operation. No defects in radio navigation equipment were reported.

Date	Nature of defect	Remedial action taken
19.1.73	Tires of forward part of the landing gear severely worn	Replace wheels
	Excessive play in the fuel supply control system and No. 3 thrust reverser	Tighten linkages
4.2.73	Crack in No. 1 engine casing	Lap-joint applied
	Right outboard section of flap making contact with the wing	Flap adjusted
	Gap in rod linkage on No. 3 thrust reverser	Tightened up
	Excessive play in the No. 1 engine thrust reverse latch control	Tightened up
7.2.73	Faulty starting in No. 1 engine	Replace starter
	No. 1 engine "heavy vibration" warning light comes on during descent and thrust reduction	Replace block B7-8

Date	Nature of defect	Remedial action taken
9.2.73	No. 3 engine fails to start	Replace starter
	Forward part of landing gear retracts slowly during take-off	Grease retracted position limit switch
11.2.73	Faulty operation of the 514 air-conditioning unit	Replace 514 unit
14.2.73	MSRP-12 not working	Replace unit
	Excessive play in No. 3 engine thrust reverser linkage	Tighten up
	Track in skin covering round V aft suspension of No. 1 thrust reverser flaps	Lap-jointed

All faults were rectified in the proper manner during operation. The faults indicated could not, following the remedial action taken, have caused the accident.

b) Weight and centre of gravity

According to the weight and balance sheets for Tu-154, Registration CCCP 85023, flight CU-141 of 19 February, the load was as follows:

Weight empty	42 274 kg
Crew weight	640 kg
Weight of galley and stewardesses	800 kg
Take-off fuel weight	27 000 kg
Aircraft operating weight	75 714 kg
Maximum gross take-off weight	90 000 kg
Maximum permitted load	14 286 kg

According to passengers' declarations and the combined load sheet the aircraft was carrying the following load:

85 adult passengers, 1 child under 12 years, 1 infant under 2 years, total weight	6 420 kg
112 pieces of baggage	1 202 kg
Special baggage	155 kg
Handbaggage	192 kg
Cargo (358 pieces)	2 223 kg
Mail (45 pieces)	410 kg
Total load:	10 602 kg
Actual take-off weight	86 316 kg
Landing weight, including 12 tonnes of residual fuel	71 316 kg

According to the load and trim sheet the passengers and cargo were distributed as follows:

Flight deck:		6 crew members
Forward cabin	row 1	2 passengers + 2 crew members
	row 2	4 passengers
	row 5	6 passengers
	row 6	6 passengers
	row 7	6 passengers
	row 8	6 passengers
	row 9	6 passengers
Aft cabin	rows 10 - 11	12 passengers
	rows 12 - 13	12 passengers
	rows 14 - 15	12 passengers
	rows 16 - 17	14 passengers

Forward service bay: 2 crew members (cabin staff)

Middle service bay: 3 crew members (cabin staff)

No. 1 baggage hold:	compartment 1 -
	compartment 2 - 500 kg
	compartment 3A - 500 kg
	compartment 4 - 1 223 kg
No. 2 baggage hold:	compartment 5 - 1 000 + 410 kg
	compartment 6 - 500 kg
	compartment 7 - 702 kg

Based on the above load distribution, the centre of gravity of the aircraft minus fuel was 20.3 per cent MAC, which is within the permissible limits of 16.5 - 28 per cent MAC with the permitted -5.5° maximum stabilizer deflexion on landing, and 28 - 32 per cent MAC with the smaller -3° deflexion of the stabilizer.

An imprecision appears in the documents inasmuch as the declarations of the passengers and the combined load sheet give a total weight of baggage, cargo and mail amounting to 3 835 kg, to which must be added the weight of the special cargo (155 kg), i.e. the correct figure should be 3 990 kg, whereas on the load and trim sheet the total weight of baggage, cargo and mail is shown as 4 735 kg, i.e. 745 kg more then on the combined load sheet. Although it could not be established from the documents which entry was correct, this circumstance could not have influenced the safety of the flight. Neither the take-off, nor the landing weights were exceeded. The most adverse centre of gravity changes produced by the weight differential of 745 kg were investigated, but in each case the aircraft's centre of gravity remained within permissible limits. Its value could fluctuate from the 20.3 per cent MAC to 19.3 - 22 per cent MAC, which are still within permissible tolerances. The centre of gravity displacement due to fuel consumption also remains within permissible limits.

c) Type of fuel used

The fuel used was of the approved type and was not linked to the cause of the accident.

1.7 Meteorological information

1. Weather situation

The eastern edge of a high-pressure wave over western Europe was located above Czechoslovakia.

2. Meteorological conditions between the Frydlant and Roudnice beacons

Wind and temperature in the upper air:

300 mb	9 000 m STD	:	100°	20 m/sec	-50°C
500 mb	5 500 m STD	:	070°	15 m/sec	-25°C
700 mb	3 000 m STD	:	030°	7 m/sec	-10°C

Cloud cover:

4-7/8 Ac, As 2 700-3 500 m STD, 3-5/8 Sc 1 400-1 600 m STD

Precipitation:

Brief snowfalls in different places.

No hazardous meteorological phenomena - turbulence or icing - were forecast or reported by aircraft

3. Meteorological conditions during approach

Wind and temperature in the upper air:

850 mb	1 500 m STD	:	300°	6 m/sec	-8°C
	1 000 m STD	:	300°	6 m/sec	-5°C
	500 m STD	:	260°	6 m/sec	0°C

Cloud cover:

The flight was conducted under the lower limit of the cloud base.

No hazardous meteorological phenomenon - turbulence - was forecast or reported by aircraft

Temperature gradient: about 0.67°C/100 m

Vertical wind shear: very small (1 m/sec)

Precipitation: brief local falls of snow

4. Meteorological conditions at the accident site at approximately 0907GMT

Wind 260° 6-8 m/sec; between 0900 and 0915 GMT maximum measured wind speed 11 m/sec

Visibility: 5 km

Precipitation: brief snowfall

Cloud cover: 3/8 Sc 1 200 m SOL 7/8 Ac 2 700 m SOL

Temperature: 0°C

Dew point: -2°C

Air pressure: QFE on Runway 25: 973.0 mb 28.75 in, 730.1 mm Hg (torr),
QNH: 1 015 mb

5. Present weather at Prague/Ruzine airport

a) TAF valid 0900-1800 GMT

230° 7 m/sec 5 km snowfall GRADU 1000-1300 GMT

wet snow 6/8 Sc 600 m TEMPO 09/12 GMT

PROB 30% 1 200 m snowfall 6/8 St 150 m

b) Trend-type landing forecast, valid 0830 to 1030 GMT

Visibility: 3.5 km, at times (TEMPO) 1 800 m

Cloud cover: cloud base above 450 m SOL
valid 0900 - 1100 GMT

Visibility: 5 km, at times (TEMPO) 1 800 m

Cloud cover: cloud base above 450 m SOL

6. Transmitted meteorological data

ATIS 112.6 MHz and VOLMET Prague 128.6 MHz concord with the values contained in the regular Prague airport meteorological reports between 0730 and 0900 GMT on 19 February 1973.

The wind and temperature gradient values in the atmospheric layer up to 100 m above the surface did not preclude the possibility of turbulence in the approach zone to Runway 25 on the morning of 19 February 1973.

1.8 Aids to navigation

Immediately following the accident a ground check was made of all navigational aids which the crew might have utilized in its approach to Runway 25, i.e. ILS LOC, ILS GP, NDB "PR", MKR "OM", L "L", MKR "MM".

Between 1500 and 1600 GMT a special flight check was made of all the above radio aids. Up to the time of the accident on 19 February 1973 the navigational facilities for landing on Runway 25 were functioning normally.

During the ground flight checks all the facilities were in operation and their parameters complied with order L-10 and the technical specifications of the manufacturer.

1.9 Air traffic control and communications

Throughout its flight over the territory of the Czechoslovak Socialist Republic the aircraft maintained the prescribed routes and flight levels and did not report any anomalies on the ATC frequencies. Communications between the aircraft and the ATC units were normal. The aircraft clearly acknowledged all communications from the ATC units on the territory of the Czechoslovak Socialist Republic.

1.10 Aerodrome and ground facilities

Runway 25, 3 100 m long and 45 m wide, was clean and dry at the time of the accident and could be utilized over its entire length and width. In view of the favourable meteorological and daylight conditions the approach and landing lighting systems were not switched on.

1.11 Flight recorders

The aircraft carried three flight recorders, of which two were damaged:

a) a MSRP-12 flight data recorder

b) a MS-61 cockpit voice recorder.

The third, a K3-63, flight recorder was not recovered.

1. The recording part of the MSRP-12, in its crash-proof case, was recovered from the fairing of the rudder. The recording part was extracted and sent for expert analysis. No fire damage was found; one holder was broken and the surface of the casing was damaged in several places.

2. The MS-61 cockpit voice recorder was recovered from the front part of the wreckage, behind the flight deck. The recording part in its crash-proof container was extracted and sent for expert analysis. The surface of the recording part was severely damaged by fire.

1.12 Wreckage

Initial contact with the ground was made by the nose of the fuselage at a point 467 m before the threshold lights of Runway 25. The nose part of the gear was destroyed on impact; thereafter the right gear was also destroyed, after which the lower part of the forward fuselage and the right wing struck the ground.

The first fragments of the aircraft were found at the point where the nose of the fuselage and the right wing struck the ground, i.e. at a distance of 320 m before the threshold lights of Runway 25. These were parts of the nose gear, the outer part of the stabilizer and part of the wing flap.

In the ensuing phase the right wing and right landing gear became completely detached from the fuselage; they were found at a distance of 257 m before the threshold lights of Runway 25. At this moment the fuel, which had escaped from the burst right wing tanks, was ignited. Most of the aircraft became enveloped in flames.

The fuselage continued to move forward, rotating to the right, and the tail unit and right engine became detached. The right engine turned upside down, along the left wing, and came to rest at a point 50 m before the threshold lights of Runway 25 and 75 m to the right of its centre line.

The fuselage was destroyed by fire, which consumed the entire length of the passenger cabins and flight deck.

Parts of the instruments and radio navigation equipment, together with the electrical equipment, were wholly or partially destroyed in the crash and fire.

1.13 Medical and pathological information

Thirty-four persons - 25 passengers and 9 crew - survived the accident. Eighteen persons sustained different degrees of injuries, and 16 were unharmed.

Sixty-six persons died. Thirteen bodies were found outside the wreckage and 53 inside. In 51 cases the cause of death was fire; the other 15 died of multiple injuries that were not survivable.

1.14 Fire

It was clear from the wreckage, the ground traces and witnesses' testimony that the integral tanks burst at impact of the right wing with the ground at 0907 GMT, fuel spillage occurred and fire broke out.

After the cabin turned over, the fuel began to penetrate the wrecked passenger compartments and spread through the whole of the passenger cabin. The fire increased during the movement of the wreckage along the ground. The intensity of the fire during this movement is evident from the distribution of charred pieces of the aeroplane.

At 0909 GMT the entire aft part of the fuselage, from the mid-wing section to the engines was enveloped in flames on both the inside and outside. The windows in this part of the fuselage had already splintered in the fire.

At 0914 GMT the fire spread along the whole left side of the fuselage and engulfed all parts of the cabin. Compressed air cylinders began to explode in the forward part.

At 0920 GMT the fire was localized, but by this time the entire length of the passenger cabin had been consumed as a consequence of fuel leakage.

1.15 Survival aspects

Immediately after the crash, at 0907 GMT, the duty officer in charge of technical, fire fighting and rescue services, who had watched the aircraft's approach, sounded the alarm. Ten seconds later the TWR also sounded the alarm. Twenty seconds after the crash the fire fighting service set out and covered the 1.5 km to the aeroplane in 90 seconds. At 0909 GMT the fire vehicles reached the scene of the accident and commenced rescue operations. By this time, however, the state of the fire was such that there was no hope of finding any surviving passengers in the aft part of the fuselage, i.e. from the mid-wing section to the engines. Efforts were therefore directed to rescuing the passengers in the forward part of the fuselage where, judging by the scale of damage and intensity of the fire, there was still some hope of saving occupants. Fire fighting was complicated by the fact that the aircraft turned over and escaping fuel penetrated the interior of the fuselage. As a result a fierce fire raged, not only outside, but also inside the fuselage where it was constantly fed by fuel escaping from the tanks.

In the first 3-4 minutes of operations 34 persons were successfully extricated, i.e. part of the passengers and the crew, partly with the assistance of survivors, but mainly by members of the fire fighting and rescue service, members of the crew and aerodrome personnel.

At 0914 GMT it was no longer possible to continue rescue work in the forward part of the fuselage due to the fact that the compressed air cylinders had begun to explode, metal alloys were burning, the fuel was entering the forward part of the fuselage in large quantities, the temperature was extremely high and, despite a blanket of foam applied to the area, the fire enveloped the opening through which passengers were being pulled clear. At 0917 GMT reinforcements from fire fighting units outside the aerodrome were sent to the accident.

The fire was brought partly under control at 0920 GMT and was completely and finally subdued, both in the wreckage of the aircraft and on the aerodrome surface, by 0945 GMT. The equipment of the fire fighting and rescue service complied with Instruction VP-3 of the Czechoslovak Ministry of Transport, developed in conformity with ICAO requirements. The fire fighting equipment used greatly surpassed these standards.

1.16 Tests and research

The following units and instruments were bench-tested:

- stabilizer trim mechanism
- stabilizer servo-control mechanism
- stabilizer position indicator
- auto-pilot control
- aircraft control components
- flight altitude control instruments
- flight speed control instruments
- climb (descent) speed control instruments
- flap position indicator

There was no evidence of defect or failure in the units and instruments tested which might have caused the accident.

2.- Analysis and Conclusions

2.1 Analysis

- Pre-flight preparation of the crew and aeroplane was conducted in accordance with applicable standards. No defects were discovered on the aircraft. The flight took place along the prescribed routes and at the prescribed heights up to the vicinity of the "L" beacon. During the flight the crew did not report any anomalies or difficulties.

- In the crash itself 66 persons died, 18 were injured and 16 escaped unhurt. Except for four stewardesses, the crew survived the accident.

- The aircraft was completely destroyed.

- Approach lights to Runway 25 were damaged.

- All crew members possessed the requisite qualifications, held valid licences and were in good health.

- The aircraft carried a valid Certificate of Airworthiness and had been maintained in accordance with applicable instructions and technology. The aircraft had not undergone any modifications during its operating life and all reported defects had been corrected.

- Neither the take-off nor landing weights were exceeded. The centre of gravity was within permitted limits.

- Fuel of the approved type was used.

- No dangerous meteorological phenomena were forecast or reported by aircraft during the flight and approach to land. Prior to landing, the flight was conducted in visual meteorological conditions. The wind and temperature gradient values in the atmospheric layer up to 100 m above the ground did not preclude the possibility of turbulence in the final approach area.

- The radio aids to navigation on the air route and at the aerodrome were working normally.

- Contact between the aircraft and ATC units were normal.

- No failure of radio aids occurred at the aerodrome during the aircraft's flight and approach. All facilities were operating normally within prescribed tolerances.

- The flight recorders were operating and were sent for expertise after the accident.

- No part of the aircraft became detached prior to impact with the ground. Fragments of the aeroplane were scattered over a distance of 320 m ahead of the runway threshold.

- Fire broke out immediately after the right wing struck the ground; it was extremely fierce and spread rapidly. After the aircraft turned over, the fuel began to enter the fuselage and fed the fire inside and outside the fuselage. Rescue and fire fighting operations commenced immediately (120 seconds) after the crash.

- During rescue operations 34 persons were extricated from the wreckage. According to passengers' statements, the work of rescue and evacuation was complicated by the design of the seat belt locking mechanism.

2.2 Conclusions

a) Findings

The following can be ruled out as probable causes of the accident:

- preparation of the crew and aircraft for the flight

- qualifications and medical fitness of the crew

- the technical condition of the aircraft, its weight and centre of gravity, and the fuel used

- the en-route meteorological conditions during the flight

- the radio aids and technical facilities en route and on the aerodrome, and the work of the ATC units

- external interference.

b) Cause or Probable cause(s)

Owing to the high degree of destruction and total disintegration of the aircraft in the crash and ensuing fire it was not possible to establish the precise cause of the accident. The influence of unexpected atmospheric turbulence during the aircraft's final approach cannot be entirely ruled out.

ICAO Ref.: AIG/019/73

No. 6

Balkan-Bulgarian Airlines, IL-18, LZ-BEM, accident at Moskva/Sheremetievo, USSR, on 3 March 1973. Report not dated, released by the Deputy Minister of Civil Aviation of the USSR

1.- Investigation

1.1 History of the flight

On 3 March 1973, IL-18 LZ-BEM, belonging to the Balkan-Bulgarian Airlines, was on a scheduled passenger flight No. 307 Sofia-Moscow/Sheremetievo. The aircraft took off from Sofia Airport at 0613 GMT.

Pre-flight service maintenance of the aircraft at Sofia Airport was performed by Balkan Airlines personnel in accordance with the current technical regulations of the airline. Pre-flight briefing of the crew took place at Sofia Airport in accordance with current airline regulations. All the necessary meteorological information and documents were supplied to the pilot-in-command. The flight plan and decision to take-off were signed by pilot-in-command. Pre-flight preparations were conducted under the supervision of the Deputy Detachment Commander. The meteorological conditions (forecast and present weather at intended destination), on the basis of which the crew decided to take-off, were within the prescribed aerodrome and airline operating minima.

The flight from Sofia to the vicinity of Sheremetievo Airport took place in accordance with the flight plan. At 1227:53.5 local time the crew made contact with the Sheremetievo controller. At 1228:34.0 the crew was given the landing conditions, which were within the official airport minima, although icing was noted in the clouds. The landing runway was in a normal state of serviceability. The coefficient of friction was 0.34. The radio and lighting systems, as well as the airport radiocommunications, were functioning in accordance with current regulations and no reports had been made on them on 3 March 1973.

At 1229:20.2 the crew was cleared for a straight-in approach to Runway 07, but owing to deviations from the glide path and course line a missed approach was carried out.

At 1244:03.3 contact was made with the Sheremetievo landing controller.

At 1244:5.13 the crew was given distance from runway 8.5 km by the controller and cleared to descend to 200 m at the outer marker.

At 1245:29.8 the controller reported to the crew that they were 5 km from the runway and 15 m below the glide path.

At 1245:39.0 contact with the crew was lost. The aircraft began to lose height rapidly, went into a nose dive, crashed to the ground, disintegrated and caught fire.

The accident occurred at 1245:50 local time (0945:50 GMT) in daylight flight conditions.

The aircraft struck the ground 4 330 m before the runway threshold and 70 m to the right of the extended centre line on a magnetic heading of 068°. The elevation of the accident site was 187.75 m (2.25 cm below the level of the runway).

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	8	17	–
Non-fatal	–	–	–
None	–	–	

1.3 Damage to aircraft

First contact with the ground was made by the nose of the fuselage at an angle of 90°; complete disintegration followed and fire broke out.

ICAO Note: Paragraphs 1.4 to 1.16 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

On its first approach the aircraft entered the outer marker zone at an altitude of 250 m and the crew decided to execute a go-around. This fact was confirmed by the flight data recorder read-out and the radiocommunications between the crew and the TWR controller.

The second approach, executed in clouds, was normal up to a point about 5 km from the runway, with the landing gear extended, 30° of flaps and at speeds consistent with the actual landing weight.

On reaching the outer marker the aircraft was 50 m below the glide path and, in order to intercept the latter, the crew executed a manoeuvre which consisted in first increasing, and then reducing, the pitch angle. In the latter phase, the g-loading went down to 0.6 - 0.5. The elevator angle at the time was about 8° down.

Thereafter, the motion of the aircraft was characterized by a continuous increase in the negative pitch angle culminating in a steep nose-dive. In the course of 0.5 seconds, the elevator angle changed from 8° to full nose down (15°).

The motion of the aircraft during this phase was derived from:

- the parameters recorded by the flight data recorder;
- the mode of collision between the aircraft and the ground and the destruction of the former;
- mathematical calculations of the aircraft's actual flight path;
- the testimony of several witnesses who observed the aircraft after it had emerged from the cloud bank.

During the investigation, the Commission considered the following hypotheses for the steep dive assumed by the aircraft. After careful study they were rejected:

a) Disintegration of the aircraft in flight

Despite careful inspection of the area overflown by the aircraft prior to the collision with the ground, no aircraft parts were found on the ground. The state of destruction of the aircraft components points to the absence of any damage prior to impact.

b) Failure of pitch control

Investigation of the pitch control system components broken by the impact, taken in conjunction with the analysis of the flight parameters recorded by the flight data recorder, precluded the possibility of linking the cause of the accident to any anomaly in the pitch control system.

c) Failure of the powerplant accompanied by negative thrust in the propellers

This hypothesis is precluded by the following:

- the flight data recorder read-out did not show any marks of negative thrust or anomalies in the propeller control system which would appear in such cases.

- at impact, all engines were working with 38^{o} positive thrust on the fuel lever position indicator, as was established from investigation of the powerplant.

d) Spontaneous or inadvertent switching on of the autopilot

The flight data recorder read-out showed that the crew disconnected the autopilot prior to let-down and that it remained disconnected thereafter.

The disconnexion of the servo-units, discovered during investigation of the autopilot components, can only be explained as action undertaken by the crew in an effort to extricate themselves from the prevailing emergency.

e) Violent, deliberate manoeuvre of the aircraft to avoid a bird strike

According to the findings of an expert of the Academy of Sciences of the USSR, there were no concentrations of migratory birds in the cloud cover, in the area and at the flight level of the aircraft.

At the time of the aircraft's manoeuvres in the vicinity of Sheremetievo Airport icing prevailed in the clouds.

This is clear from:

- analysis of the atmospheric data;

- the weather forecast issued to the airport ground services;

- the testimony of flight crews who had flown in the vicinity of Sheremetievo Airport around the time of the accident.

The results of numerous flight tests and investigations of the IL-18 submitted to the Commission showed that the aircraft's stability and controllability characteristics ensure a reliable margin of safety in all flight regimes and all deviations from normal conditions compatible with those that can occur in actual operation.

To maintain these characteristics in flight with the stabilizer iced up (to cater for outage for the stabilizer de-icing mechanism), the aircraft operating manual provides for partial extension of the flaps during approach (15°).

These recommendations are confirmed by the results of flight tests in natural icing conditions and with simulated ice on the stabilizer.

The nature of the fluctuations in the aircraft motion parameters and piloting characteristics recorded by the flight data recorder warrants the belief that these flight parameters could occur in the presence of an adverse combination of pitch manoeuvre and full (30°) flaps, provided that ice was present on the stabilizer leading edge.

2.2 Conclusions

a) Findings

The flight training and experience of the pilot-in-command and other crew members and their qualifications and ratings for IL-18 operations, particularly on the Sofia-Moscow route, satisfied the requirements of Balkan Airlines.

Their medical fitness and duty/rest schedule also satisfied the current requirements of Balkan Airlines and could not have had an adverse effect on the flight.

The aircraft was airworthy and neither its technical status nor its flight documentation could have been a reason for the accident.

The aircraft's load and trim were within prescribed limits.

The atmospheric conditions in the vicinity of Sheremetievo Airport at the time of the aircraft's arrival accorded with the aerodrome minima and the crew minima establish by Balkan Airlines.

The radio and lighting aids to landing and radiocommunications facilities at Sheremetievo Airport were functioning correctly, in accordance with current regulations.

ATC had duly supplied the crew with all the necessary information concerning approach conditions, including the presence of icing in the clouds, as well as the necessary operational data concerning the circuit and descent-to-land flight path parameters.

No fire, explosion or disintegration of the aircraft in flight occurred prior to collision with the ground.

The second approach was performed normally up to a point approximately 5 km from the runway, after which the aircraft went into a steep dive.

Up to the time of impact with the ground the aircraft's configuration was characterized by extended landing gear, 30° flaps, all engines functioning.

The accident was not the consequence of failure of pitch control, engine outage or spontaneous or inadvertent switching on of the autopilot.

It is unlikely that the accident resulted from a manoeuvre to avoid a bird strike.

After the accident occurred, all emergency measures at the disaster site were taken.

b) Cause or
Probable cause(s)

The accident occurred during a second approach when the aircraft was descending along the glide path.

The Commission considered that the most probable cause of accident was an adverse combination of the following factors:

- icing of the stabilizer (probably due to lack of heating in the leading edge);

- a pitch manoeuvre executed to correct a deviation from the glide path which resulted in a g-loading of 0.6-0.5;

- extension of the flaps to the full landing setting, which had the effect of degrading the airflow over the lower surface of the stabilizer and, consequently, of producing loads on the control column which promoted a further increase in the negative g-loading and prevented recovery of the aircraft from the developing nosedive.

Owing to the destruction of the aircraft it was not possible to check the actual functioning of the stabilizer de-icing system.

ICAO Ref.: AIG/034/73

No. 7

VARIG, Boeing 707, PP-VJZ, accident near Paris/Orly, France, on 11 July 1973. Report, dated December 1975, released by Secrétariat d'Etat aux Transports, France.

1.- Investigation

1.1 History of the flight

On 11 July 1973 Boeing 707 PP-VJZ of VARIG was on scheduled flight RG 820 from Rio de Janeiro to Paris. The aircraft took off from Galeao Airport at 0303 hours at a weight of 326 700 lb, including 117 passengers and 17 crew members. Flight level 330, its cruising level, was reached at 0350 hours and the flight proceeded at a March number of about 0.8. At 0626 hours the aircraft climbed to FL 370 and at 1153 hours to FL 390; the cruising flight was completed at FL 350. At 1340 hours, when the aircraft contacted the Paris western terminal sector ACC it was descending towards the Chartres (CHW) VOR, which it estimated at 1352 hours. At 1343 hours it was passing FL 230 and at 1346 hours FL 170. At 1350 hours Paris ACC instructed the aircraft to turn slightly to the right, which by-passed CHW, and cleared the aircraft for a continued descent to FL 100 which was reached at 1352 hours, then to FL 80, which was reached at 1355 hours. At that time the aircraft was flying towards Toussus (TSU) VOR. At 1357 hours, VARIG 820 was transferred to Orly approach, which it contacted one minute later. The aircraft was instructed to maintain FL 80 and to head for OLS, which would take it to the downwind leg of Orly Runway 26 in use. Meteorological conditions were excellent, so that an IFR approach procedure was not required.

At 1358:20 hours it reported "problem with fire on board" and requested an "emergency descent". According to the pilot-in-command, this request followed a report by cabin personnel of smoke at the rear of the passenger cabin. At 1359 hours the aircraft was cleared to descend to 3 000 ft for a landing on Runway 07, from which it was then only 22 NM away, allowing for a direct approach. In reply to a request by control, the pilot reported "total fire" at the time when the radar was guiding the aircraft to 07 centre line 10 NM from the threshold. According to the crew this message was prompted by the alarming announcement of the chief steward, who stated that the situation was becoming more and more serious, that the smoke had invaded the cabin and that passengers were being asphyxiated. At about this time smoke was smelled in the cockpit.

At 1401:10 hours the aircraft was cleared to descend to 2 000 ft, the acknowledgement of this clearance being the last message received from the aircraft. The transponder code appeared for about another minute on the Orly radar screen. The crew members put on oxygen masks and anti-smoke goggles, but then there was so much black smoke in the cockpit that the pilot could no longer see the instruments and the side windows were therefore opened. The pilot-in-command then decided that, in view of the untenable situation, a forced landing was necessary. This was carried out at 1403 hours, the pilot looking at the ground through the side windows.

Witnesses saw the aircraft just before its forced landing and noticed a trail of smoke escaping from the underneath of the rear fuselage. The site selected for the forced landing, on a heading of 230° from the threshold of Runway 07 and 5 km from it, consists of level ground used for market gardening south of the hamlet of Saulxier (community of Saulx-les-Chartreux, Essonne); the average elevation is 76 m.

The aircraft landed with the gear down and the flaps partly extended at a heading of about 080°, slightly banked to the left and with a considerable nose-up attitude. It touched down immediately beyond a small road, having truncated a few small fruit trees. The impact was very hard and the left landing gear collapsed, immediately followed by the right landing gear. The aircraft then slid on its engines and then on its belly for almost 500 m. The asymmetric loss of its main landing gear and the initial left bank caused a skidding movement which increased until the aircraft came to a final stop. The aircraft came to rest on a heading of 280°, having lost all its engines and half the left wing; the fuselage sustained little damage, only the fairings at the rear of the main landing gear wells being deformed. According to eyewitnesses the only evidence of the fire when the aircraft had stopped was smoke issuing from the right of the fin root.

Ten occupants abandoned the aircraft by their own means: four via the cockpit right window, four via the left window, one via the left front "passenger" door and one via the front right "galley" door. Of these ten survivors, all flight crew members, two (the pilots) were seriously injured, one by a tree branch which pierced the front pressure bulkhead during the skid along the ground, the other affected by inhaled smoke.

These survivors were quickly joined by farmers who witnessed the crash, but intervention was impossible because of the fire which broke out inside the cabin and prevented access. When the firemen arrived, six to seven minutes after the crash, the fire had burned through the upper part of the rear fuselage. The aircraft was filled with smoke and there was no sign of life. The firemen evacuated four unconscious occupants via the front door; only one survived.

A fire broke out in the right wing between the pylons of engines 3 and 4 shortly before the arrival of the firemen, but this fire did not spread. The right and left wing root fuel tanks and the central tank did not catch fire, but fire broke out in the rear hold almost one hour after the crash.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	7	116	-
Non-fatal	10	1	-
None	-	-	

1.3 Damage to aircraft

The aircraft was completely destroyed, with the exception of the equipment in the electronics compartment, which could be recovered.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

Location of the origin of the fire

Examination of the wreckage revealed that the area in which the fire originally started and developed was the area of the pressurized cabin located above the cabin floor and aft of the tourist class galley, i.e. in the area occupied by the three aft toilets, the coat closet and the central corridor which provides access to them. This as well as other observations made, eliminates the possibility of a fire in the hold. Similarly, the assumption of a fire fed originally by fuel or hydraulic fluid was considered unlikely because of the location of the systems and the checks made after the accident.

Although as a result of witnesses' statements research was concentrated in the toilets themselves, the possibility of a fire in the space between the ceiling of the pressurized section in the critical area defined above and the fuselage was considered. Some electric wiring passes through this space parallel to the aircraft centre line and on either side of the plane of symmetry. The only wires carrying appreciable power are those which feed the tailplane motor. The servo-trim motor, which runs constantly as long as the automatic pilot is in use, takes 3 amperes per phase at 115 V. The manual control trim motor takes 15 amperes per phase at 115 V when the pilot operates the control column switches. This motor is used intermittently and for a few seconds at a time. The pilots reported no trouble with the elevator trim during the initial descent. Moreover, no previous case of short circuit involving this wiring had been reported in this type of aircraft.

In addition, bearing in mind the distance of this wiring from combustible elements which could have propagated the fire and the fact that the characteristic smell of overheated electrical insulation had not been reported, the Commission considered it most unlikely that the fire had started in the false ceiling at the rear of the cabin.

With regard to the discovery of the smoke two accurate and concordant statements were available from two eyewitnesses. When their attention was drawn to the port toilet, no flames were visible. At the most the smoke filled the top third of the toilet and did not appear to come from a particular area. The toilet was gradually filled with smoke, but its source could not be located. Two hypotheses can be made:

- the fire started in the left toilet;
- the fire started in an adjacent area and developed unbeknown to the occupants. It was detected when smoke penetrated into the left toilet. This toilet is adjacent to the coat closet on one side and the aft right toilet, which is symmetrical to the left toilet.

The coat closet consists of two partitions perpendicular to the aircraft centre line and backs onto the left side of the fuselage. It is only separated from the central corridor by a curtain. It is equipped with an air inlet located at half the height of the fuselage wall. This ventilation is taken from the passenger cabin. Any smoke produced in the coat closet can therefore only spread into the cabin and not into the neighbouring toilet. It follows that the fire did not start in the coat closet but in one of the two aft toilets.

Study of the fire risk and propagation conditions in the aft toilets

Since the two aft toilets are identical the study of the fire risk in one applies to the other as well. The furnishing materials used are not non-flammable. American regulations specify that they should not easily propagate fire but there is no requirement concerning the emission of smoke. According to the manufacturer these materials comply with Standard CAR 4B-381 in force when the aircraft was taken into service. Nevertheless, an ignition test carried out with a waste disposal lid taken from a forward toilet, which had sustained little fire damage showed that this element was easily ignitable.

However, the paper, of which a large quantity is present in the form of towels, napkins, seat covers, etc., rather than the furnishings, represents the major fire risk. The aft toilets contain three main paper supplies:

a) the cupboard located against the aft pressure bulkhead. No electric circuit passes through this space. It is made up of a sheet metal case of which the front can be hinged downwards and contains a slot for extracting seat covers. This cupboard is separated from the water-closet unit by a space which is normally empty;

b) the towel dispenser located above the washbasin against the fuselage wall, half way between the tip of the basin and the toilet ceiling. No electric circuit passes through it. The dispenser side panel is bulged in shape and has several openings in which various products are located;

c) the washbasin unit, of which the inside acts as disposal container. The casing of this unit is partly sheet metal, partly wood. The rear face against the fuselage wall is sheet metal and has openings through which the electric wires, the air supply for the individual vent and the waste water drain of the toilet pass. This rear face is backed by a metal sheet attached to the fuselage frames and which continues the inner fuselage lining in the toilet. The sides and top of this unit are made of chipboard and the front of wood covered with plastic. The top, back and basin itself of the washbasin are made of a stainless steel sheet. A perforated central partition divides the unit into two compartments.

A cabinet containing the electric connexions, an electric control box and the water heater surrounded by a protecting sheet are located underneath the basin. In addition this space is used as a towel disposal container. The towels are normally pushed through a trap door above the back of the washbasin and accumulate below the basin. There is no actual bin, presumably because of the piping and wires which cross the area, but only a pan 15 cm deep which lines the bottom of this compartment. A neighbouring compartment is taken up with the sheet metal drawers for the air sickness bags, which are introduced through trap doors in the front of the unit and removed from the other compartment. There is no electric installation in this second part of the washbasin unit which does in fact continue as far as the pressure bulkhead.

The presence of reinforcing plates against the frame to which the pressure bulkhead is attached creates a horseshoe-shaped space, common to the two toilets, which cannot be used; it extends from the floor of the left toilet to the floor of the right toilet via the ceiling of the two. This space is closed off from the toilets by a light wooden panelling covered with plastic. Near the ceiling it is pierced by the wiring mentioned earlier, which continues into the tail cone. The only equipment in the area is the passenger PA loudspeaker at the side. The washbasin unit partition forms a dividing wall with this space and has in it a hole approximately 15 cm in diameter.

The fire risk is all the greater because easily inflammable substances are close to a possible hot point. The hot points in question are either electrical or the result of human carelessness, such as the discarding of a cigarette end. Previously reported electrical troubles in B-707, other than the problem of the heater jacket discovered after the accident to PP-VJZ, concern the following points:

- Razor socket supply
- Mirror strip lighting supply
- Water-closet flushing motor supply.

Except for the razor socket wiring, these circuits are away from readily inflammable substances.

An examination of the location of inflammable substances reveals that the three supplies of paper are not subject to the same fire risk. It seems difficult for the two paper dispensers to be ignited electrically. Although a cigarette end can easily be thrown into the dispenser above the washbasin, this is far more difficult in the case of the dispenser above the water-closet. Moreover the stacking of the paper in the dispensers does not promote combustion.

In contrast the space used for towel disposal combines all the conditions for a cigarette end or an electrical fault to start a fire, the extent of which will depend on the accumulation of paper. In the present case, a long flight (11 hours) with the tourist class almost full (97 passengers for 109 available seats), it could well be assumed that the disposal container was full. The long flight also suggested that many of the used towels had time to dry out. The atmosphere already very dry during cruising, is furthermore heated in the washbasin unit by thermal losses from the water heater.

Checks after the accident to PP-VJZ revealed that disposal containers fairly often contained cigarette ends. This seemed to indicate that the ashtray in the front face of the washbasin unit was not sufficiently obvious. In conclusion the fire risk was classified as follows:

- Dispenser above water-closet: slight risk
- Dispenser above washbasin: moderate risk combined with passenger carelessness.
- Towel disposal space: high risk, both as a result of carelessness by a passenger and an electrical defect.

During pressurized flight air circulation in the toilet is as follows: air enters partly from the individual air outlet, partly from the ceiling and partly from the central corridor. The air is extracted from an opening near the toilet seat and is evacuated directly to the atmosphere.

If there is a fire in one of the dispensers, their design not only prevents the smoke from escaping elsewhere than into the toilet but the air system will only return it to the toilet. It should be added that the air system will not promote the fire during its initial phase.

Fire in the washbasin unit will have different characteristics. The volume of air in the unit and the crumpling of the paper will spread the fire very rapidly; it is likely to develop in three directions:

- upwards towards the waste disposal slot
- sideways towards the box containing the loudspeaker
- downwards if the plastic washbasin drain pipe (which is depressurized) is pierced.

Moreover, the hose which connects the individual air outlet to its supply pipe is made of flexible rubber. This is likely to burn through very quickly, thus creating a supply of air directly on to the fire.

Discussions and hypotheses adopted

First hypothesis: fire in the left toilet.

The fact that a female passenger came out of the left side toilet revealed that the escape of smoke was recent, otherwise she would not have entered. If the smoke originated in this toilet it means that the fire had only just started. If the fire originated in one of the dispensers it is difficult to understand why it could not be localized and why no flame appeared soon afterwards. It is more likely that the smoke came from a fire in the washbasin unit. The presumed disconnexion of the "return to seat" circuit would confirm this hypothesis.

One of the few objective indications was the fact that the recorder stopped; its supply passes through the starboard toilet ceiling, then into the unused space common to the two toilets above the water-closet.

For the electrical circuit to be interrupted by a fire in the left toilet, an interruption which occurred almost at the same time as the crew reported fire on board to the ATC services, it was necessary for the fire to have progressed very rapidly in the unused space and to have damaged the wiring. This would seem doubtful since in this area there are few easily combustible materials and air circulation is limited as long as the walls of this space have not disappeared.

Second hypothesis: fire in the right toilet.

Survivors reported that the right toilet door was closed when the smoke was discovered and that nobody had opened this door afterwards. There is no doubt that during pressurized flight and as long as there is not too much smoke, no smell and even more so no smoke will be evident in the cabin during the initial stages of a fire in a closed toilet. The time factor, which is especially troublesome in the case of the hypothesis of a fire in the left toilet, is not troublesome in the hypothesis of a fire in the right toilet.

Tests with the forward toilet partitions, which are of the same type, revealed a good resistance to fire. It is therefore possible that when smoke filtered into the left toilet, the fire on the right side had already developed appreciably. The ceiling of this toilet is not very resistant to fire. It can be assumed that the fire was already propagating in the false ceiling and this would also provide a better explanation for the interruption of the recorder. The fact that little heat was radiated into the left toilet tends to support this hypothesis.

The sudden appearance of smoke in the central corridor between the toilets could correspond to a failure of the ventilation ducts which supply the air outlet in the ceiling of this corridor.

Propagation of the fire forward can be explained by the presence of life-saving equipment above the galley area and the moulded plastic cabin ceiling.

Although the hypothesis of a fire which originated in the left toilet cannot definitely be excluded, it is more likely that the fire started and developed in the aft right toilet, probably in the washbasin unit.

Crew actions

The Flight Engineer, who was not on duty at the time the smoke was discovered, played an important role in the fire fighting by the cabin crew and in the measures taken by the flight crew in attempting to prevent spreading of the fire.

Although the cabin crew quickly used extinguishers, this was not effective because the source of the fire was never located.

The hypothesis of an electrical defect was plausible. Switching off the toilet circuits, followed by the non-essential supply, was therefore logical.

Increasing cabin altitude is the recommended method for accelerating the evacuation of smoke; this was carried out.

In spite of this the smoke continued to propagate but its progress in the cabin was not regular and logically prompted the suspicion of trouble in the air-conditioning system. Examination of the wreckage revealed that the emergency procedure in the case of smoke emission from the air-conditioning system had been initiated.

The rapid sequence of events prompted the flight crew to partly implement various procedures in succession which, since they involved different hypotheses, were not really coherent. Nevertheless, the actions of the flight crew were sound.

The decision by the crew not to release the passenger oxygen masks was specially investigated. Besides the fact that the toilets are also equipped with masks, whose output would have worsened the situation, the use of the masks would not have protected the passengers against carbon monoxide poisoning, since these masks supply a mixture of pure oxygen and ambient air. Instructions therefore justifiably preclude the use of oxygen in the case of smoke.

Tests carried out by Boeing showed that opening the cockpit side windows does not improve the situation in the cockpit in the case of smoke which originates in the fuselage. It was admitted, however, that at the time when the windows were opened, the density of smoke in the cockpit was such that the instruments could no longer be seen. Nevertheless, this action enabled the aircraft to be piloted visually and thus made the forced landing possible.

Medical findings

Carbon monoxide coefficients equal to or exceeding 0.66 were sufficient by themselves to explain the death of 78 per cent of the victims. A carbon monoxide coefficient between 0.50 and 0.60 represented a possible although not certain cause of death for 9 per cent of the victims. Finally, in 13 per cent of the cases left the coefficient below 0.50 did not justify death by carbon monoxide poisoning. The probable cause of death in these cases was an inhibiting reflex prompted by hydrofluoric or hydrochloric acid.

The poisoning level was especially high for those passengers known to have been sitting at the rear of the cabin. Two passengers had a coefficient of 0.78 and a carbon monoxide content in the blood of 140 ml per litre. In contrast the poisoning level in the blood of the Flight Engineer, who was killed instantly in the cockpit, showed a poisoning coefficient of 0.37 and a carbon monoxide content in the blood of 90 ml. An intermediate although still fatal poisoning coefficient was found in a body which was discovered in the first class galley; the victim was probably still breathing after the crash (0.66 and 130 ml of carbon monoxide).

It should be stressed that the affinity of haemoglobin for carbon monoxide is far higher than that for oxygen. In the presence of a gaseous mixture which comprises 220 volumes of oxygen and 1 volume of carbon monoxide, haemoglobin will fix these two gases half and half. When the mixture has saturated, the haemoglobin analysis will reveal half carboxyhaemoglobin and half oxyhaemoglobin. The presence of 1 volume of carbon monoxide to 500 volumes of air (1/500 carbon monoxide in air) causes death within a few hours. The presence of 1 volume of carbon monoxide to 20 volumes of air (1/20 carbon monoxide) causes death in 15 minutes.

The carbon monoxide poisoning coefficient of Nicloux and Balthazard corresponds to a saturated ratio carboxyhaemoglobin/haemoglobin.

A poisoning coefficient between 0.10 and 0.20 produces slight breathing difficulty.

A coefficient of 0.30 causes headaches.

A coefficient between 0.30 and 0.40 causes nausea and dizziness.

A coefficient between 0.40 and 0.50 results in fainting.

A coefficient of 0.50 and 0.60 causes convulsions.

Coma and death result above 0.60.

2.2 Conclusions

a) Findings

The aircraft held a valid Certificate of Airworthiness and had been maintained in accordance with the regulations in force. The structure of the aircraft, its controls and control surfaces, its engines, its mass and trim had no bearing on the accident.

The crew held the licences and ratings required for the flight in question.

During the approach a fire broke out in the cabin in the area of the aft toilets.

Although the crew took action as soon as smoke was discovered, its intervention was not effective because the origin of the fire could not be located.

The smoke propagated very rapidly and made the situation so untenable that the pilots decided to make a forced landing 5 km from the runway threshold. The aircraft was destroyed by fire on the ground, in spite of the prompt intervention by fire fighting personnel.

No prior defect likely to explain the start of the fire was found in the aircraft equipment. There was no evidence of foul play.

Nothing suggests that the cabin furnishing material did not comply with the manufacturer's specifications.

Nevertheless there is some doubt whether the Boeing specifications comply with Standard CAR 4B. Indeed, some of the samples taken from the cabin were readily combustible and the waste towel disposal containers did not meet the requirements of CAR 4B 381, paragraph d); in fact they were not able to prevent the development of a possible fire.

The forced landing was as successful as circumstances permitted. The deceleration involved could easily be withstood by any occupant normally secured. Only one member of the flight crew, who was not wearing a safety belt, was killed by the impact.

Although the doors and exits were not jammed, only the occupants of the cockpit and two stewards located forward in the cabin were able to abandon the aircraft by their own means.

Analyses carried out showed that a major proportion of the deaths were caused by carbon monoxide poisoning. Tests made on the body of the engineer killed by the impact confirm that at that time the carbon monoxide poisoning of the occupants was sufficient to prevent physical action.

The proportion of deaths due to carbon monoxide poisoning exceeded 75 per cent; most of the other deaths were apparently caused by the effect of inhaling other toxic gases.

b) Cause or
Probable cause(s)

The probable cause of the accident is a fire which appears to have started in the washbasin unit of the aft right toilet. It was detected because smoke had entered the adjacent left toilet. The fire may have been started by an electrical fault or by the carelessness of a passenger.

The difficulty in locating the fire made the actions of cabin personnel ineffective. The flight crew did not have the facilities to intervene usefully from the cockpit against the spread of the fire and the invasion of smoke.

The lack of visibility in the cockpit prompted the crew to decide on a forced landing. At the time of touchdown the fire was confined to the area of the aft toilets. The occupants of the passenger cabin were poisoned, to varying degrees, by carbon monoxide and other combustion products.

After the aircraft came to a stop the fire worsened and spread towards the front of the aircraft, so that neither the crew members, who themselves were injured or intoxicated, nor the first witnesses were able to evacuate the passengers.

3.- Safety recommendations

The accident to PP-VJZ was the second public transport aircraft accident in France resulting from a fire in the toilet unit. The first was on 11 September 1968 when a French aircraft crashed into the sea off Nice under similar circumstances causing the death of its 92 occupants.

During the years before the VARIG accident and afterwards an appreciable number of cabin fires were reported, many of which had started in the toilets. These cabin fires involved various types of transport aircraft, including wide-bodied aircraft. In some cases events resulted in a critical situation and at other times catastrophes were only just avoided. This prompted the Investigation Commission to formulate some recommendations in the "Subsequent Notification" submitted to ICAO in September 1973.

These recommendations concerned the following:

- reduction of the fire hazard to a minimum, especially in the toilets, by eliminating or neutralizing sources of ignition;

- the systematic supervision of closed spaces such as the toilets;

- enforcement of the smoking prohibition in the toilets;

- the regular checking of these facilities.

Studies were also initiated in France and in other countries with a view to selecting cabin furnishing materials which are fire resistant and do not emit toxic gases or large quantities of smoke. These studies should be actively pursued so that appropriate standards can be drawn up as soon as possible. In the meantime, the results of such studies should be widely circulated to national authorities, manufacturers and operators.

In the meantime, the Commission recommends that the following measures be adopted immediately, either to reduce the fire hazard or to limit the consequences of a fire:

1. Reminder of the smoking prohibition as soon as passengers embark and careful monitoring by cabin personnel to ensure that this is complied with.

2. Provision of very obvious ashtrays both outside and inside the toilets, together with obvious "No smoking" signs.

3. The use in aircraft of non-inflammable waste bins, preferably metal, of a shape designed to limit the propagation of an internal fire, of a sufficient capacity and perfectly adapted to the opening in the washbasin unit in order to prevent paper towels or other inflammable objects from falling outside the bin.

4. The provision of an adequate number of readily accessible fire extinguishers effective against all types of fire, including electrical ones, and of easily used tools to obtain access to fires through partitions.

5. The provision of a sufficient number of full-face oxygen masks for cabin personnel.

6. The inclusion in safety manuals of instructions for the supervision of toilets and other areas not used during the climb or descent phases and period of night rest of the passengers.

7. The experimental study and inclusion in operating manuals of smoke evacuation procedures adapted to each type of aircraft and to every situation, as well as measures to be taken to prevent the cockpit being invaded by smoke.

8. The elimination, especially in the toilets, of readily inflammable objects and products (alcoholic products, etc.).

9. Instructions to personnel on the dangers of cabin fires, even limited ones, and on the importance to act on the fire itself without delay, and training for this personnel in fire fighting and emergency procedures in a smoke-filled atmosphere.

10. Check of the facilities and fire fighting equipment at specified intervals.

Following the accident at Saulx-les-Chartreux, most of the recommended measures have been made mandatory by many national authorities.

The Commission considers that smoke or heat detectors should be fitted inside toilets and at certain points in the false ceiling of the cabin and that washbasin units should be equipped with automatic extinguishers, of which efficient and compact models are available.

Special attention should be paid to the design and adjustment of equipment which consumes appreciable electrical power, such as water heaters, etc. The electrical supply to this type of equipment should be kept well away from combustible materials.

Finally the Investigation Commission stresses the need for a reliable communication system and efficient operating instructions for the rapid transmission of safety communications between the flight crew and cabin personnel and vice versa, especially in wide-bodied aircraft.

ICAO Ref.: AIG/219/73

No. 8

Delta Air Lines, DC-9-31, N-975NE, accident at Boston/Logan, U.S.A., on 31 July 1973. Report No. NTSB AAR-74-3, dated 7 March 1974, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

On 31 July 1973, Delta Air Lines, Inc., Flight 723, a Douglas DC-9-31 (N-975NE), was a scheduled passenger flight from Burlington, Vermont, to Logan International Airport (BOS), in Boston, Massachusetts. An unscheduled stop was made at Manchester, New Hampshire, to pick up passengers who were stranded because an earlier flight had been cancelled because of weather. Flight 723 was a continuation of Flight 524, which had originated at BOS earlier the same day.

The flight departed the airport gate at Manchester, New Hampshire, at 0957[1/], with 83 passengers, 5 crew members, and a cockpit observer on board. After several delays, due to weather conditions at BOS, the flight was cleared to BOS on an instrument flight rules flight plan, and departed at 1050. From take-off at Manchester until the time of the crash, the co-pilot in the right seat piloted the aircraft, and the pilot-in-command handled air-to-ground communications.

At 1051:22, Boston Approach Control (AR-1) cleared the flight to the Lawrence, Mass., VOR[2/] advising, "... no delays, plan vectors ILS[3/] four right, the Boston altimeter is three zero one one. Weather is partial obscuration, estimated four hundred overcast, mile and a half and fog".

Flight 723 acknowledged the clearance from AR-1 at 1051:32, and climbed to an assigned altitude of 4 000 ft[4/]. During the climb, the cockpit observer[5/] called out the after-take-off check-list challenges, and the pilot-in-command responded.

At 1054:25, the flight advised BOS AR-1, "Delta seven two three approaching Lawrence", after which AR-1 told the flight, "Seven two three roger, fly heading now one eight zero, radar vectors ILS four right". The flight acknowledged the clearance and complied.

At 1055:57, the cockpit observer began calling out the challenges in the descent check-list.

At 1056:24, BOS AR-1 cleared the flight to descend to 3 000 ft. The flight acknowledged the request and complied.

1/ All times herein are eastern daylight, based on the 24-hour clock.
2/ VOR - Very high frequency omnidirectional radio range.
3/ ILS - Instrument landing system.
4/ All altitudes herein are mean sea level unless otherwise indicated.
5/ A former Northeast Airlines, Inc., captain, in the process of requalification after he was grounded for an extensive period of time because of illness.

At 1057:36, BOS AR-1 requested, "Delta seven two three, fly heading two two zero". The flight complied.

From 1058:50 until 1100:17, the cockpit observer called out the challenges in the approach check-list; the pilot-in-command responded.

From 1101:18 until 1104:07, BOS AR-1 requested four heading changes, and the flight complied.

At 1104:30, BOS AR-1 requested, "... Delta seven two three, fly a heading of zero eight zero now, intercept the localizer course and fly it inbound, over". This heading change was the final vector provided by BOS AR-1. At 1104:35, the flight replied, "Okay, zero eight zero for intercept".

About 45 seconds later, during intracockpit conversation, the pilot-in-command stated, "Localizer is alive". The co-pilot then asked, "Go down to two thousand now, can't we?" The pilot-in-command answered, "He didn't say to go down".

At 1105:39, the pilot-in-command asked BOS AR-1, "Is seven two three cleared for ILS?" BOS AR-1 immediately replied, "Yes, seven two three is cleared for the ILS, yes".

According to flight data recorder information, the approach descent was initiated at 1105:27, following the pilot-in-command's observation that the localizer was alive. The descent continued uninterrupted until the crash.

The flight path constructed from flight recorder data indicates that the aircraft had just passed the outer marker (OM) when the co-pilot called, "check-list". The time was 1106:33.5. The co-pilot's call was followed by the cockpit observer's statement: "Three green, pressure and quantity". The only other reference to items on the before-landing check-list on the cockpit voice recorder (CVR) was recorded about 1107:8, when the observer said, "Before landing ... before landing is complete".

Between 1106:43 and 1107:05, the following conversation took place between the pilot-in-command (CAM-1) and the co-pilot (CAM-2):

1106:43.5

CAM-1: Get on it Joe, ah, Sid.

1106:47.5

CAM-2: Getting down, ah thousand feet a minute.

1160:50.5

CAM-1: Leave it below one*[6/]

1107:05

CAM-2: This ##[7/] command bar shows*.

CAM-1: Yeah, that doesn't show much.

6/ * - Unintelligible word.
7/ # Non-pertinent word.

At 1107:14, BOS AR-1 stated, "Seven two three is cleared to land, tower one nineteen one". Three seconds later, the flight replied, "Seven two three".

Between 1107:19 and 1107:40, the following cockpit conversation took place between the pilot-in-command and the co-pilot:

1107:19

CAM-1: Going like a ##

1107:28

CAM-1: Okay, your localizer, startin' to come back in now.

CAM-2: Okay

1107:35

CAM-2: Set my power up for me if I want it.

1107:38

CAM-1: Okay, just fly the airplane.

1107:40 (25 seconds before impact)

CAM-1: You better go to raw data, I don't trust that thing.

Twenty-two seconds before impact, the pilot-in-command radioed the following: "... Boston, Tower, Delta seven two three, final". BOS tower controller replied, "Cleared to land four right, traffic's clearing at the end, the RVR[8/] shows more than six thousand, a fog bank is moving in, it's pretty heavy across the approach end". The flight's acknowledgement of that clearance and advice at 1107:52 was its last radiocommunication.

At 1107:54, according to the CVR, the pilot-in-command stated, "*'ll let's get back on course". The co-pilot replied, "I just gotta get this back".

At 1108:04.05, the pilot-in-command stated, "*'en out", which was followed immediately by a shout, believed to be by the cockpit observer.

At 1108:05.5, the aircraft struck a seawall about 165 ft to the right of the extended Runway 4R centre line and about 3 000 ft short of the runway displaced threshold. The impact and subsequent fire destroyed the aircraft.

The accident occurred during daylight hours. The weather was characterized by lowering ceilings and visibilities; sea fog of increasing density was moving across the airport from an easterly direction.

One witness, about 0.6 NM from where the aircraft crashed, saw it for a few seconds fly directly overhead at an altitude which appeared lower than normal. The captain of a tug boat passing within 400 yards of the impact point heard the aircraft pass overhead but was unable to see it because of the dense fog. Several other witnesses heard the aircraft pass overhead and crash but could not see it.

8/ RVR - Runway Visual Range.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	6*	82	-
Non-fatal	-	1 (Died 11 Dec. 73)	-
None	-	-	

* Includes cockpit observer.

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced.

2.- Analysis and Conclusions

2.1 Analysis

The crew members were properly certificated, trained, and qualified for the flight. Both pilots had adequate rest periods before reporting for duty. There was no indication of any medical or physiological problem that would have affected the performance of their duties.

The aircraft was certificated, equipped, and maintained according to requirements and regulations. The gross weight and centre of gravity were within prescribed limits during the take-off at Manchester and the approach to Boston.

There was no evidence of in-flight fire, structural failure, or flight control or powerplant malfunction. There was insufficient evidence to determine conclusively whether the flight director or navigation systems had functioned properly.

The pilot-in-command's altimeter indicated an altitude of 660 ft. The altitude pointer was free to rotate because the internal driving gear mechanism had separated from the pointer. Therefore, the Board concluded that this altimeter indication was not valid.

The impact mark on the face of the co-pilot's altimeter, which corresponded approximately with the impact site elevation, suggests that altimetry error was not a factor in this accident. Such a conclusion is supported further by flight data recorder information related to assigned altitudes before initiation of the final approach.

Since the aircraft's impact below the glide slope cannot be attributed to altimetry problems, the remainder of this analysis deals with the operational aspects of the approach, including air traffic control and the weather information received by the crew.

As Flight 723 was proceeding inbound toward the localizer course at the assigned altitude of 3 000 ft, the BOS AR-1 controller's attention was drawn to an aircraft, transferred to him by Boston Air Route Traffic Control Center, which was in potential traffic conflict with another aircraft at the same altitude. At a time when

BOS AR-1 should have been clearing Flight 723, as regulations require, he was trying to resolve the potential conflict and to avoid a possible mid-air collision. Consequently, an approach clearance was not given to Flight 723 until the flight crew first requested it. Subsequent communications difficulties with one of the aircraft involved in the potential traffic conflict further occupied BOS AR-1 and delayed release of Flight 723 to BOS tower control. Nevertheless, proper monitoring of the flight's progress would have provided the crew with indications that should have caused them:

1) To have been aware of their position relative to the localizer and the OM;

2) To have anticipated localizer interception outside the OM; and

3) To have reduced airspeed to that which would have been compatible with the aircraft's arrival over the OM in a stabilized condition which would have permitted the continuation of the approach and landing.

Actually, the aircraft's airspeed at the OM was about 206 kt. That speed was 46 kt above the maximum speed recommended by company procedures, and 63 kt above the minimum speed computed for the aircraft's gross weight, which was estimated at 87 000 lb. During most of the approach inbound from the OM, the airspeed was maintained well over the computed 1.3 V_s + 5 speed (about 123 kt).

The faster-than-normal airspeed during the approach, together with the delay in initiating the descent, resulted in two other problems for the crew. First, it increased the difficulty they had in capturing and maintaining the glide slope. The aircraft passed over the OM at an altitude more than 200 ft above the glide slope. At normal approach speed, the aircraft could easily have reached glide path altitude by increasing slightly the rate of descent. However, at the faster-than-normal airspeeds, a rate of descent of more than 1 300 ft per minute would have been required to intercept the glide path before reaching decision height. If the flight crew had attempted to capture the glide slope at such a rate of descent, they would have had difficulty decreasing airspeed to an acceptable approach speed.

Second, through experience and exposure to instrument approaches during instrument meteorological conditions, pilots generally learn to pace their activities while flying such an approach. The faster-than-normal airspeed of Flight 723 during the initial and final phases of its approach required the crew to act more quickly than usual.

Another factor in an approach initiated high and fast concerns the use of the flight director system. In normal use, the VOR/LOC mode of the flight director system would be selected. Operation in the VOR/LOC mode requires following the roll command bar to maintain the heading necessary to intercept and capture the localizer. Sensing the localizer signals, the command bar will command the lateral manoeuvres necessary for localizer intercept and final approach guidance. Concurrently, the system arms to capture the glide slope; after capture, pitch command information is displayed as a function of glide-slope deviation. However, the system is designed so that an aircraft operating in the VOR/LOC mode must be on or below the glide slope at the time the localizer is intercepted in order to capture the glide slope. If the aircraft is too high and the glide slope is not captured, the pilot will not have flight director pitch guidance information for the initial approach. Consequently, he cannot use the instrument to make an asymptotic interception in the VOR/LOC mode. The flight director system can accommodate an interception from above the glide slope, if the APP mode is used. Selection of the APP mode presents a fly-down command which will force capture of the glide slope.

The derived flight track and altitude profile of Flight 723 showed that the aircraft was flying well above the glide slope when it intercepted the localizer course. Thus, because of the design, if the flight director system had been in VOR/LOC, it would not have captured glide-slope signals, nor would it have displayed pitch command information. During simulation of the localizer interception, it was necessary to switch to APP mode in order to obtain pitch command information on the flight director instrument.

The Board believes that the manner in which the flight director was used during the final approach impaired the crew's awareness of their altitude.

The flight path derived from the recorded data shows an asymptotic approach to the localizer centre line, followed by a continuous deviation of the aircraft to the left of the centre line. During the simulator tests, such an interception could not be reproduced by using the flight director steering command information. In the tests, director guidance commands invariably resulted in centre line overshoot and subsequent recovery to the localizer course before the outer marker was passed. The resulting flight path would be similar to that derived from the flight recorder data, if a $2^{\circ} \not+$ correction were applied to heading information. Such an error is compatible with the evident difference between recorded heading and vector heading throughout the interception sequence. Since such an error is within the tolerance specified for the flight data recorder, the Board believes that the flight path traversed by Flight 723 was similar to that which was produced by the simulator: the aircraft passed the outer marker and tracked along the localizer centre line for another 30 seconds.

Thereafter, the flight path of Flight 723 and crew member comments recorded on the CVR indicate that the crew was experiencing problems in attempting to maintain lateral position on the localizer centre line. The first deviation from the localizer course started immediately after the pilot-in-command's comment, "Get on it, Joe, ah Sid", made at 1106:43.5. At that time, according to the flight recorder data, the aircraft's altitude was 1 600 ft, still above the glide slope; the airspeed was still excessive. The Board believes that this comment was a reference to the aircraft's position above the glide slope and that it prompted a change from VOR/LOC to APP mode in order to obtain pitch guidance information. The subsequent lateral-steering problems, however, would have been understandable only if the flight director system had been inadvertently placed in the G/A mode at that time. In the G/A mode, localizer signals are removed from the flight director system, and the roll steering command functions only to keep the wings level. Conceivably, the co-pilot might have been confused by the pitch command displayed on the flight director instrument at that time. If he had failed immediately to analyse the situation, he would have continued to obey the roll-steering signals. Simulator tests showed that such action would produce significant deviation from the localizer centre line.

Subsequent conversation by the crew indicated confusion and the realization that the flight director system was no longer providing reliable localizer or glide-slope information. Furthermore, examination of the wreckage verified that the flight director mode selector switch had been in the G/A position on impact. Since the CVR revealed no evidence that the crew had intended to execute a missed approach, it is reasonable to assume that the G/A mode was inadvertently selected earlier during the approach. In view of this possibility, the background of the crew, particularly in regard to habits previously formed, must be considered.

Before the merger of Delta Air Lines and Northeast Air Lines, these crew members were employed by Northeast and became accustomed to the Collins flight director instrumentation. After the merger and the modification programme that replaced the Collins flight director with the Sperry system, they were trained to adapt to the different instrumentation. The APP mode in the Collins equipment is selected by full clock-wise rotation of the rotary switch; whereas, the same position on the Sperry system rotary switch corresponds to the G/A mode. It is conceivable that without observing the switch, a crew might, by habit, inadvertently select the G/A mode in the Sperry system instead of the Approach mode.

During the simulator tests, investigators also found it possible unintentionally to select the G/A mode while rotating the mode selector switch to the Approach position. A very slight overshoot of the APP position detent caused the flight director to display cues associated with the G/A mode of operation. Even if the selector switch were returned to the APP detent, the system would remain in the G/A mode because of its design. If the flight crew believed that the selector switch was in the APP mode position, and in the absence of a mode annunciator panel to indicate otherwise, they would expect the system to react in the APP mode. Actually, however, the system would be reacting to a G/A situation and localizer guidance would no longer be presented. If the flight crew had recognized the incorrect status of the flight director system in such a situation, they would have obtained proper indications by turning the selector switch through the "standby" position, then back to the APP mode position. In view of the position of the rotary switch at impact, this hypothesis is discounted.

Since the investigation disclosed a history of repetitive discrepancies of the flight guidance and navigation systems, a system malfunction also was considered as the cause for abnormal flight director guidance. However, examination of the recovered system components revealed no evidence of a system malfunction in the accident aircraft.

Although there is insufficient evidence to establish the underlying cause, it is apparent that the crew was aware of an abnormal display on the flight director. At 1107:05, about 21 seconds after the pilot-in-command had told the co-pilot to "get on it", the latter commented "This # # command bar shows", and the pilot-in-command responded, "Yeah, that doesn't show much". At 1107:40, the pilot-in-command stated, "You better go to raw data, I don't trust that thing". At this point the aircraft was well to the left of the localizer and still high on the glide slope, and was passing through an altitude of 400 ft. Because conditions were not stable, it should have been obvious to the crew that, in order to continue the approach, radical heading and pitch corrections would be required to attain the proper aircraft-to-runway relationship. The flight recorder data showed continual heading changes from the time the pilot-in-command made the above comment to impact. While passing through an altitude of less than 50 ft above decision height, the aircraft was heading 20° to the right of the published approach course. Since the crew did not consider a missed approach at this point, they might have fully expected to break out of the reported weather at an altitude that would have provided a safe manoeuvring margin.

Weather information provided the flight crew when radio contact was first established with BOS AR-1 reported: "... weather is partial obstruction, estimated 400 overcast, a mile and a half and fog". Twenty-two seconds before impact the pilot-in-command called BOS tower. This call was not required, since the approach controller had already cleared the flight to land. In his response to the pilot-in-command's call, the BOS tower controller gave the flight not only a second clearance to land, but also traffic conditions and further weather information. During this transmission, the flight had approached and passed through the decision height. The radio transmission from BOS tower contained two statements that conflicted: An RVR for Runway 4 of "more than 6 000 ft", and "... a fog bank is moving in. It's pretty heavy across the approach end". This conflicting information, received by the pilot-in-command at a very critical phase of the approach, added to the distraction already existing in the cockpit.

When the RVR value of "more than 6 000 ft" was given to the crew, the actual value was already considerably less than 6 000 ft and dropping rapidly to about 1 600 ft. Because the digital displays in the tower cab cycle each 51.1 seconds following a 48.5-second computer-integrating period, there is no reason to believe that either call-out (6 000 ft or 2 000 ft) was incorrect in terms of what had been displayed. The controllers could read only the display they were observing; they had no way of knowing what the RVR at the transmissometer site was registering on a continuing basis.

An RVR value transmitted to a pilot is intended to represent runway visibility when his aircraft touches down near the ILS touchdown point. This value would represent the actual distance he could see down the runway, only if the atmosphere above the runway and above the transmissometer site were homogeneous. Often, however, the atmosphere is not homogeneous, particularly during fog conditions.

Another factor in the discrepancy is the location of the transmissometer equipment in relation to the runway. For Runway 4 on the Logan International Airport, the location is approximately abreast of the ILS touchdown point, on a 250 ft base line, and about 500 ft to the left of the runway. The RVR value from transmissometer equipment installed according to FAA's criteria, might still be misrepresentative, because fog covering the runway might not be covering the equipment and vice versa. The 51.1-second cycling time of the RVR digital display can further complicate the problem. With rapidly changing visual conditions over the runway, considerable disparity can exist between actual conditions and the values presented by the digital displays and reported to the flight crews.

Further, RVR was never intended to represent the distance the pilot expects to be able to see from the outer marker, middle marker, decision height, or over the runway threshold. Before the RVR can be representative, the aircraft must be near the touchdown point on the runway. Testimony during the public hearing revealed that not all pilots may be aware of all of the limitations of the RVR reporting system.

Even if the crew was preoccupied with the attempted lateral corrections to the localizer centre line and by the air-to-ground communications, they should have followed recommended altitude-monitoring and call-out procedures. Because of the crew's operational experience with the weather in the Boston area, their primary concern during the approach should have been to monitor their altitude at all times, particularly at decision height.

The before-landing check-list requires the pilot not flying the aircraft to monitor the approach and to call out, "200' above, 100' above, and minimums", as the aircraft approaches decision height. These call-outs were never made in Flight 723, nor was any reference made to altitude after the aircraft had departed the OM.

The altitude call-outs are not required if visual conditions prevail before the call-out altitudes are reached. The weather given to the flight crew when radio contact was first established with BOS AR-1 indicated a partial obstruction, an overcast ceiling at an estimated height of 400 ft, and a visibility of 1 1/2 miles in fog. Actually, the ceiling and visibility, reported by witnesses who were located below the final approach path of Flight 723, were virtually zero. The two flights immediately following Flight 723 were unable to see the runway, and they conducted missed approaches. There was no evidence that the crew of Flight 723 had seen the ground or any other object outside the cockpit during the approach. It is not expected that they would have placed more reliance on the reported weather than on the conditions as they actually encountered them.

This accident demonstrated how an accumulation of discrepancies, none of them critical, can rapidly deteriorate, without positive flight management, into a high-risk situation. In this regard, the most significant factors were:

1. Vectors given by BOS AR-1 to intercept the localizer course were not according to standard operating procedures; nevertheless, the flight crew accepted the vectors and continued the approach at an excessive airspeed.

2. Approach clearance and other required instructions first had to be requested by the flight crew, before they were given to the flight, which delayed the flight's descent to the correct approach altitude.

3. The co-pilot, who was flying the aircraft, was preoccupied with the information presented by his flight director system, to the detriment of his attention to altitude, heading, and airspeed control.

4. The pilot-in-command divided his attention among the problem with the flight director system, the communications with air traffic control, and the weather and visibility information given by the local controller.

The Board also considered the distraction that might have been caused by the presence of the observer in the cockpit. The CVR indicates that the observer's activities were limited to reading the challenges in each check-list and listening for the proper response and action by the flight crew. All check-lists, but one, were completed routinely. There was no record on the CVR of the prescribed challenges and responses of the before-landing check-list. The only statements related to that check-list were a response concerning the position of the landing gear and an announcement that the "... before landing is complete"; both were made by the cockpit observer. The Board could not determine whether the observer had accomplished the complete check-list by himself, or whether he had been assisted in any way by the flight crew. However, if the observer had attempted to accomplish the check-list items himself, he would have interfered with the flight crew's activity.

In a two-man crew, the pilot not flying the approach (in this case the pilot-in-command) would normally be required to read the check-list challenges and call out specific altitudes during the approach. That the observer in Flight 723 was allowed to read the check-list challenges, varied from routine procedure and company instructions and might have interfered with normal crew co-ordination.

In summary, the Board believes that the crew's preoccupation with the flight director's presentation was the most detrimental factor during the critical phase of the approach. This preoccupation led directly to the crew's failure to monitor altitude and to recognize passage of the aircraft through decision height.

The Board could not determine why the pilot-in-command had not exercised positive flight management. At several points during the approach, he had been confronted with large deviations from the approach profile, especially with regard to airspeed and localizer and glide slope alignment, that should have prompted him to abandon the procedure and initiate a missed approach. In making this observation, the Board recognizes the pilot-in-command's role as the final judge in all matters pertaining to the safety of his flight. Although the distractions caused by non-standard air traffic control services and a misleading flight director display created an error-inducing environment, the pilot-in-command should not have allowed these distractions to interfere with the exercise of his command responsibility for altitude awareness and his decision to abandon the approach.

Although the misunderstanding between local and ground controllers about the location of Flight 723 had no bearing on the accident, the Board is concerned about the accident potential of such a communications breakdown in the air traffic control system. The inability to communicate with Flight 723, in conjunction with the alarms of the approach light system, should have been sufficient reasons for the controllers to issue missed approach clearances to the flights that followed Flight 723.

2.2 Conclusions

a) Findings

1. There was no evidence that either pilot had been physically incapacitated before the accident.

2. The cockpit observer was not qualified to act as a flight crew member, nor was he authorized to participate in the conduct of the flight.

3. There was no evidence of pre-impact structural failure, fire, or flight control or powerplant malfunction.

4. The flight was vectored to the localizer course with an excessive approach course interception angle.

5. The approach controller's attention was diverted by an air traffic control problem involving two other flights, which resulted in a delay in the issuance of approach clearance and other required approach information and in a late release of the flight to the tower control.

6. Based on observations by witnesses and other flight crews, visibility in the approach zone would have prevented the crew from sighting the airport environment, either before reaching or upon reaching decision height.

7. The RVR given to the flight was not indicative of the actual visibility on the approach to Runway 4.

8. The aircraft approached and passed the OM above the glide slope at an excessive airspeed.

9. The flight crew was preoccupied with the guidance information presented by the flight director system.

10. The mode selector switch of the flight director system was found in the G/A position.

11. The flight crew did not make the required altitude call-outs during the final approach.

12. The flight crew made no attempt to abandon the approach.

13. The flight crew did not monitor the altimeters during the final portion of the approach.

14. The flight that preceded Flight 723 made a successful approach and landing on Runway 4R.

15. The two flights that followed Flight 723, without knowledge of the accident, abandoned their approaches at the decision height because of weather.

16. The air traffic controllers in BOS tower mistakenly assumed that Flight 723 had landed safely.

17. The ALS warning system in BOS tower was ignored by air traffic personnel because of previous false alarms and misunderstanding of the operation of the system.

b) Cause or
Probable cause(s)

The National Transportation Safety Board determines that the probable cause of the accident was the failure of the flight crew to monitor altitude and to recognize passage of the aircraft through the approach decision height during an unstabilized precision approach conducted in rapidly changing meteorological conditions. The unstabilized nature of the approach was due initially to the aircraft's passing the outer marker above the glide slope at an excessive airspeed and thereafter compounded by the flight crew's preoccupation with the questionable information presented by the flight director system. The poor positioning of the flight for the approach was in part the result of non-standard air traffic control services.

3.- Recommendations

As a result of this accident, the Safety Board on 28 August 1973, submitted recommendations (A-73-62 to 64) to the Administrator of the FAA. Copies of the recommendation letter and the Administrator's response are included in Appendix I.

ICAO Note: Appendix I not reproduced. The specific recommendations were:

"The Safety Board recommends that the Federal Aviation Administration:

1) Investigate the adequacy of the modification programme, its implementation, and the quality control aspects monitored by the appropriate FAA office.

2) Review the adequacy of the Delta Air Lines' quality control procedures in detecting and correcting the reported discrepancies.

3) Consider the necessity of imposing appropriate operational restrictions on the modified DC-9 aircraft until the underlying reasons for the avionics discrepancies have been identified and corrected."

Recommendations concerning one false alarm caused by the approach light system at BOS, and the mode selector of the Sperry Flight Director System, were forwarded to the Administrator, FAA, on 25 January 1974, (A-74-1 to A-74-4). Copies of the recommendations and Administrator's response are included in Appendix I.

ICAO Note: Appendix I not reproduced. The specific recommendations were:

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Require that the Sperry Flight Director mode selection switch be modified to prevent inadvertent selection of the G/A mode.

2. Require an annunciator panel whenever any flight director system is installed. The panel would indicate electronically the mode in which the flight director is operating, regardless of the position of the mode selector switch.

3. Require that controllers receive formal training in procedures for using the approach light system monitor panel.

4. Revise air traffic control operational procedures to assure that the ground controller is provided, concurrently, with the same arrival sequence information that is provided the associated local controller."

Testimony at the public hearing indicated that pilots do not fully understand RVR (Runway Visual Range). Opinions concerning the interpretation of the reported RVR value differed. Generally, pilots are not aware of the criteria for locating the transmissometer equipment, nor of the 51.1-second delay in updating the digital displays in the FAA facilities. The fact that RVR values may differ from actual runway visibility conditions in a non-homogeneous atmosphere apparently is not understood.

Further investigation revealed that FAA Advisory Circular, AC-00-13A, issued on 24 February 1965, which had dealt with the subject of runway visibility measurement, had been cancelled. No advisory circular replacing AC-00-13A has been issued.

Since no description of RVR equipment, its location, operation and limitations exists, the Board recommends that the Federal Aviation Administration:

> Issue an advisory circular which describes the RVR equipment and emphasizes that the RVR value is a sampling of a small segment of the atmosphere, usually near the touchdown point. It should also be emphasized that RVR value does not necessarily represent actual runway visibility conditions near the touchdown point and includes a significant time delay before reaching the crew. This information should also be placed in the Airmen's Information Manual. (Recommendation A-74-19.)

ICAO Ref.: AIG/278/73

No. 9

Aviación y Comercio (AVIACO), SE-210, EC-BIC, accident at Montrove, La Coruña, Spain, on 13 August 1973. Report not dated, released by Subsecretaria de Aviación Civil, Spain.

1.- Investigation

1.1 History of the flight

The aircraft was on a scheduled passenger flight from Madrid to La Coruña. It took off from Madrid/Barajas at 0830 GMT and proceeded normally. At 0914 radio contact was made with La Coruña tower and the flight crew reported 3 minutes away. The tower controller informed the flight that the airport was BELOW MINIMA - COMPLETELY BELOW MINIMA, that he had just asked the weather service for the trend and that improvement would be slow and take at least one hour. The flight crew then decided to hold over LIMA ROMEO ALPHA and said they would report when holding. Shortly thereafter they informed the tower that they would make an approach down to minima to get a more precise idea of the weather and would hold thereafter. The controller said he was switching on the VASIS and at 0921 he informed the flight that visibility was around 350 m, although he could not see the VASIS at the threshold of Runway 22. The flight then reported at 3 000 ft beginning the approach. At 0923 the controller reported a visibility of 600 m. At 0924 the pilot said he would attempt to land, that he was 2 200 ft on approach and had not yet entered clouds, which meant that the cloud layer was very thin. At 0925 the controller told the flight that the flashing lights of the VASIS on Runway 22 were quite visible from the tower. At 0928 he reported 800 m visibility, but that a light breeze was coming up and fog was again closing in from the sea. The pilot told the tower that he had descended to the minima and seen nothing and would therefore begin to hold. At 0932 the flight crew reported holding at 6 000 ft and requested to be informed of any change that might take place. At 0934 the controller reported a visibility of 400 m, that the VASIS was still visible and that the Runway 22 threshold, which was 894 m from the tower, had become slightly clearer. The flight crew acknowledged and said that, since they had fuel, they would make another attempt, although the tower suggested holding a little to see if the weather would improve. At 0935 the flight crew said they would try to break out in any case as the weather was clearer than before. At 0935 the controller informed the flight that the QFE was 1007.9 and the QNH was 1020 and instructed it to switch on the aircraft lights when passing the beacon on approach. At 0936 the flight crew reported passing LIMA ROMEO ALPHA on approach. The controller answered that the lights of the VASIS were no longer visible and that some fog had collected over the runway threshold. The pilot then decided to resume holding. At 0945 the controller told him that visibility to the north was 700 m and in other directions 500 m, and that the runway threshold was visible from the tower. The pilot said he could see the fog breaking from above and that he would wait a little for an improvement. At 0951 the controller reported a visibility of 800 m in all sectors and at 0958 a horizontal visibility of approximately 1 000 m and a vertical visibility of 100-150 m. At 1001 the controller transmitted the QNH 1019.8. At 1009 he reported a horizontal visibility of 1 km and a vertical visibility of 100-150 m and at 1012 a horizontal visibility of 1 200 m and a vertical visibility above the airfield of about 150 m. At 1020 he reported a horizontal visibility of 1 500 m and a vertical visibility of 150 m and at 1023 that the vertical visibility had improved to between 250 and 300 m. The pilot acknowledged and said he was leaving 5 000 ft for approach. The controller requested that the aircraft lights be switched on in case they could be seen when leaving LIMA ROMEO ALPHA. At 1027 the controller instructed the flight to report beacon inbound to the runway. The flight acknowledged and reported outbound. At 1031 the flight reported passing LIMA ROMEO ALPHA. At 1032 the flight reported discontinuing the approach. The controller informed the flight that he had spotted it momentarily just ahead of the runway, but that it had disappeared again in the fog. At 1038 the pilot said he was initiating another approach and would report over LIMA ROMEO ALPHA. The controller said the situation was the same as during the last approach. At 1039 the pilot asked whether the wind was zero and the controller replied COMPLETELY CALM. At 1039 the pilot reported over LIMA ROMEO ALPHA on approach and the controller said he would watch for the aircraft. At 1040 the pilot replied Roger. At 1041 the controller reported that a slight wind had arisen - 60°/5 kts - but despite several repetitions no answer was received. At 1046 the tower was informed by the chief of the airport that the aeroplane had crashed at Montrove. The above data were all taken from the transcript of the tower tape recording at La Coruña Airport.

The aeroplane had collided with some eucalyptus trees, crashed to the ground and burned out.

Time (GMT) of accident: approximately 1040 hours.

Geographical location of site of accident: approximately 3 km before the threshold of Runway 22 at La Coruña Airport. The coordinates were approximately 43°18'N; 08°23'W.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	6	79	-
Non-fatal	-	-	-
None	-	-	

1.3 Damage to aircraft

The aircraft was destroyed by the crash and fire.

1.4 Other damage

Private property, trees and houses were damaged.

1.5 Crew information

Pilot-in-command: Airline transport pilot licence No. 794, issued 26 October 1968. Proficiency rating 794, valid 18 June 1973 to 19 December 1973.

Hours on Caravelle: 304. Total flying time: 8 610.

Co-pilot: Senior commercial pilot licence No. 1247, issued 4 August 1970. Proficiency rating 1247, valid 5 May 1973 to 13 November 1973.

Total time on Caravelle: 997. Total flying time: 6 283.

Pilot on type training: Senior commercial pilot licence No. 1377 issued 11 December 1971. Proficiency rating No. 1377, valid 1 June 1973 to 6 December 1973.

Time on Caravelle: 75. Total flying time: 1 815.

1.6 Aircraft information

Certificate of Registration No. 413 and of Airworthiness No. 828, valid until 28 September 1973. Total hours at time of accident: 13 118. Hours since last 640-hour service check: 506. Hours since last 5 000-hour overhaul: 3 643. Number of landings: 9 380.

Engines

2 Pratt Whitney JT 8D-7.

No. 1 engine: Hours since overhaul: 5 282.

Total hours: 5 282. Hours since last service check: 137.

Number of landings: 3 559.

No. 2 engine: Hours since last overhaul: 3 092.

Total hours: 9 604.

Hours since last general overhaul: 3 020.

Number of landings: 2 992.

1.7 Meteorological information

Data supplied to the tower by the Meteorological Office at La Coruña Airport on 13 August 1973 from 0900 to 1040.

The first request for information by the tower was made at 0910 and the following QAM was provided:

QAN calm QBA 150 m QNY fog. Sky invisible.

QNH 1020 mb = 30.12, Temperature = 20°C. Dewpoint = 20°C.

Owing to the reduced visibility this was virtually the only item mentioned in subsequent requests from the tower. Fluctations of the visibility are shown hereunder:

0914 Indication that the weather would develop slowly and fog would take a long time - at least an hour - to disperse.

0918 Visibility northern zone 200 m, southern zone 250 m.

0920 Visibility 350 m.

0923 Visibility 600 m.

0927 Visibility 500 m.

0934 Visibility 400 m.

0935 Visibility north 600 m. All other directions 400 m. QFE 1007.9 QNH 1020

0944 Visibility north 700 m, elsewhere 500 m.

0950 Visibility 800 m.

0952 Vertical visibility 100-150 m.

1001 Visibility 900 m. QNH 1019.8.

1009 Visibility 1 km. Vertical 100-150 m.

1012 Visibility 1 200 km. Vertical 150 m.

1020 Visibility 1 500 m.

1022 Vertical visibility 250-300 m.

1040 Wind 060°/05. Visibility 1 800 m.

This last information was not received by the aircraft.

The forecast conditions at La Coruña Airport indicated very slow improvement. Up to the last moment the pilot was continually informed of the weather at La Coruña, Santiago, Madrid and Valladolid.

The weather along the route was ideal, and this applied equally to Santiago Airport where, throughout the morning, there was zero wind; visibility 8 km; temperature 23° to 25° and dew-point 16°. While holding over La Coruña Airport, the flight reported that it had not yet entered cloud at 2 200 ft.

Conditions which might have given rise to ice formation were totally absent.

1.8 Navigation aids

Normal.

1.9 Communications

Normal.

1.10 Aerodrome and ground facilities

Normal.

1.11 Flight recorders

Were recovered and interpreted.

1.12 Wreckage of the aircraft

Around 300 m before the site of the crash the aircraft felled three eucalyptus trees and shaved the tops of 23 more, among which was found the right elevator. The aircraft embedded itself in the roof of dwellings at Pazo del Rio.

The location of the aircraft components at the accident site indicated that the impact was upside down. In particular the right stabilizer was found embedded upside down.

The cockpit separated from the fuselage on impact and was found about 10 m away from it. It did not catch fire, although a small outbreak was caused by the cockpit wiring.

The left stabilizer and the tail cone separated on impact. The left stabilizer was found 10 m from the fuselage. The right main landing gear was found about 50 m from the fuselage.

1.13 Fire

The aircraft caught fire on impact and three minor explosions occurred afterwards. The fuselage was completely destroyed by the post-impact fire.

The fire was brought under control rapidly. When the airport fire fighting service arrived the city fire department was already in action. The latter handed over the control to the more effective airport service which used the two vehicles available. When they left for replenishing, the city fire fighters remained on the scene. When the airport vehicles returned, they were no longer needed as the fire was virtually extinguished.

1.14 Survival aspects

The accident was non-survivable.

1.15 Tests and investigations

The investigation revealed that the aircraft was flying well below minima and struck some eucalyptus trees, first with the right stabilizer and then with part of the fuselage. The trees were standing on a small hill at an elevation of 105 m. The right elevator fouled the trees. The pilot probably applied full power and initiated a steep climb, which suggests that his speed was low. The airspeed indicators read 85 and 90 kt respectively. The altimeter read 170. The trim tab was raised 16^{o}, the aileron controls were fully to the right, the rudder tab was 16^{o} to the left; the cockpit clock, with the hands buckled, indicated 1005 hours.

2.- Analysis and Conclusions

2.1 Analysis

It is quite clear from the investigation that the aircraft, its engines and instruments were operating normally at all times. This was evidenced by the fact that three missed approaches were carried out down to minima without any abnormality of a technical nature being reported.

On the third approach the pilot must have caught a glimpse of the runway, and the tower controller actually saw the aircraft and so informed the pilot. The pilot must therefore have assumed that by going slightly more below the minima he would be able to land.

He apparently initiated the fourth approach at the precise time the tower reported a slight improvement in the weather. He left LIMA ROMEO ALPHA on a 21° track, in accordance with the approach chart, expecting a maximum obstacle height of 105 m, the height of the hill. The airport elevation is 97 m. Since the fog was ragged the pilot was most probably looking outside in an attempt to see the ground, without checking his altitude on the altimeter. He was suddenly faced with the eucalyptus trees, which were 12 to 15 m higher than the top of the hill, pulled back on the control column and applied full power, but was unable to prevent the right stabilizer from colliding with the trees.

2.2 Conclusions

a) Results

The crew held valid licences.

The aircraft's documents were in order. From the inspections carried out at the accident site, the data collected at the tower and the data derived from the flight data recorder it is concluded that the accident was not due to mechanical failure.

The behaviour of the pilot is incomprehensible, since on a flight which should have taken a maximum of 50 minutes he spent an hour and a half holding and endeavouring to land, when it would have been much quicker and more economical to land at Santiago Airport where the meteorological conditions were favourable.

b) Cause or Probable cause(s)

Pilot violation of the regulations and instructions governing flight over national territory, and the international standards in force in Spain.

3.- Recommendations

The following recommendation was made in relation to this accident:

Standards to be followed when landing in "below minima" meteorological conditions:

1) When an aircraft is proceeding to an airport, the Air Traffic Services shall, in their first radiocommunication with the aircraft, supply in extenso the latest weather report for the airport and add "weather conditions below minima" whenever the ceiling or visibility - or both - are below the minima published in the Spanish AIP instrument approach charts.

2) Pilots-in-command, if so authorized by their director of operations, may attempt an approach in "weather conditions below minima" without descending below the critical height specified in the approach charts. The purpose of the approach shall be to check whether the actual weather coincides with that given in the weather report. If the weather is above the prescribed minima the landing may be made.

3) When the aircraft lands in "weather conditions below minima", the pilot-in-command shall inform the chief of the airport of the reasons for his decision, and the chief of the airport shall report accordingly to the Directorate General of Air Transport.

When such report is received, a copy shall be forwarded to the company or agency responsible for the pilot-in-command with instructions to analyse the case and forward it to the Under-Secretariat of Civil Aviation.

ICAO Ref.: AIG/285/73

No. 10

Pan American World Airways, Boeing 707-321C, N-458PA, accident at Boston/Logan, U.S.A., on 3 November 1973. Report No. NTSB-AAR-74-16, dated 2 December 1974, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

Pan American World Airways Clipper Flight 160 was a scheduled cargo flight from John F. Kennedy International Airport (JFK), New York, to Frankfurt, Federal Republic of Germany, with a scheduled stop at Prestwick, Scotland. At 0825 EST1/ the flight departed JFK. The aircraft was carrying 52 912 lb of cargo, 15 360 lb of which were chemicals.

The flight crew consisted of a pilot-in-command, a co-pilot, and a flight engineer. The pilot-in-command neither received nor signed written notice of the amount and type of restricted articles2/ he was carrying as required by Federal Aviation Regulations.

After departure, Clipper 160 was vectored on course while climbing to flight level 330 (FL 330). At 0844, Clipper 160's clearance was amended, and it was instructed to maintain FL 310 as a final cruising altitude. Clipper 160 reported level at FL 310 at 0850. As the flight approached Sherbrooke VORTAC3/ 100 miles east of Montreal, Canada, at about 0904, it advised Pan American Operations (PANOP) in New York that smoke had accumulated in the "lower 41" electrical compartment, and that the flight was diverting to Boston.

At 0908, Clipper 160 advised Montreal Centre that they were level at FL 310 and wanted to return to JFK. Montreal Centre cleared Clipper 160 for a right turn to a heading of 180°.

At 0910, Clipper 160 advised PANOP that it was returning to New York and that the smoke seemed to be "getting a little thicker in here". At 0911, the crew advised PANOP that they were now going to Boston and that "this smoke is getting too thick". They also requested that emergency equipment be available when they arrived at Boston. During this conversation, the comment was made that the "cockpit's full back there".

During its return to Boston, the flight was given preferential air traffic control treatment, although it had not declared an emergency.

1/ All times used herein are eastern standard, based on the 24-hour clock.

2/ The terms "restricted articles", "dangerous articles", "hazardous materials" are used on an interchangeable basis in this report, depending upon the document, organization, or source under discussion at the time.

3/ Collocated VOR (very high frequency omnirange station) and the TACAN (ultra-high frequency tactical air navigational aid).

After issuing appropriate descent clearances en route so that fuel could be burned off more rapidly at lower altitudes, at 0926:30 Boston Center advised Boston Arrival Radar (AR-2) that the flight was at 2 000 ft. At 0929, Clipper 160 asked Boston Center for the flight's distance from Boston, and added, "The DME's don't seem to be working". The Center answered, "You're passing abeam, Pease Air Force Base, right now, sir, and you're about 40 to 45 miles to the northwest of Boston". The first communication between Clipper 160 and AR-2 was at 0931:21. The flight was cleared "direct Boston, maintain 2 000". AR-2 asked if the flight was declaring an emergency the reply was "negative on the emergency, and may we have Runway 33 left?" The AR-2 controller approved the request, and the flight proceeded to Boston as cleared. At approximately the same time, the pilot-in-command instructed the crew to "shut down everything you don't need".

At 0934:20, AR-2 asked, "Clipper 160, what do you show for a compass heading right now?" Clipper 160 answered, "Compass heading at this time is 205". AR-2 then asked, "will you accept a vector for a visual approach to a 5-mile final for Runway 33 left, or do you want to be extended out further?" The crew replied, "Negative, we want to get it on the ground as soon as possible".

At 0935:46, the AR-2 controller stated, "Clipper 160, advise any time you have the airport in sight". Clipper 160 did not reply. At 0937:04, the AR-2 controller made the following transmission: "Clipper 160, this is Boston approach control. If you read, squawk ident on any transponder. I see your transponder just became inoperative. Continue inbound now for Runway 33 left, you're No. 1. There is a Lufthansa 747 on a 3-mile final for Runway 27, the spacing is good. Remain on this frequency, Clipper 160".

At 0938:31, the AR-2 controller, who was talking to another flight, stated: "... this Clipper has lost his transponder and nobody's working him, and he's been given a clearance to land in the blind. He's just about 4 miles east of Boston now".

At 0940:23, the AR-2 controller transmitted the following message: "All aircraft on the frequency, the airport is closed at Boston". The AR-2 controller transmitted the message, because ATC personnel had seen Clipper 160 crash. Witnesses saw the left cockpit window open and smoke come through the window. Aeronautically qualified witnesses saw the aircraft approach Runway 27 at a faster-than-normal speed and saw it enter roll and yaw manoeuvres. These manoeuvres increased in severity until the aircraft assumed a final nose-high attitude. The nose-high attitude was followed by an abrupt nose-down attitude, and the left wing and nose contacted the ground simultaneously. The aircraft was nearly vertical at impact.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3	-	-
Non-fatal	-	-	-
None	-	-	

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced.

2.- Analysis and Conclusions

2.1 Analysis

Operation of the flight

The flight was routine until just before 0904, when the crew advised Pan American operations at JFK that smoke had accumulated in the lower 41 and that they were turning back to Boston or New York. From 0904 until 5 minutes before the crash, several conversations regarding smoke in the aircraft were recorded by the CVR. According to the CVR, the crew donned oxygen masks at 0911 and put on their smoke goggles at 0912.

At 0914, they asked to remain on the current radio frequency because "its too hard to change". This remark infers that the smoke in the cockpit was so dense that they had difficulty seeing the frequencies on the control panels. The crew, however, did not at any time become alarmed by the situation. At 0931, shortly before the CVR ceased to function, the pilot-in-command noted that the smoke was suddenly getting worse and advised the crew to "shut down everything you don't need".

Other conversations recorded on the CVR indicate that the crew was firmly convinced it was an electrical problem.

The final actions taken by the flight engineer, as prescribed by procedures if smoke continues, include the positioning of the "essential power selector" in the "external power" position. If the selector is positioned to "external power", the yaw damper becomes inoperative. The FDR parameters and the CVR disclosed that the wing flaps had been lowered. There is evidence that spoilers had been extended for about 4 1/2 minutes and probably had remained selected at the extended position when the speed was reduced for final approach.

Performance data for the Boeing 707-321C show that lateral control capability may be extremely limited, if not impossible, with an inoperative yaw damper, extended spoilers, and lowered flaps.

The evidence suggests that the pilot-in-command was not aware that the flight engineer's actions had rendered the yaw damper inoperative. In addition, the position of the spoiler control level may not have been visible through the smoke in the cockpit.

Since the smoke detector indicators apparently failed to provide an early and positive indication of the source of the smoke, the flight crew assumed that the smoke in the lower 41 was from an electrical or avionic source. This assumption probably influenced the subsequent actions of the flight crew more than any other factor.

Although the exact reason for the pilot-in-command decision to fly to Boston instead of landing at an appropriate airfield en route could not be determined, these factors were considered:

1. Since the flight crew believed the smoke to be from an electrical source, they knew that the source could be readily isolated and, therefore, would not constitute a serious threat.

2. There is no evidence to indicate that any member of the flight crew was aware of the restricted articles on board. It is possible that the cabin cargo areas would have been immediately suspect as a smoke source had the flight crew been aware of the quantity, nature, and location of the chemicals on board; however, the smoke migration pattern, which caused smoke to emerge from lower 41 compartment would have further confused the crew as to the origin of the smoke and thus would have seriously impeded timely and accurate assessments.

The Safety Board recognizes, that while safety considerations are foremost in the operations of a flight, underlying logistic considerations may enter into the decision making processes of the operating flight crews and company management.

The Safety Board believes that had an electrical problem in lower 41 actually been the source of the smoke as the flight crew suspected, the logical decision from a safety and logistic viewpoint would have been to land at the nearest airport where Pan American maintenance personnel and facilities were available to accomplish required maintenance, return aeroplane to service, and to continue the flight. In this case, the nearest airport with such Pan American facilities was Logan International Airport at Boston.

Apparently, the problem was underestimated or misunderstood by the crew of Clipper 160. Late during the approach to Boston, conditions in the cockpit rapidly deteriorated. Serious impairment of visibility inside the cockpit and drastic impairment of outside visibility prompted the opening of the cockpit window. Since opening the window was not prohibited, this action taken by the crew is understandable. The procedure was prescribed by Boeing and Pan American at the time of the accident. However, as discovered during smoke evacuation tests after the accident, opening the cockpit window allows even more smoke into the cockpit when the source of the smoke is continuing and originates in the cabin.

One of the critical factors in the final accident sequence was the flight engineer's execution of emergency procedures while other crew members were not aware of his actions. Various switch settings found on the flight engineer's panel after the crash and information from the CVR indicate that the flight engineer performed the "smoke evacuation emergency procedure" and was in the process of performing the prescribed steps of the "electrical smoke and fire procedures", as prescribed in the Boeing 707 flight manual. The latter procedure requires that the essential bus power switch be placed in the "ground power position", thus removing all power from the systems on the essential bus. Included on the essential bus are: the pilot-in-command's flight instruments, the No. 1 VHF radio, the cockpit voice recorder, intercom, the yaw damper, and the No. 1 transponder. If these systems are de-activated without the pilot-in-command's knowledge, the pilot-in-command may conclude that the smoke problem in the lower 41 compartment has worsened.

The "electrical smoke and fire emergency procedure" requires that the radios be changed to the No. 2 position before the essential bus is isolated. Since the radio was not changed, only the flight engineer knew what had occurred when the essential bus was isolated. Why the flight engineer did not return the power to the bus could not be determined.

Flight recorder data indicates that a stable approach was never established. The airspeed, altitude, and heading traces fluctuated constantly throughout the approach. Under conditions in which the flight parameters are constantly changing, careful monitoring by the crew is necessary in order to avoid entering a dangerous flight regime. However, since the crew of Clipper 160 could not communicate verbally with each other and probably could not see the instruments because of dense smoke, they could not monitor airspeed and altitude during the final phase of the approach. This could easily lead to a stall or an uncontrollable manoeuvre at an altitude too low for recovery. Heading excursions during the final moments of flight also indicate that the crew may have had difficulty seeing the runway because of the dense smoke in the cockpit.

According to FDR traces, the airspeed deteriorated from about 160 to 122 kt during the last portion of the flight. Stall speed for the aircraft's configuration at the time of the accident was 118 kt in wings level, unaccelerated flight. Since the FDR indicates a continuous heading change, the aircraft must have been in a bank or a yaw. If the aircraft stalled during such a manoeuvre, considerable altitude would have been required to recover safely.

The FDR reading of 344 KIAS, 5 minutes before impact could possibly be explained by either exposure to or severance from heat on air data sensors which lead to the FDR unit. Although high speeds were observed by ground witnesses, the aircraft's performance characteristics suggest that an IAS of 344 kt would not have been possible.

Involvement of hazardous materials on Clipper 160

While discrepancies were found in the packaging, documenting, and labelling of most of the restricted articles on board Clipper 160, the most serious and potentially dangerous discrepancy was the manner in which the nitric acid was packaged and stowed.

The nitric acid, although non-combustible, is an oxidizing material which reacts with many materials. When nitric acid comes in contact with most organic materials, a spontaneous reaction begins to produce heat and large quantities of smoke, as verified by tests. IATA regulations require packaging of nitric acid in T4A specification wooden boxes with 1C.1 earthenware or glass inside containers of not more than 2.5 litres capacity, individually enclosed in tightly closed metal cans. The regulations recognize the reactivity of nitric acid and, therefore, require that nitric acid be packaged with suitable non-combustible mineral cushioning material. In addition, the IATA regulations require that the boxes be labelled "cargo aircraft only" and "corrosive".

The boxes used for the outer packaging were not manufactured to DOT specifications nor were they marked with required specification numbers. The bottles were not packed in metal containers, and the cushioning material used was combustible sawdust. The required "cargo aircraft only" labels were not affixed to the outer containers. The "corrosive liquid" labels required for air shipment were not affixed to the boxes. "Corrosive" labels required for surface shipment were present. Arrows pointing to the top of the box were present, but the required "this end up" labels were omitted.

In addition to deviations from packaging requirements, numerous boxes which fit the description of those containing the nitric acid, were placed on their sides on the pallets during the repalletizing operation. Therefore, it was entirely possible for the nitric acid to leak into the sawdust. A cracked or broken bottle, a bottle cap which was loose, overtightened, or cracked, or a cap that was tight at sea level pressures could have started to leak when the aeroplane reached its cruising altitude of 31 000 ft.

The latter possibility is considered the most likely in view of the 14-minute interval between Clipper 160 levelling off at 31 000 ft and the first appearance of smoke.

The variable smoke density could be explained if a series of reactions were set off by the heat and/or fire created by the leakage from one bottle. The fact that laboratory analysis of soot samples did not detect traces of nitrates is not considered of major significance, since the soot samples were of limited quantity and were in all probability either immersed in sea water or subjected to the fire fighting operations after the crash. Any contact with water could easily have dissolved and removed detectable traces of nitrate deposits.

The theory that there was intense heat in the cabin area is further supported by the metallurgical findings in the area of fuselage station 960N and 980, which suggest the possibility of temperatures as high as 1 000°F. The possibility that the elevated skin temperatures occurred after impact is not likely in view of the structural deformation which apparently took place at impact.

The termination of the CVR operation about 5 minutes before impact and about 1 minute before radiocommunications were lost may also be related to a fire or high temperatures in the aft cabin. The recording ceases when the 600 Hz cyclic tone appears. The 600 Hz tone can only be produced by activating the CVR test circuit or grounding of the test circuit wiring. The evidence, therefore, suggests that the wiring in question may have been heated or burned during the last minutes of the flight. This type of condition would strongly support a rapidly deteriorating situation aboard the aeroplane at that time.

<u>The system of hazardous materials regulations and control</u>

During its investigation, the Safety Board found that the system for regulating the shipment of hazardous materials by surface and by air is extremely complex, widely misunderstood, and poorly enforced; and therefore pose a serious and continuous threat to life and property.

The FAA did not exercise adequate surveillance of shippers and carriers to effectively detect and cause the removal of improperly prepared or otherwise illegal shipments from commerce. The FAA did not have adequate resources, authority or technical capabilities to conduct effective surveillance of shippers and carriers.

The DOT Office of Hazardous Materials did not have adequate resources or jurisdiction to ensure an effective hazardous material compliance programme. No single document that contains all applicable regulations was available to operating personnel handling restricted articles shipments. The lack of such a document resulted in widespread confusion and misunderstanding as to what was expected. Because of its simplicity of use as a working document, personnel who need to know the requirements for air transportation of hazardous materials have used the IATA Restricted Articles Regulations. IATA regulations, however, are not enforceable under U.S. regulations.

Eight parties were involved in the process by which restricted articles were handled for air carriage. The responsibility for certification of compliance at each interface with the parties is unclear. The Director of the DOT Office of Hazardous Materials, who is also the Chairman of the Hazardous Materials Regulations Board, indicated that he understood that the shipper or his agent was responsible for this certification at each interface. The number of parties handling such shipments for air carriage, their geographic separation, and the time constraints suggest that this expectation requires re-examination. It follows that enforcement would be difficult, if not impossible, in these circumstances.

The handling of these shipments by the air carriers indicates that existing FAA regulations were neither known or internally disseminated to carrier personnel. Non-compliance with DOT regulations was found to be commonplace. For example, regulations regarding accessibility to restricted articles on board all cargo flights were ambiguously interpreted, and if enforced to the letter, virtually impossible to cope with.

Emergency procedures

Extensive testimony by FAA technical personnel, the Boeing Company, and Pan American Flight Operations personnel disclosed conflicting data regarding the validity of smoke evacuation procedures in force on 3 November 1973.

Initial testimony by the FAA and the Boeing Company indicated that existing procedures for evacuating smoke were adequate if followed to completion. However, data developed during and subsequent to the smoke evacuation tests disclosed that the smoke test conducted during the initial certification of the Boeing 707 did not take into consideration a continuing source of smoke. In view of these findings, the Safety Board believes that the procedures in effect at the time of accident were not effective in controlling or evacuating smoke. On the contrary, it appears that smoke origin and circulation made it virtually impossible to determine accurately the source of the smoke.

In view of the data developed during the March 1974 smoke evacuation tests, the Safety Board believes that if effective smoke detection and smoke evacuation procedures had been available to the crew of Clipper 160, the ultimate events resulting in loss of control might have been averted.

An examination of the smoke goggles of the type used by the crew disclosed that an adequate fit with or without glasses was difficult, if not impossible. Therefore, the crew members of Clipper 160 did not have adequate eye protection. In fact, eye irritation by toxic smoke would probably make it virtually impossible for an individual to keep his eyes open.

2.2 Conclusions

a) Findings

1. The flight crew of Clipper 160 was qualified and certificated.

2. The aircraft was maintained in accordance with applicable regulations.

3. Certification of the basic aircraft was in accordance with applicable regulations.

4. There was no failure or malfunction of the aircraft's flight controls, systems, structure, or powerplants.

5. Initial certification smoke evacuation testing of the aircraft did not consider procedures for evacuation of continuously generated smoke.

6. Dispatching of the flight was accomplished in accordance with applicable regulations, with the exception of the handling of pilots' notification of restricted articles.

7. The pilot-in-command was not properly notified of the restricted articles on board as required by regulation.

8. The aircraft's weight and centre of gravity were within allowable limits.

9. The flight crew was misled by the appearance of smoke from the lower 41 compartment and initiated emergency actions required for electrical problems.

10. The severity of the emergency was underestimated by the flight crew.

11. Clipper 160 overflew several airports capable of accommodating the aircraft.

12. Flaps and spoilers had been extended for speed reduction.

13. The yaw damper was rendered inoperative by the unco-ordinated execution of emergency procedures.

14. The Boeing 707 becomes extremely difficult to control at low speeds with wing flaps and spoilers extended and yaw damper inoperative.

15. Handling of the restricted articles shipments was in violation of many Federal and company regulations.

16. Most personnel handling the restricted articles shipments were inadequately trained to do so.

17. Nitric acid was improperly placed on the pallets and probably leaked. The leakage produced intense smoke and heat when it spontaneously reacted with the sawdust surrounding the bottle.

18. Federal regulations and enforcement programmes governing the transportation of hazardous materials were inadequate.

19. The carrier's procedures for handling hazardous materials were inadequately enforced by the carrier and the FAA.

20. DOT jurisdiction over certain parties handling restricted articles moving in air transportation is questionable.

b) Cause or Probable Cause(s)

The National Transportation Safety Board determines that the probable cause of the accident was the presence of smoke in the cockpit which was continuously generated and uncontrollable. The smoke led to an emergency situation that culminated in loss of control of the aircraft during final approach, when the crew in unco-ordinated action de-activated the yaw damper in conjunction with incompatible positioning of flight spoilers and wing flaps.

The Safety Board further determines that the dense smoke in the cockpit seriously impaired the flight crew's vision and ability to function effectively during the emergency. Although the source of the smoke could not be established conclusively, the Safety Board believes that the spontaneous chemical reaction between leaking nitric acid, improperly packaged and stowed, and the improper sawdust packing surrounding the acid's package initiated the accident sequence.

A contributing factor was the general lack of compliance with existing regulations governing the transportation of hazardous materials which resulted from the complexity of the regulations, the industrywide lack of familiarity with the regulations at the working level, the overlapping jurisdictions, and the inadequacy of government surveillance.

3.- Recommendations

As a result of the accident, the Safety Board has made 16 recommendations to the Administrator of the Federal Aviation Administration (FAA). (See Appendix H.)

ICAO Note: Appendix H not reproduced. The specific recommendations were as follows:

Safety Recommendation A-73-110, issued 29 November 1973

"The Safety Board recommends that the Federal Aviation Administration issue a telegraphic alert to all air carriers involved in the transportation of hazardous materials citing the dangers associated with the handling and transportation of liquid restricted articles, including the need to preclude the air shipment of any improperly labelled hazardous materials packages, and the need to comply with regulations concerning "This Side Up" or "This End Up" stencils on properly labelled hazardous materials packages, to prevent spillage from improperly oriented packages".

Safety Recommendations A-73-119 to 122, issued 10 January 1974

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Take immediate steps to determine whether the present smoke chute installation on Boeing 707 cargo and cargo-passenger aircraft satisfies the provisions of FAR 25.855 and 25.857.

2. Effect retroactive modifications on all subject aircraft to ensure full compliance with provisions of FAR 25.855 and 25.857 pertaining to prevention of hazardous quantities of smoke, flames, or noxious gases from entering the flight crew compartment.

3. Provide operators of the subject aircraft with data to enable flight crews to identify smoke sources, and require operators to establish procedures in their operating manuals to control and evacuate smoke effectively during the specific flight regimes.

4. Re-evaluate previous smoke evacuation tests conducted during certification relative to the quantity and source of smoke as applicable to smoke evacuation procedures currently employed by operators of Boeing 707 aircraft".

Safety Recommendations A-74-5 and 6, issued 6 February 1974

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Require that transport category airplanes certificated under Part 4b of the Civil Air Regulations prior to the effective date of Amendment 4b-8 comply with Part 25.1439 of the Federal Aviation Regulations.

2. Require that a one-time inspection be made of all smoke goggles provided for the flight crew of all transport category airplanes to assure that these goggles conform to the provisions of Part 25.1439 of the Federal Aviation Regulations".

Safety Recommendations A-74-20 to 26, issued 26 March 1974

"The recommendations submitted herein are intended to be interim measures, pending a more definitive resolution of the hazards disclosed during this inquiry.

The National Transportation Safety Board recommends that the Administrator, Federal Aviation Administration:

1. Conduct a comprehensive inspection of each air carrier's procedures for compliance with 14 CFR 103 and 14 CFR 121.433(a), specifically with regard to receiving, palletizing, consolidating, and aircraft loading, as well as the related training. This inspection should be completed at the earliest possible date and not later than 60 days from the date of this recommendation.

2. Develop, in cooperation with the Department of Transportation, Office of Hazardous Materials, a compliance checklist to determine whether or not a shipment conforms to Federal hazardous materials regulations. This checklist should be circulated to all involved agencies and organizations.

3. Develop and disseminate information about Federal regulations which apply to air carriage of hazardous materials to the air carriers' marketing or sales representatives and their appointed agents.

The Board believes that recommendations two and three should be acted upon immediately inasmuch as they are within the scope of current regulatory authority.

The Board recognizes that the following recommendations may require additional research and evaluation before they can be implemented. However, they should be implemented as quickly as possible in light of the hazards involved.

4. Amend 14 CFR 121.597 to require the person authorized to exercise operational control over the flight in the case of supplemental air carriers and commercial operators of large aircraft to inform the captain of any dangerous articles aboard the flight, as outlined in 14 CFR 103.25. Further, amend 14 CFR 121.601 to make the dispatcher responsible in the case of scheduled air carriers, for informing the captain of dangerous articles aboard the flight, in addition to the notification required by 14 CFR 103.25.

5. Amend 14 CFR 135 to require each operator under this part to develop procedures to insure that the captain is informed of any dangerous articles aboard. This notification should contain the information outlined in 14 CFR 103.25.

6. Rescind the provision in 14 CFR 103.3(a) which allows the aircraft operator to rely on the shipper's statement as prima facie evidence that the shipment complies with the requirements of this part. Instead, require the air carrier to institute a monitoring system to assure that all dangerous articles shipped by air are inspected against all regulatory safety controls which can be verified at the air carriers receiving point.

7. Institute rulemaking to require that air carriers notify the shipper and the FAA when a shipment, or its documentation, deviates in any manner from Federal or air carrier regulations. Further, require that when non-conforming shipments are detected by the air carrier, they may not be moved until the deficiency is remedied, or the transportation of the deficient packages - with prescribed safety controls - is authorized by the cognizant Federal agency. The deficiencies should be entered on the shipping documents, a copy of which should be retained by the carrier and be made available to the cognizant Federal agency".

Safety Recommendations A-74-65 and 66, issued 1 October 1974

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1) Issue appropriate notices to alert air carriers to inform flight crews who may be involved in carriage of certain dangerous articles capable of producing self-sustaining chemical reactions that reliable in-flight threat assessment of problems associated with such articles often will be extremely difficult, if not impossible.

2) Advise air carriers to inform flight crews that smoke or fire caused by oxidizing agents and certain other chemicals cannot be controlled by existing emergency procedures, and that any abnormal in-flight occurrence which could be linked to dangerous articles should be considered an unsafe condition as prescribed by 14 CFR 121.557 and 121.559, requiring an immediate decision and action to "Land the airplane at the nearest suitable airport, in point of time, at which a safe landing can be made".

ICAO Ref.: AIG/491/73

No. 11

Turkish Airlines, F-28, TC-JAO, accident at Izmir/Cumaovasi, Turkey, on 26 January 1974. Report No. T-5-199, not dated, released by the Ministry of Communications, Turkey.

1.- Investigation

1.1 History of the flight

On 24 January 1974, the aircraft completed the flights Istanbul/Izmir/Athens/Izmir normally. The aircraft and crew remained overnight in Izmir.

On 25 January aircraft flights, number TK-301 Izmir/Istanbul and TK-304 Istanbul/Izmir, were completed without incident. Later, on the same day, flight TK-309 departed Izmir for Istanbul but, owing to bad weather conditions at Yesilkoy Airport, returned to Izmir. Then, after completing an Izmir/Athens/Izmir flight the same crew and aircraft remained overnight at Izmir/Cumaovasi Airport.

On 26 January at 0507 GMT (0707 local) the aircraft was ready for the Izmir/Istanbul flight with the same flight crew. Having completed ground servicing, filed a flight plan, and boarded passengers the pilot-in-command made his aircraft walk-around inspection. At this time the station manager gave the weight and balance sheet to the pilot-in-command.

Shortly after closing the doors and receiving tower permission the aircraft was taxied to the threshold of Runway 35 and began a rolling take-off without delay. According to witnesses the aircraft had run approximately 3 200 ft before becoming airborne. When about 8 to 10 m above the ground it yawed to the left and pitched nose-down. Contact with the ground was made in a nearly level attitude, first by the outboard fairing doors of the left wing flap, then by the left side of the fuselage belly, hitting the bank of a drainage ditch, which parallels the left (west) side of the runway at a distance of 28 m from the runway. The aircraft then disintegrated and caught fire within 100 m of travel.

Airport personnel and others who witnessed the accident ran towards the site and tried to assist in personnel evacuation. The airport fire department, helped by the fire services of the city of Izmir and of a nearby military airport, was able to control the fire and then extinguish it. Simultaneously the injured crew members and passengers were taken to hospital for medical care.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	60 adult 2 infant	-
Non-fatal	1	5 adult 1 infant	-
None	-	-	

1.3 Damage to aircraft

The aircraft was destroyed by the impact and subsequent fire.

1.4 Other damage

None.

1.5 Crew information

The Pilot-in-command, aged 37, married, was the holder of a valid airline transport pilot licence with F-27, F-28 and instrument ratings. He graduated from the Air Force Academy in 1958 and had 2 600 flight hours, including F-86, F-104 and T-34 jet time. In 1970 he resigned from the Air Force to join Turkish Airlines. He received F-28 training in the Kingdom of the Netherlands and in Turkey, and became a captain in 1972. In 1973 he was qualified as an F-28 check pilot. He had accumulated 1 903 flight hours in F-27 and 577 in F-28 aircraft.

The Co-pilot, aged 36, married, was the holder of a valid airline transport pilot licence with F-28 and instrument ratings. He was a graduate of the Air Force Academy. When he resigned from the Air Force in 1973 he had a total flying experience of 2 794 hours including C-47, Viscount, C-54 and H-19 helicopter time. In 1973 he joined Turkish Airlines and completed F-28 training in the Kingdom of the Netherlands. Before the accident he had flown 395 hours, all in F-28 aircraft.

1.6 Aircraft information

The aircraft, serial number 11057, was built in 1972 by Fokker-VFW NV. It met requirements and Airworthiness Certificate L-1954 was issued on 23 November 1972 by the Netherlands Civil Aviation Authority. Also a type certificate for F-28 aircraft was granted by the U.S. Federal Aviation Administration. A Turkish Airworthiness Certificate was issued to this aircraft and it was registered as TC-JAO on 9 January 1973 with annual renewal. According to the records the Airworthiness Certificate was valid until 13 December 1974 and there had been no damage sustained and no unusual mechanical difficulties encountered prior to the accident. Relevant documents revealed that all periodic inspections and required maintenance had been performed. Examination of the weight and balance document showed that prescribed limits were observed. No contamination of the JET A-1 fuel supply was found. Shortly before departure the aircraft was checked by the pilot-in-command and ground technicians by a walk-around inspection.

1.7 Meteorological information

According to reports issued by the Cumaovasi Airport Meteorological Office the weather conditions were as follows:

Hour	Visibility	Wind	Temperature	Clouds	Pressure	Humidity
0445 GMT	7 km Slight fog	$200^{o}/02$ knots	$0^{o}/0^{o}C$	1/8 So 3 000 1/3 Ac 10 000 3/8 Ci 20 000	1 022.0 mb 30.18 in	97%
0545 GMT	5 km Slight mist	$310^{o}/02$	$0^{o}/-1^{o}C$	1/8 So 3 000 2/8 Ac 10 000 3/8 Ci 20 000	1 022.2	95%

According to reports issued by Cigli Airport Meteorological Office (approximately 15 km distant) the temperatures and humidities recorded there were as follows:

Date	Hour	Temperature	Humidity
25 Jan 1974	2100 GMT	4/3	91%
26 Jan 1974	0100 GMT	1/-1	91
26 Jan 1974	0400 GMT	0/-2	95
26 Jan 1974	0500 GMT	3/2	97
26 Jan 1974	0700 GMT	6/1	90

1.8 Aids to navigation

Not applicable; however, at Izmir there are navigation aids, such as VOR and NDB. Inspection revealed that those aids were in normal operation and there were no NOTAM pertaining to them.

1.9 Communications

Normal VHF communications existed between the aircraft and the tower. Permission to taxi and take-off was obtained.

1.10 Aerodrome and ground facilities

a) Aerodrome. Cumaovasi Airport has one runway, 17/35, which is asphalt covered, 150 by 6 005 ft. On its east side, 150 m from the runway edge the terrain begins a gradual rise. On the west side, approximately 28 m from the runway and parallel to it, there is a drainage ditch having an average depth of 1.3 m. Near the north end of the runway and 50 m west of it there was a gravel pile 7 to 7.5 m high. South of this, but 150 m from the runway, was a quantity of empty 50 gallon drums stacked 2 to 3 m high.

b) Fire and rescue facilities. Cumaovasi Airport has two jeeps, each one carrying 136 kg of dry chemical dust and one fire fighting truck with a capacity of 400 litres of foam and 4 tons of water. There was one ambulance equipped with four 20 kg CO_2 bottles. On the date of the accident the fire fighting truck was inoperable but the other vehicles were serviceable and used. In the fire fighting and rescue team there were two drivers and three firemen on duty. Off-duty personnel in the area also participated in the rescue operation.

The fire fighting trucks and ambulance were situated in front of the hangar and were ready when the aircraft engines were started. The take-off and accident were seen by the firemen and the alarm was given also by the tower operator. The fire fighting team arrived promptly at the scene of the accident and began fire fighting and rescue operations. Ten minutes later one fire fighting team arrived from the Gaziemir military airport and one from the city of Izmir. They were of considerable help in putting out the fire in the total time of 30 minutes.

Military and civilian personnel in the area assisted in sending the injured crew and passengers to hospitals.

1.11 Flight recorder

The aircraft was equipped with flight recorder Sundstrand UCDD Model FA-542, S/N 4606. It was found in good condition and sent to the U.S. National Transportation Safety Board for analysis. The following data was provided by the read-out:

Recording was started before take-off and lasted for 1.30 minutes, until the time of the accident.

Elevation - The height record did not show any real elevation but the fluctuation in static pressure and the statement of witnesses indicated that the aircraft reached a height of approximately 8 to 10 m above the ground.

Velocity - The airspeed indicator line started recording 3 seconds before the aircraft was lined up with the runway heading which indicates a rolling take-off was made. The maximum recorded speed was 133 KIAS. In the last 4 seconds the line was found to be meaningless.

Magnetic heading - The heading trace shows that take-off was on Runway 35. In the total recording time of 20 seconds the aircraft heading had veered left to 289 degrees at power cut-off time. The airspeed, when heading change occurred, was 124 KIAS.

1.12 Wreckage

Examination of the accident site

Inspection showed that the aircraft had a ground run of 3 200 ft, became airborne to an altitude of about 8 to 10 m, then banked to the left and first hit the ground slightly with the left wing flap outboard fairing doors. After 16.5 m of travel the left wing was raised and for 45 m was in apparently level flight. Then it banked left and touched the ground again with the fairing doors. Thereafter, the left side of the fuselage belly contacted the bank of the drainage ditch which was 50 cm above the runway surface. Shortly afterwards impact with the ground ruptured the left wing fuel tank and fire started.

From that point, aircraft disintegration began and the tail and engine empennage separated from the fuselage, overtaking it and striking the forward fuselage between the cabin and cockpit sections. This resulted in separating the cockpit from the passenger cabin. The main fuselage turned upside down. The nose section, passenger door and a part of the service door scattered ahead of the fuselage's final travel and came to rest in the stack of empty drums (mentioned in 1.10).

Detailed inspection

As shown in the attached sketch* the aircraft diverted heading 45 degrees to the left on reaching a point 4 050 ft down the runway; after hitting the bank of the ditch the aircraft disintegrated within 100 m and caught fire. The main fuselage, wings and some other parts burned out completely where they were scattered.

During disintegration the nose wheel spar went 30 m to the left of the fuselage and one tire from the main landing gear came off and travelled 110 m eastward. Flap actuator spindles were found in a burned-out condition. Subsequent examination of the spindles substantiated symmetric flap extension of 18 degrees.

1.13 Physical and pathological information

The physical condition of each pilot was satisfactory according to 6 month periodic medical certificates prepared by government hospitals designated by the Ministry of Health. Both the pilot-in-command and co-pilot licences were renewed according to these medical reports. Examination of these reports revealed no evidence of any diseases.

1.14 Fire

As explained above, the aircraft was destroyed by fire except for the tail, engine and cockpit sections.

1.15 Survival aspects

The accident was not survivable. Because of the quick starting fire, which spread over the accident site, it was not possible to save all passengers and crew with the attendant fire fighting and rescue facilities.

1.16 Tests and research

Some parts and components, listed below, were taken from the wreckage and sent to the appropriate manufacturer for testing and examination. The results showed no failures and normal functioning before the accident.

Parts and components sent to Rolls-Royce

Fuel flow
Fuel backing pump (LP)
Fuel pump (HP)
Air flow control
Regulator
Top temperature control actuator
Low pressure governor

*ICAO Note: Sketch not reproduced.

Parts and components sent to Fokker-VFW

Lift dumper manifold
Elevator booster unit
Tension regulator
Elevator gust lock unit
Auto pilot elevator servo unit
Stabilizer control unit
Rudder control unit
L.H. aileron control unit
Voice recorder tape

In addition, two stick shakers were tested in Turkish Airlines' facilities and found normal.

2.- Analysis and Conclusions

2.1 Analysis

The aircraft remained overnight at Cumaovasi Airport in an open area. In the morning, 26 January at 0400 GMT, the temperature was 0 degrees C and the relative humidity was 95 per cent. When the take-off was made the temperature had reached +3 degrees C and the humidity 97 per cent. In that weather condition some frost accretion existed on the upper wing surfaces and elevators. (The same kind of frost occurred on the wings of another F-28 waiting at the apron at the same hours next day under almost the same meteorological conditions.)

During the walk-around inspection prior to take-off, frost formation was not noticed. It is quite possible that the temperature on the wings and tail of an aircraft parked overnight in the open could be even lower due to radiation.

The length of Cumaovasi runway is 6 005 ft. According to the temperature and to the load of the aircraft a run of 2 800 ft is required to reach V_1 and V_R. Indications of the flight data recorder were that the aircraft became airborne when it reached 124 kt and a 3 200 ft run. The data recorder also showed that the speed of the aircraft reached 133 kt then dropped to 124 kt when it veered left. This indicates that the aircraft was rotated more than the normal angle of attack. It is believed that the frost accretion on the wings caused the aircraft to stall soon after take-off, whereas it would have flown safely in normal conditions.

Because of the low altitude after take-off the pilot could not recover from the stall.

2.2 Conclusions

a) Findings

1. The aircraft was in an airworthy condition.
2. The pilots were properly licensed and rated.
3. Periodic maintenance checks had been performed.
4. The Cumaovasi Airport is suitable for F-28 aircraft operation.

5. The fire fighting team and equipment were not adequate for a large fire.

6. Examination of the same type of aircraft which remained overnight at Cumaovasi, on the day following the accident, showed frost accumulation on the wings with more on the left wing than on the right one, which was towards the buildings.

7. Subsequent detailed examination of the parts and components removed from the wreckage showed no defects.

8. It was learned that on 25 February 1969 an F-28 of another airline, experienced a stall on take-off attributable to frost on the wings.

9. Examination of a sample of hydraulic oil taken from the wreckage revealed that the oil was dirty but it was not contributory to the accident.

10. Inspection of oil spot samples taken from the runway showed no evidence of having originated from this aircraft.

b) Cause or Probable cause(s)

The aircraft stalled on take-off due to over-rotation and frost accretion on the wings.

ICAO Ref.: AIG/006/74

No. 12

Turkish Airlines, DC-10-10, TC-JAV, accident in the Ermenonville Forest, France, on 3 March 1974. Report, dated February 1976, released by the Secrétariat d'Etat aux Transports, France and published in English by the Department of Trade, United Kingdom, as Aircraft Accident Report 8/76.

1.- Investigation

1.1 History of the flight

On Sunday 3 March 1974, DC-10-10, registration TC-JAV, landed at Orly at 1002 hours, as scheduled for flight TK 981 Istanbul-Paris-London on which it was engaged.

On landing there were 167 passengers on board, of whom 50 disembarked at Paris.

The aircraft was parked on stand A2 of the west satellite of Orly-Sud air terminal, where it was taken over by THY station staff and personnel of the airport services.

As regards the security of the TC-JAV parking stand, there was a gendarme stationed at a fixed point and surveillance by a mobile patrol of three men.

The refuelling operations entailed the supply of 10 350 litres of Jet A1 fuel.

In addition to the airline personnel, Paris Airport staff concerned with flight preparation and traffic operations, baggage and cargo handling, technical operations (apron starter unit, aircraft towing) and aircraft cabin cleaning were involved with the aircraft.

The normal stop is for 1 hour but was increased to 1 hour and 30 minutes because of the last minute embarkation of numerous passengers from British Airways and Air France. These fresh passengers numbered 216 and embarked after passing through the routine police checks.

During the stop electric power was provided by the auxiliary power unit from 1000 hours until the engines were started (the apron starter unit initially arranged for was not used). The door of the aft cargo compartment on the left-hand side was closed at about 1035 hours.

A radio car of the Air Transport Gendarmerie escorted the aircraft from the stand to the take-off runway threshold.

The sequence of events entailed by the departure procedure included the following, according to the times of the air/ground communications:

- 1111:30 hours: First contact with Orly-Prévol for departure operations.

- 1124:00 hours: Clearance by Orly-Sol to taxi to Runway 08.

- 1128:40 hours: Clearance by Orly-Airport to line up on the take-off runway - departure route 18[1] - initial climb to flight level 40.

The meteorological conditions were good:

- Wind: 060°/10 kt

- Cloud: 2/8 Cumulus at 900 m

- QNH: 1016.2 mb

- QFE: 1004.4 mb

- Temperature: 6.2°C

The aircraft took off at approximately 1130 hours. The flight then proceeded as follows:

- 1133:00 hours: Orly-Départ cleared the aircraft for flight level 60.

- 1134:00 hours: TC-JAV reported at flight level 60 at which it was subsequently transferred to the North Area Control Centre.

- 1136:10 hours: After contact was made with the Area Control, TC-JAV was cleared to climb to flight level 230.

- 1136:35 hours: The Control asked the aircraft to turn to the left to Montdidier.

- 1137:00 hours: Flight level 70 was reached.

The read-out of the flight data recorder shows that, in accordance with the THY operating rules, the climb was probably carried out in the automatic mode of the flight control system. The end of the turn to Montdidier and stabilization on a heading of 345° occurred at about 1138 hours, flight level 90 was reached and the CAS was of the order of 300 knots.

Three or four seconds before 1140:00 hours, the noise of decompression could be heard on the cockpit voice recording, the co-pilot said: "the fuselage has burst" and the pressurization aural warning sounded.

- 1140:13 hours: The controller who was following the progress of flight TK 981 heard a confused transmission, a heavy background noise mingled with words in the Turkish language and the pressurization warning and then the overspeed warning.

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[1] Departure route 18 assigned to the aircraft included the following points: Tournan intersection, Coulommiers and Montdidier.

At the same time as the overspeed warning signal was heard, the label with the flight number "981" disappeared from the secondary radar scope. Flight level "130" remained on the scope for a few moments. On the primary radar the aircraft echo split in two: one part (which may correspond to the parts ejected from the aircraft) remained stationary at about 24 NM on a bearing of 045° from Orly and persisted for two or three minutes; the second part, the echo of the DC-10 itself, continued on a path which curved to the left from heading 350° to heading 280°.

- 1140:41 hours: The confused transmission ceased to be received by the Control.
- 1141:04 hours: A fresh very short transmission was recorded on the ground.
- 1141:06/07 hours: A final transmission was heard and continued until 1141:13 hours.

From 1141:50 hours, the controller made repeated calls to TK 981 but received no reply.

The various recordings (air/ground communications, cockpit voice recorder, flight data recorder) show that about 77 seconds elapsed between the time of decompression and the impact with the ground.

The flight data recorder shows that, in the seconds immediately after depressurization, the speed of No. 2 engine dropped sharply and the aircraft turned to the left (9°) and went into a nose-down attitude. This nose-down attitude increased rapidly (down to -20°) and the speed increased (360 knots) although Nos. 1 and 3 engines had been throttled back. The pitch attitude then decreased progressively to -4° and the speed became steady around 430 knots (800 km/h).

TC-JAV crashed in the forest of Ermenonville at the place known as "Bosquet de Dammartin", in the commune of Fontaine-Chaalis (Oise), about 15 km from the village of Saint-Pathus over which initial decompression and the initial loss of parts of the aircraft occurred. There was no fire.

At the accident site, 37 km NE of Paris, the aircraft was flying at high speed, 430 knots (about 800 km/h). It was banked to the left by about 17° and the angle of descent was of the order of 4°.

The aircraft cut through the forest from east to west and caused damage over a rectangular area of 700 m by 100 m.

No call was heard on the distress frequency (121.5 MHz).

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	12	334[1]	-
Non-fatal	-	-	-
None	-	-	

[1] Including 6 passengers ejected from the aircraft over Saint-Pathus about 15 km from the main point of impact.

1.3 Damage to aircraft

After the ejection of the aft cargo door on the left-hand side and of various parts of the aircraft structure (floor, seats), the aircraft literally disintegrated on the subsequent impact at very high speed in the forest.

ICAO Note: Paragraphs 1.4 to 1.16 not reproduced (the Foreword refers).

2.- Analysis

2.1 Analysis of the process of ejection of the aft cargo door on the left-hand side

The initiating factor in this accident was the opening and ejection of the aft cargo door during flight.

Expert examination of the wreckage of the door, of which the closing system (latches, latch actuator and operating mechanism) was found in good condition, has revealed various deficiencies. The latter were such that the aircraft's take-off was undertaken with the latches very near to their correct position when closed, but at the same time the links which control the latches had not achieved over-centre (Fig. 2) and as a natural consequence the lock pins could not have been engaged.

Under these conditions, the chain of operation between actuator and latches is not irreversible: any force exerted on the latches is re-transmitted to the actuator instead of being absorbed by the 4 stops provided for that purpose (Fig. 1).

The actuator withstood the compression force without displacement of its shaft, since it is irreversible. It therefore transmitted the force from the 4 latches to the two bolts (titanium 0.25 inch in diameter) which attach its fixed part to the door structure.

The force on the latches is directly proportional to the difference between the pressure inside the fuselage and atmospheric pressure. The force is nil on take-off and increases progressively with altitude up to about 22 400 ft.

There is no way of knowing what measures were taken by the flight crew as regards cabin pressurization. No malfunction had been reported and the flight level of 240 chosen for cruise and the fact that the aerodromes of departure and arrival had the same elevation give reason to assume that pressurization was under automatic control. In that case, at 12 000 ft the cabin altitude was close to sea level and the fuselage pressure differential must have been between 330 and 360 mb (4.7 and 5.2 psi). It should be noted that these are figures of the same magnitude as those estimated in connexion with the previous accident at Windsor (Ontario).

The force transmitted to the actuator attachment bolts is the product of the force on the latches and the position of the lever arms of the system. (When the link arm pivots are at dead centre the force on the actuator bolts is zero; the force increases as the arms move away from the dead centre position.)

The door therefore remained closed as long as the two bolts attaching the actuator to the door structure withstood the increasing pressurization force.

When the two bolts gave way, the latches opened and the door opened suddenly after breaking the top shaft of the door actuator.

As a result of the sudden stress on the fuselage combined with the dynamic pressure of the air, the door broke into several pieces and became detached from the aircraft.

For the configuration of the door of TC-JAV, the studies undertaken have shown that the incomplete closing of the latches resulted from incomplete extension of the actuator shaft.

The tests and research on the parts recovered from the wreckage failed to establish the process with certainty.

- Either the control switch was maintained in an active position for too short a time (the modification contained in SB 52-44[1] had not yet been applied to TC-JAV so that a visual light indicator showing that the shaft had reached the end of its travel was not available to the operator).

- Or the extension of the actuator shaft stopped too soon because of:

  - the slip of its torque limiter;

  - the normal operation of the thermal protection trip device of the electric motor;

  - accidental cut-off of the electric power supply.

Since the electric motor of the actuator was not found after the accident, it is impossible to establish which of the above reasons was the cause of the actuator's malfunction.

Finally, it should be noted that the door had had to be closed by the manual drive tool on numerous earlier occasions, which would confirm the hypothesis of erratic functioning of the actuator.

2.2 Consequences of the ejection in flight of the aft cargo door on the left-hand side

The loss of the door caused an almost instantaneous drop in the pressurization established in the cargo compartment beneath the passenger cabin floor.

The various pressure relief vents between the cargo compartment and the passenger cabin are not of a size to accommodate a discharge of air as large as that which passed through the door which had suddenly opened. As a result, there was an instantaneous excess pressure above the floor of the order of 36 KPa (about 3.6 tonnes/m^2) in the same order of magnitude as in the case of the DC 10-10 N 103 AA accident on 12 June 1972 near Windsor (Ontario).

In the case of TC-JAV, this excess pressure, added to the normal stresses on the floor, caused damage such that parts of passenger seats were ejected from the aircraft together with six passengers probably occupying two triple seat units in line with and above the cargo door. This damage was therefore clearly more substantial than in the case of N 103 AA in which the initial floor loading was lighter.

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[1] Parts ordered by THY and supplied by Douglas, but modification not yet carried out.

Studies were undertaken in an attempt to reconstruct the damage sustained by the controls, but the impairment of their functioning could not be established in precise detail. Nevertheless, because all the horizontal stabilizer and elevator control cables are routed beneath the floor of the DC-10 and because of the priority assigned in this aircraft to each of these mechanical controls, the state of airworthiness of TC-JAV after the loss of the cargo door and the disruption of the floor structure must have been such that the crew were left with no means of regaining sufficient control of the aircraft.

3.- Conclusions

3.1 Results of the inquiry

The findings of the Inquiry are as follows:

- The crew members held the certificates, licences and qualifications required for the performance of their duties in the type of aircraft and on the flight in question.

- The aircraft was certificated, equipped and operated in accordance with national and international requirements; both on take-off and at the time of the accident, its load and centre of gravity position were within the appropriate limits.

- Nevertheless, as regards the aft cargo door on the left-hand side:

  - A service Bulletin 52-37, specifying the installation of a support plate designed to prevent forced closing of the locking handle and the vent door in the case of incomplete engagement of the latching system, had not been applied to the aircraft before delivery and this oversight had not been detected at the time of delivery. It was found, however, that work on the application of this modification had begun on the lock tube where chamfering had been roughly carried out.

  - While the aircraft was in service, a modification (direct access to the drive mechanism) had been carried out in a way which did not comply with Service Bulletin 52-38.

  - The adjustments of the lock pins and the lock limit warning switch were incorrect.

  - The striker of the unlock limit switch had two shims of Douglas origin, surmounted by a shim with no reference and of a quality not to aeronautical standards.

- During the aircraft's stop at Orly, the aft cargo door on the left-hand side had been closed without any apparent abnormality, the locking handle had been pulled down and the vent door closed, although the lock pins were not engaged and no visual inspection had been made through the view port provided for the purpose of verifying that the lock pins were in place.

- The take-off and climb progressed without incident until the aircraft reached approximately 12 000 ft at about 1140 hours.

- At the time, the aft cargo door on the left-hand side opened in flight and became detached from the aircraft structure.

- The drop in pressure in the cargo compartment caused an immediate pressure differential which was sufficient to cause the disruption of the floor structure and the consequent ejection of six passengers, their cabin seats and various pieces of wreckage.

- The deformation and disruption of the floor led to serious impairment of the controls of No. 2 engine and of the flight controls of which the cables run under this part of the aircraft structure and the damage was such that it was impossible for the crew to regain control of the aircraft.

- Because of the design of the mechanism as a whole, the incomplete application of modification SB 52-37 (absence of support plate specified) and the adjustments found on measurement to be incorrect (lock pins and striker), it was possible for the door locking handle to be pulled down without the use of any abnormal force and for the flight deck visual warning light to be switched off, when the latches were not fully engaged and the lock pins not in place. The tests and research have confirmed incomplete engagement of the cargo door latches and in correlation the non-engagement of the lock pins.

- The Inquiry into an accident at Windsor (Ontario) on 12 June 1972 had provided evidence of the grave risks entailed by sudden depressurization of the cargo compartment: the inadequacy of the pressure relief vents had resulted in the disruption of the floor under which the flight control cables run, thereby causing the jamming or rupture of the cables.

3.2 Causes of the accident

The accident was the result of the ejection in flight of the aft cargo door on the left-hand side: the sudden depressurization which followed led to the disruption of the floor structure, causing six passengers and parts of the aircraft to be ejected, rendering No. 2 engine inoperative and impairing the flight controls (tail surfaces) so that it was impossible for the crew to regain control of the aircraft.

The underlying factor in the sequence of events leading to the accident was the incorrect engagement of the door latching mechanism before take-off. The characteristics of the design of the mechanism made it possible for the vent door to be apparently closed and the cargo door apparently locked when in fact the latches were not fully closed and the lock pins were not in place.

It should be noted, however, that a view port was provided so that there could be a visual check of the engagement of the lock pins.

This defective closing of the door resulted from a combination of various factors:

- incomplete application of Service Bulletin 52-37;

- incorrect modifications and adjustments which led, in particular, to insufficient protrusion of the lock pins and to the switching off of the flight deck visual warning light before the door was locked;

- the circumstances of the closure of the door during the stop at Orly, and, in particular, the absence of any visual inspection, through the view port, to verify that the lock pins were effectively engaged, although at the time of the accident inspection was rendered difficult by the inadequate diameter of the view port.

Finally, although there was apparent redundancy of the flight control systems, the fact that the pressure relief vents between the cargo compartment and the passenger cabin were inadequate and that all the flight control cables were routed beneath the floor placed the aircraft in grave danger in the case of any sudden depressurization causing substantial damage to that part of the structure.

All these risks had already become evident, nineteen months earlier, at the time of the Windsor accident, but no efficacious corrective action had followed.

4.- Safety recommendations

After the accident near Windsor, Ontario, two safety recommendations were issued by the National Transportation Safety Board (NTSB):

- Recommendation A-72-97 relating to the modification of the cargo door locking system to make it impossible to position the locking handle and vent door to their normal door-locked positions unless the lock pins are fully engaged.

- Recommendation A-92-98 relating to the means of minimizing the effect on the flooring in the event of sudden depressurization of the cargo compartments.

The Ermenonville accident has shown that the modifications made to the locking system, modifications moreover incompletely applied to TC-JAV, were inadequate and that the measures proposed to mitigate sudden decompression had not been carried out.

Since the accident, the Certification Authorities and the manufacturer have decided to put new procedures and modifications into operation.

The Commission is of the opinion that their application should be mandatory and that they should be implemented as soon as possible in the case of all aircraft of the type in question.

In general, the Commission recommends that in the case of all the aircraft particular attention should be paid to the efficacy of the cargo door closing, locking and checking systems, and also to the behaviour of the flooring in the case of sudden depressurization of the cargo compartments.

Alongside the above measures, the fact remains that the case of TC-JAV has shown that the necessary redundancy of the flight controls could be inadequate when the routing of the systems as a whole was concentrated at points where structural damage could occur.

The case of TC-JAV has also drawn attention to the possible consequences of damage to a control circuit, damage which should never inhibit the operation of the surviving circuits.

The Commission recommends that the training of personnel responsible for operating the cargo doors or checking their closure should be organized in accordance with a detailed programme established by agreement between the manufacturer and the airline and approved by the official services.

Examination of the procedures used after the Windsor (Ontario) accident, in order to advise the manufacturer and the airline of the necessary modifications, has shown that the method of the "airworthiness directive" was not used; for that reason, the recommended measures were not mandatory and appropriate means were not employed to bring the matter to the attention of those concerned.

The Commission recommends that the mandatory procedure of "airworthiness directives", whatever the financial repercussions, should be selected whenever safety could be at serious risk.

As a result of the magnitude of the disaster and, in particular, the large number of victims, there were considerable difficulties in the recovery, preservation and identification of the bodies. It became apparent, in particular, that the Institut Médico-Légal de Paris and the Paris hospitals did not have facilities on a scale related to this type of situation.

The Commission recommends that a study should be made of the measures required to take account of the new problems raised by the large capacity of the aircraft.

ICAO Ref.: AIG/033/74

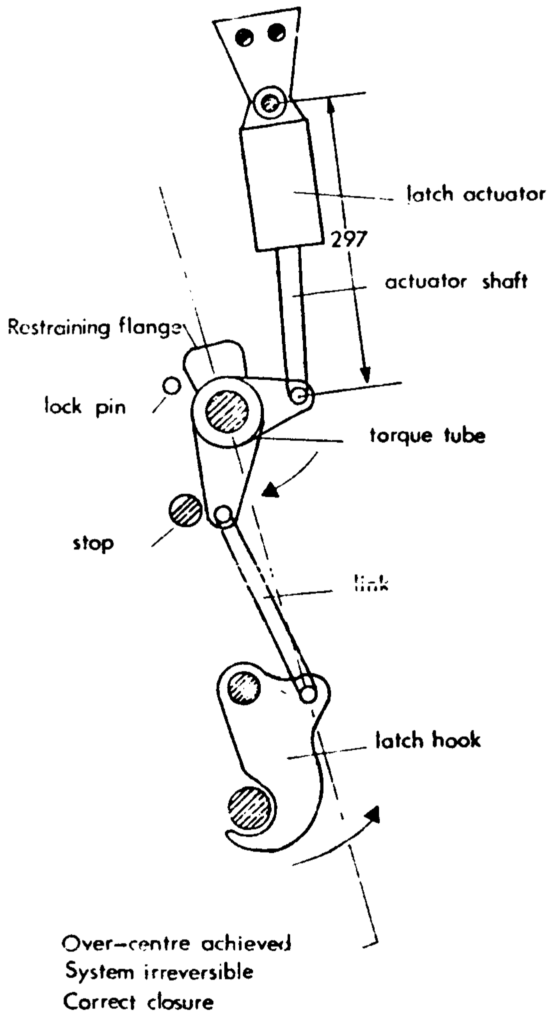


Figure 12-1

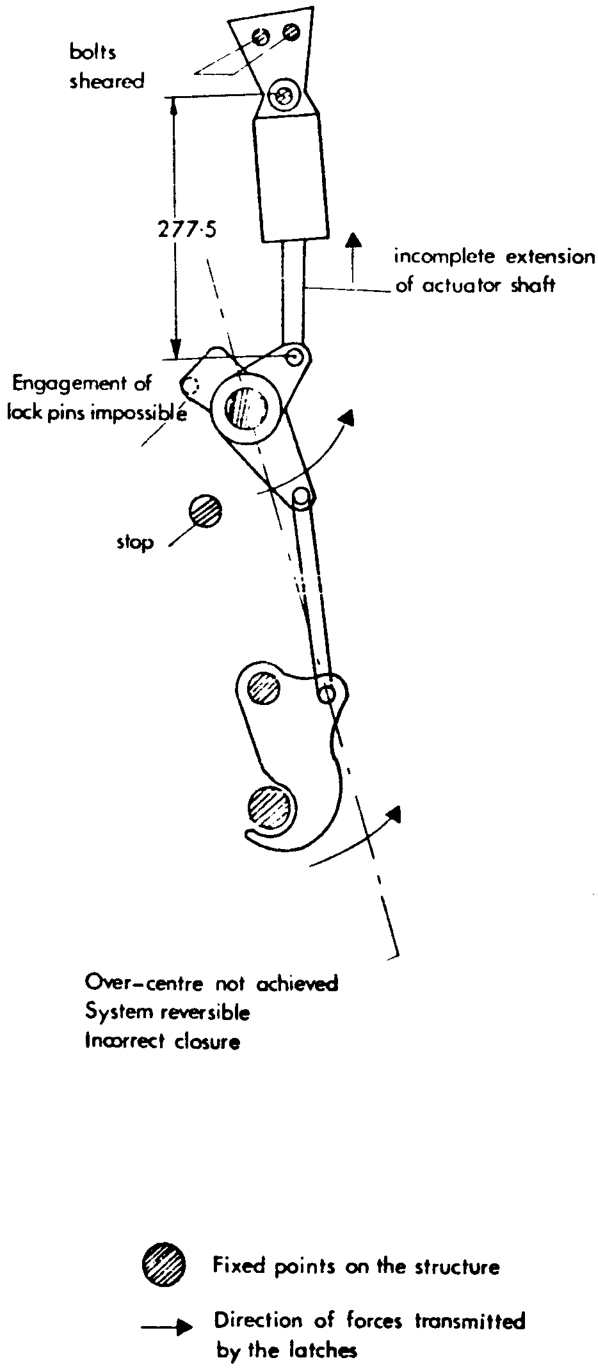


Figure 12-2

DC-10 Aft cargo door -
Latch closing system

No. 13

Pan American World Airways, Boeing 707-321C, N-446 PA, accident at Tinga-Tinga, Bali, Indonesia, on 22 April 1974. Report dated 20 March 1975, released by the Ministry of Transport, Communications and Tourism, Indonesia.

1.- Investigation

1.1 History of the flight

Flight PA-812 was a scheduled international flight from Hong Kong to Sydney with an intermediate stop at Denpasar, Bali. The aircraft took off from Hong Kong at 1108 hours* on an IFR flight plan via A-83 GYM B-67 BTT B-91 GPR B-61 VJN and Denpasar with an estimated en-route time between Hong Kong and Denpasar (Bali) of 4:23 hours.

Flight PA-812 was allocated flight level 330 from Hong Kong until BTT and thence proceeded at flight level 350 until Denpasar. The flight proceeded normally and position reports while in Indonesian UIR were carried out through Jakarta Radio on frequency 5 673 kHz.

At 1428 PA-812 was cleared by Jakarta Area Control Centre to descend to flight level 280. PA-812 established its first contact with Bali Tower at 1506 through Tower Frequency 118.1 MHz and was instructed by Tower to contact Bali control on frequency 128.3 kHz.

At 1508 PA-812 informed Bali Control of revised ETA 1527. A clearance to descend to flight level 100 was given by Bali Control and at 1509 a request was made by the aircraft for active runway. Runway in use 09 was passed on by Bali Control to the aircraft.

During descent to flight level 120, after observing that one of the ADF needles swung, at 1519 PA-812 reported over the station turning outbound and was subsequently instructed to contact Bali Tower. Twenty-five seconds later PA-812 established contact with Bali Tower informing outbound procedure, followed by a request for lower altitude.

Clearance was then given to descend to 2 500 ft and PA-812 was instructed to report reaching 2 500. At 1523 the aircraft reported reaching 2 500 ft and Bali Tower gave instructions to continue approach and to report when runway was in sight. Acknowledgement was made by PA-812 by saying "Check inbound". At 1526 the pilot-in-command requested the visibility by calling "Hey - Tower, what is your visibility out there now?".

However, according to the transcription of Air Traffic Control voice recorder this message was never received by Bali Tower. Apparently this was the last message transmitted by the aircraft. Bali Tower kept trying to contact the aircraft by calling "Clipper eight one two, Bali Tower" and "Clipper eight one two, Bali Tower, how do you read" several times. However, no answer was received from the aircraft. It was subsequently found that the aircraft hit a mountain approximately 37 NM North-West of Ngurah Rai Airport, Bali.

* All times herein are in GMT based on 24 hours.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	11	96	-
Non-fatal	-	-	-
None	-	-	

No identification and toxicological examination of the victims could be made. The number of victims stated above was based on the passenger manifest and the crew list.

1.3 Damage to aircraft

The aircraft was totally destroyed.

1.4 Other damage

Other damage was confined to the forest at the crash site.

1.5 Crew information

The pilot-in-command, aged 52, held a valid airline transport pilot's licence endorsed for Douglas DC-4 and Boeing 707/720.

At the time of the accident he had flown a total of 18 247 hours including 7 192 hours in Boeing 707/720 aircraft. His last FAA medical examination took place on 13 December 1973, with a limitation to wear glasses while flying an aircraft. He had flown 33 hours during the last 30 days and 3:40 hours during the 24 hours prior to the accident. His last proficiency check was carried out on 24 October 1973. His last entry to Denpasar was on 16 May 1973 on flight PA-811 from Sydney to Hong Kong via Denpasar.

The first officer, aged 40, held a valid ATPL endorsed for Boeing 707/720. At the time of the accident he had flown a total of 6 312 hours including 4 776 hours in Boeing 707/720 aircraft. His last FAA medical examination took place on 5 December 1973 and there were no limitations imposed. He had flown 40 hours during the last 30 days and 3:40 hours during the 24 hours prior to the accident. His last proficiency check was carried out on 7 December 1973. His last entry to Denpasar was on 16 July 1973 on flight PA-812 from Hong Kong to Sydney via Depensar.

The second officer, aged 38, held a valid Commercial pilot's licence and a current instrument rating. At the time of the accident he had flown a total of 4 255 hours including 3 964 hours in Boeing 707/720 aircraft. His last FAA medical examination took place on 8 March 1974 with no limitations imposed. He had flown 74:27 hours during the last 30 days and 3:40 hours during the 24 hours preceding the accident. His last proficiency check was carried out on 15 February 1974. His last entry to Denpasar was on 27 February 1974 on flight PA-812 from Sydney to Hong Kong via Denpasar.

The flight engineer, aged 48, held a valid flight engineer's licence. At the time of the accident he had flown a total of 14 375 hours including 7 175 hours in Boeing 707/720 aircraft. His last FAA medical examination took place on 5 November 1973 with a limitation to wear glasses while on duty in the aircraft. He had flown 26 hours during the last 30 days and 3:40 hours during the 24 hours preceding the accident. His last proficiency check ride was carried out on 21 March 1974. His last entry to Denpasar was on 17 December 1973 on flight PA-812 from Hong Kong to Sydney via Denpasar. The second flight engineer, aged 43, held a valid flight engineer's licence. At the time of the accident he had flown a total of 7 986 hours including 4 965 hours in Boeing 707/720 aircraft. His last FAA medical examination took place on 6 August 1973 with a limitation to wear glasses while on duty in the aircraft. He had flown 32 hours during the last 30 days and 3:40 hours during the 24 hours prior to the accident. His last proficiency check ride was carried out on 8 January 1974. His last entry to Denpensar was on 16 January 1974 on flight PA-811 from Sydney to Hong Kong via Denpasar.

1.6 Aircraft information

The aircraft, a Boeing 707-321 C having serial number 19268, was delivered to Pan American World Airways on 16 December 1966. The aircraft was received and operated in a passenger configuration. The total airframe hours since new until the last recorded maintenance was 27 943 hours. The total landings (cycles) were 9 123 up to the last recorded maintenance. The last recorded maintenance was accomplished at Hong Kong Airport at the termination of flight number 811 on 22 April 1974. The Certificate of Airworthiness of the aircraft was valid and the aircraft had been maintained in accordance with a continuous programme.

From the aircraft maintenance log it appeared that all actions to correct discrepancies had been taken and properly accomplished. All Airworthiness Directives, Engineering Authorizations and Quality Control Authorizations had been complied with. The last "A" check was accomplished at a ship time of 27 943 hours on 22 April 1974 at Hong Kong Airport, whereas the last "B" check was accomplished on 13 April 1974 at total aircraft time of 27 838 hours.

The powerplants were four Pratt and Whitney JT3D model 3 BAB engines.

Engine serial number 668583 was installed on N 446 PA on 9 April 1973 in the number one position. At the time of the last recorded maintenance accomplished at the termination of flight number 811/20 at Hong Kong Airport, the total engine time was 15 133 hours and the time since last overhaul was 15 133 hours, the total engine cycles were 5 590. The last combustion area inspection at TSO (time since last overhaul) 11 332, was done at a Periodic/Shop Visit on 24 July 1972. The test cell run was made on 15 September 1972.

Engine serial number ------ was installed on N 446 PA on ------------------ in the* number two position. At the time of the last recorded maintenance at the termination of flight number 811/20 at Hong Kong Airport, the total engine time was 18 475 hours and the time since last overhaul was 16 248 hours. The total engine cycles were 6 815. The last combustion area inspection at TSO 15 320, was done on a Periodic/Shop Visit on 31 July 1973. The test cell run was made on 19 September 1973.

* ICAO Note: The preceding words were added by ICAO as one line was apparently missing in the report.

Engine serial number 644755 was installed on N 446 PA on 4 March 1974 in the number three position. At the time of the last recorded maintenance at the termination of flight number 811/20 at Hong Kong Airport, the total engine time was 28 409 hours and the time since last overhaul was 10 596 hours. The total engine cycles were 9 388. The last combustion area inspection at TSO 9 723, was done on a Periodic/Shop Visit on 19 July 1973. The test cell run was made on 13 August 1973.

Engine serial number 667727 was installed on N 446 PA on 18 April 1974 in the number four position. At the time of the last recorded maintenance at the termination of flight number 811/20 at Hong Kong Airport the total engine time was 20 049 hours. The total engine cycles were 6 040. The last combustion area inspection at TSO 19 999, was done on a Periodic/Shop Visit on 5 July 1973. The test cell run was made on 2 April 1974.

1.7 Meteorological information

Advisory route forecast issued for PA-812 was sent to Hong Kong by Ngurah Rai Airport at 0415 hours 22 April 1974.

According to the transcript of the Cockpit Voice Recorder, at 1519:42 Bali Tower informed PA-812 that the surface weather at Bali Airport was as follows: wind 110/5 kt, altimeter setting 29.87 in Hg.

According to the meteorological report for take-off and landing made by the meteorological officer at Bali Airport at 1500, the surface weather at Bali Airport was as follows:

Date and time	: 22 April 1974, 1500.
Surface wind	: 110/5 kt.
Horizontal visibility	: 8 NM.
Cloud	: 1 Oktas Cu 2 000 ft.
Altimeter setting	: 1 011.6 mb or 29.87 in Hg.
Pressure at aerodrome elevation:	1 011.1 mb or 29.86 in Hg.

According to eyewitness observations, the weather at the accident site was clear (cloudless), the stars were bright and it was moonless.

1.8 Aids to Navigation

The Denpasar VOR (DPS - 115.5 MHz) is located approximately 10 kilometres South of the runway, having dual 200 Watts transmitters. The first commissioning check was carried out by the Federal Aviation Administration in July 1969. The last routine flight check, prior to the date of the accident, was carried out in February 1974. No significant troubles and/or repairs had been noted during March/April 1974. This was also stated in the maintenance log as well as in pilots' debriefings. Ngurah Rai International Airport is also equipped with an NDB (OR - 230 kHz). This is a high range beacon (300 NM) with dual transmitters. No significant troubles and/or repairs had been logged during March/April 1974. The NDB was reported functioning normally. Pilots' debriefing log was maintained and no discrepancies were reported.

1.9 Communications

At 1500 PA-812 attempted several times to establish contact with Bali Approach on 119.7 MHz and Bali Tower on 118.1 MHz but to no avail.

Contact was finally established at 1506 with Bali Tower on 118.1 MHz and PA-812 was then instructed to contact Bali Control on 128.3 MHz. Subsequently the communication between the aircraft and the ground was normal. No message indicating evidence of either distress or emergency was received by Bali Air Traffic Control prior to the accident.

1.10 Aerodrome and ground facilities

The aerodrome obtains its electric power from the main city electric power supply, however standby generators are available.

It is equipped with runway lights, threshold lights, taxiway lights, VASI, rotating light beacon and landing tee. The rotating light beacon was unserviceable during the time of the accident.

No failure of electric power supply was experienced at the time of the accident.

1.11 Flight recorders

The aircraft was equipped with a flight data recorder and a cockpit voice recorder. Both recorders were found on 16 and 18 July 1974 respectively after an intensive two-week search at the crash site. The flight data recorder having serial number 443 and the cockpit voice recorder having serial number 870 were sent to the National Transportation Safety Board, USA, for read-out and evaluation.

a) Flight data recorder

The flight data recorder was a LAS 169-C model having serial number 443. Examination of the cassette showed minor mechanical damage. The foil recording medium was removed from the cassette and found to have several mechanical tears and deformation due to impact, apparently as a result of the accident. No evidence of fire or heat damage was noted on the cassette or foil. It was noted that all parameter traces had been recording at the time of the accident. Basic reference measurements disclosed that the recorder had been operating in a manner consistent with the current calibration with no evidence of recorder malfunction or recording abnormalities. The read-out done by the NTSB laboratory was started at a point when the aircraft was at cruising altitude of 34 000 ft pressure altitude and covered the last 39 minutes and 30 seconds of recorder operations. The read-out covers a period of several seconds after impact, however, the exact point of impact was not definitely established.

b) Cockpit voice recorder

The cockpit voice recorder was also recovered and sent to the U.S. National Transportation Safety Board for evaluation. It yielded a good readable tape and a transcription was made of the last thirty minutes of the flight. The NTSB's comprehensive read-out indicated that evaluation started at cockpit voice recorder time of 1456:14 and the read-out indicated that the impact occurred at 1526:42.9. A review of the tape revealed that the cockpit voice recorder had been operating satisfactorily up to the time of the accident.

1.12 Wreckage

The accident occurred in rough mountainous terrain with trees 20 to 30 m high. The crash site is located at an elevation of approximately 3 000 ft above mean sea level and approximately 37 NM North-West of Ngurah Rai Airport. Judging from the cuts of the trees the aircraft's heading prior to impact was estimated to be between 155 and 160 degrees. It appeared from the cuts of the trees that the aircraft hit the mountain in a banked position.

The aircraft disintegrated after its final impact and the wreckage was scattered within a radius of 50 m from the point of impact.

Thorough investigation at the crash site revealed that no fire broke out prior to the accident.

The burnt area at the place of aircraft impact, which showed signs of fire from below towards the top of the trees, led to the belief that fire only occurred after the aircraft hit the ground. Further examination of the wreckage revealed that the main and nose landing gears were in down and locked positions. It was found that the right-hand wing tip struck several trees first at approximately 50 m from the impact point and then the aircraft entered a gap approximately 100 ft wide between two large trees. The right hand wing was sheared off at its root and broken into four parts. The left hand wing struck a ridge and was broken into three separate parts. It was observed that a burnt area was shown close to the main impact area, which indicated that fire broke out immediately after impact. From the distribution of the wreckage no evidence of in-flight explosion could be found.

2.- Analysis and Conclusions

2.1 Analysis

Examination on the disposition of the wreckage and inspection of the site indicated that no structural failure of the aircraft occurred before impact. No indication of any malfunctioning of engines or break up prior to impact of the aircraft with the ground was found. The Board did not find any evidence that may indicate that the aircraft was not in an airworthy condition at the time of the accident. Examination of the cockpit voice recorder revealed that the pilot-in-command of the aircraft experienced some difficulties in establishing contact with Bali Air Traffic Control. First contact between the aircraft and Bali Tower was established at 1506 whereupon Bali Tower instructed PA-812 to contact Bali Control on frequency 128.3 MHz, because the aircraft was still within the jurisdiction area of Bali Control. This was acknowledged by PA-812 accordingly. Subsequently communication between the aircraft and the ground was normal.

The cockpit voice recorder further disclosed that the pilot-in-command had encountered no difficulty with the procedures to land at Bali Airport, in which it was mentioned to maintain at 12 000 ft until the beacon and then to execute the full ADF let-down procedure. The cockpit voice recorder also disclosed that the pilots were aware of the existence of a 7 500 ft mountain 26 miles North of Bali Airport, another 10 000 ft mountain north-north-east of the airport and that flight level 120 would clear them from the mountains mentioned above. From the conversation amongst flight crew members it was further disclosed that the estimated time of arrival was 1527, which was subsequently passed to Bali Control. It was further disclosed that the pilot intended to make a right hand turn within 25 miles from the beacon for a track out on 263 degrees, descending to 1 500 ft followed by a procedure turn over the water for final approach on Runway 09 which was the runway in use given by Bali Control.

As recorded by the cockpit voice recorder at approximately 1518 the crew observed that ADF number one was swinging while ADF number two remained steady. A few seconds later at 1519 PA-812 reported to Bali Control that he was over the station turning outbound descending to flight level 120. This was acknowledged by Bali Control and PA-812 was then instructed to change over to Bali Tower. Having established contact with Bali Tower, PA-812 reported making outbound procedure flight level 110 and requested lower altitude. Clearance was given by Bali Tower to descend to 2 500 ft, with instructions to report at that height. At 1523 PA-812 reported reaching 2 500 ft.

The Board is of the opinion that the crew in an attempt to expedite their approach into Bali Airport, elected to execute an early right hand turn for track out on 263 degrees. By using this type of approach they were prevented from knowing their exact position. Such an early turn would necessitate the pilot's obtaining an early indication on the ADF that the was nearing the NDB. Evidently the right hand turn was made at the time when only one of the ADF needles swung. According to the reconstruction of the flight path, based on information obtained from the flight recorder, it is evident that the right hand turn was made at a position approximately 30 NM North of the beacon.

Although several attempts were made to regain proper indication on the ADFs after the turn, the Board believes that this would not have been possible since the aircraft would be shielded by the mountain range. However, the approach was continued as planned resulting in a collision with high ground.

The flight data recorder and cockpit voice recorder read-outs revealed no evidence of any aircraft abnormality during any part of the flight prior to the accident.

2.2 Conclusions

a) Findings

1) The aircraft was properly certificated and airworthy at the time of accident.

2) There was no sign of explosion prior to impact.

3) There was no evidence of any break up in flight.

4) There was also no sign that may have indicated a possible fire prior to the impact.

5) The flight crew was properly licensed and experienced to carry out the flight. However, from the available data, the Board was led to believe that the pilot-in-command was not very familiar with the Indonesian Aeronautical Information Publication, specifically related to local procedures at Bali International Airport.

6) The weight and centre of gravity of the aircraft were within allowable limits at the time of the accident.

7) One of the ADFs swung while the other remained steady when the aircraft was still about 30 NM North of the beacon.

8) At this point the pilot initiated a let-down procedure by making a right hand turn for track out on 263 degrees, assuming that he was nearing the NDB.

9) No evidence was found regarding the possibility of interference to the ADF induced by radio broadcasting station.

10) The Board has not succeeded in determining the cause of the needle swing of one of the ADFs. It may have been caused by either external or internal interference.

b) Cause or
Probable cause(s)

The Board determined that the probable cause of this accident was the premature execution of a right hand turn to join the 263 degrees outbound track which was based on the indication given by only one of the ADFs while the other one was still in steady condition.

3.- Recommendations

The Board submits the following recommendations:

1. Operators should encourage pilots towards a more thorough knowledge of the aeronautical information published in the Operations Manual for a certain airport, to avoid the possibility of divided attention during the critical stages of the approach.

2. Vigilant observation by the Operator's Flight Safety Officer to help them avoid accidents due to human error during a possible accident prone stage in the course of their career would be welcomed by even highly experienced pilots.

3. Although it has no bearing on this particular accident, the installation of a DME in addition to the existing VOR at Denpasar would be of great help to aircraft.

ICAO Ref.: AIG/091/74

No. 14

Taxi Aéreo Opita, Viscount 785, HK-1058, accident on Cerro El Retiro, Colombia, on 8 June 1974. Report, not dated, released by the Departamento Administrativo de Aeronautica Civil, Colombia.

1.- Investigation

1.1 History of the flight

The aircraft took off from Bucaramanga at 2707Z for Cúcuta as flight No. 514, carrying 37/1 passengers and 6 crew; flying conditions were normal. At 2221Z it reported Bagueche at 13 500 ft, flying under visual flight conditions. It was cleared for a visual descent, and at 2227Z reported 7 000 ft under VMC, estimating Cúcuta at 2235Z.

From that moment all contact with the aircraft was lost and search and rescue operations were initiated. At dusk, information was received that an aircraft had crashed against Cerro El Retiro in the Municipality of San Cayetano. Coordinates of the accident site were: Long: 72°35'W and Lat: 7°50'N. The accident happened at 2230Z in sunlight.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	6	38	-
Non-fatal	-	-	-
None	-	-	

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

There was no other damage.

1.5 Crew information

The pilot-in-command, aged 42, held licences PTL-727 and PIV-420 in addition to VV-785 since 12 June 1972 and a first-class medical certificate No. 10992, valid until 30 June 1974. The flight check was valid until 29 May 1975. The flying hours, duty and rest periods were within the limitations laid down by the Administrative Department of Civil Aviation (ADCA). He had flown a total of 7 602 hours of which 5 318 as pilot-in-command and 2 806 in the type of aircraft in question, revealing adequate flying experience; in addition his log contained 198 hours under IFR conditions and 322 hours by night. His record contained an entry for an accident on 7 October 1971 in a Vickers Viscount, which was attributed to pilot factor, in that he incorrectly judged the distance between the aircraft and the ground and for another accident on 7 June 1973 which was attributed to metal fatigue. No infringements and/or sanctions were recorded.

The co-pilot, aged 33, held licence PC-1663 and first-class medical certificate No. 9637 valid until 31 January 1975; his flight check as co-pilot in the type of aircraft in question was valid until 21 November 1974. He had flown a total of 880 hours until 10 September 1973, of which 370 in the type of aircraft in question, revealing little flying experience. His record contained no entries for accidents, incidents or sanctions.

Also aboard were two stewardesses, who held the licences and medical certificates required for the type of aircraft in question, as well as a mechanic and a despatcher, with no active duties during the flight.

1.6 Aircraft information

The aircraft was bought by the operator from Alitalia in Rome, Italy, in November 1968; in October 1971, after accident damage had been repaired in Colombia, TAO was authorized to fly the aircraft to London, where it was overhauled in the workshops of Field Aircraft Services Ltd. for standardization according to the maintenance plan or programme followed by the British Aircraft Registration Board. The aircraft returned to Colombia in January 1972, being in possession of Certificate of Airworthiness No. 0303 valid until 1 January 1975.

The aircraft was involved in two accidents, one on 4 May 1970 and another on 27 May 1973, which damaged the powerplants and the leading edge of the left wing.

A check of the weight and balance calculation revealed that the aircraft was within the prescribed operational limits, both according to FAA Specification 814 for this type of aircraft and according to the Certificate of Airworthiness issued by the ADCA. The fuel was JP-1; based on the consumption calculation it was determined that at the time of the accident the tanks still contained approximately 565 gallons (3 760 lb).

1.7 Meteorological information

At 1730 hours, the approximate time of the accident, weather conditions at Cúcuta were as follows: wind 360°/8 kt, visibility 15 km, smoke, 2/8 cumulus at 3 000 ft, 3/8 cirrus at 20 000 ft, temperature 32°, dew-point 22°, barometric pressure 1 013 mb (29.88 in). There was a note to the effect that the airport was closed to single-engine aircraft from 0900 hours until 1515 hours because of 30 kt winds at 150°.

1.8 Aids to navigation

The Bucaramanga and Cúcuta beacons were available for this flight and were fully serviceable; the aircraft was equipped with ADF and VOR; those were also serviceable.

1.9 Communications

The exchanges between the aircraft and the tower and vice versa were normal until 1727 hours local time, at which time the aircraft reported 7 000 ft in VMC, estimating Cúcuta at 1735 hours.

1.10 Aerodrome and ground facilities

These had no influence on the accident.

1.11 Flight recorders

The aircraft was equipped with a voice recorder located in the lower part of the fuselage at station 888.958; it was not recovered.

1.12 Wreckage

The accident occurred against Mount "El Retiro" on the property of San Isidro, Municipality of San Cayetano, Department of North Santander. Ground marks indicated that the aircraft struck the ground perpendicular to the surface. The aircraft disintegrated under the violence of the impact and the subsequent explosion and fire. The wreckage was spread over an area 100 m^2; it was therefore impossible to check the instrument readings or the positions of switches and controls.

1.13 Fire

The aircraft caught fire as a result of the collision with the ground.

1.14 Survival aspects

An emergency was declared as soon as the Cúcuta control tower lost radio contact with the aircraft and search and rescue operations were initiated. Since the aircraft had not arrived at its destination at the estimated time, it was justifiably assumed that something serious had happened. At 1940Z the control tower received a call from Cúcuta police to the effect that a peasant had found the aircraft burned out on Cerro San Isidro, 10 minutes' flight away. At 2220Z the fire brigade reached the site and confirmed that the aircraft was burned out and that there were no survivors.

1.15 Tests and research

Progressive fatigue evidence was found in the top flange of the left tailplane spar. On request from the manufacturer's representatives in Colombia that component was sent to the factory for laboratory tests, in order to determine the possible cause of the failure.

1.16 Other pertinent information not already included

None.

2.- Analysis and Conclusions

2.1 Analysis

On the day of the accident the aircraft had completed the following flights: Bogotá-Neiva-Florencia-Neiva-Bogotá-Bucaramanga. The accident took place during the following stage, namely Bucaramanga-Cúcuta, when the aircraft had already flown approximately four hours and had made five landings. Recordings of messages at the control towers revealed that these flights were normal. The aircraft took off from Bucaramanga at 2007Z and at 2110Z reported Bagueche at 13 500 ft in VMC, so that it was cleared for a visual descent. The aircraft contacted the tower again at 2227Z, reporting 7 000 ft and estimating Bogotá at 2235Z; the pilot then requested the controller to contact the operator and to inform it of the need for a quick clearance because of the closeness of the deadline. These circumstances prompt the assumption that the pilot made his approach at the maximum authorized speed with the landing gear lowered, since this was the configuration of the aircraft at the time of the crash. Between 0900 and 1500 hours local time Cúcuta Airport remained closed for single-engined aircraft because of a 150^{o}/30 kt wind. At the time of the crash, however, conditions had improved markedly, the instruments indicating NNE winds at 8 to 10 kt; the possibility that this factor may have contributed to the accident is not discarded, since areas of turbulence occur fairly regularly in the region and these have a considerable effect on flight operations.

An examination of the aircraft wreckage and its location suggest the following:

a) The aircraft collided with the mountain in a 60^{o} nose-down attitude and perpendicular to the slope of the mountain, thus indicating that something serious had happened.

b) Since the aircraft disintegrated at impact, it was impossible to determine whether all its components were at the accident site. Reconnaissance flights were made along the flight path and a piece of tail section was found at a distance of approximately 1 500 m from the main wreckage. When examined this proved to be the left junction between the tailplane and the elevator. When these surfaces were inspected and tested, it was determined that the top flange of the tailplane spar showed evidence of a progressive fatigue failure over a distance of 3 in and of instantaneous fracture over a distance of 3/4 of an inch, similarly the bottom flange showed evidence of instantaneous fracture throughout its width in the same area. These findings clearly showed that the aircraft had sustained a total failure of the tailplane spar in flight, most probably on entry into a turbulent area, resulting in the loss of these components (left tailplane and elevator) and a complete loss of control of the aircraft.

The aircraft had been involved in one accident and two incidents in Colombia, during which the structure was subjected to major stresses and excessive vibration. Even though the prescribed repairs were carried out and the aircraft had been in service for a long time, it is quite possible that as a result of such mishaps the tail unit had been affected and that in time and because of the loads imposed in service the fault had progressed. When the structure was then subjected to a major stress beyond the point which it could withstand, the components failed completely. There are well-founded reasons to suggest that structural components are adversely affected when aircraft are regularly subjected to excessive vibration.

The pilot-in-command had considerable flying experience in Vickers aircraft, was disciplined and complied strictly with the technical operating standards, which prompts the conclusion that the flight was being made within the prescribed limitations and that pilot factor was not involved in this accident.

The aircraft had been duly certified by the ADCA for the scheduled carriage of passengers over the particular route. The aircraft log book showed that maintenance had been carried out in accordance with the plan recommended by the manufacturer; technical shortcomings were found in the presentation of the documents, in particular with regard to the implementation of service directives and the replacement of components during periodic servicing, but these factors had no bearing on the accident.

It should be pointed out that the structural failure occurred in an area to which access is difficult, since the fractured flange is underneath the attachment fitting of the left tailplane at a point in line with the outer bolt. The technical representatives of Vickers, who came to Colombia following the accident, stated that this type of fatigue in the tailplane spar was the first case to occur in the 400-odd aircraft of this type flying throughout the world.

Laboratory examination at the factory of the left tailplane revealed that its failure in flight had been caused by a fatigue fracture in the upper part of the tailplane. This fracture had started at the outer hole of the steel fitting at the spar flange where it joins the fuselage.

One eyewitness stated that he had seen the TAO aircraft fly through a vapour trail left by a jet flying from Cúcuta and that the former aircraft emerged on fire and in a nose-down attitude, also that he had seen flames from the rear section. This was discarded because an analysis of air traffic from Cúcuta and the air traffic control recordings revealed that only one jet aircraft was flying the following itinerary that evening. This aircraft took off from Bogotá at 2042Z and arrived at Cúcuta at 2122Z; on the return it took off from Cúcuta at 2215 hours reported 20 000 ft over Bucaramanga at 2230Z, Buenavista at 2243Z and finally landed at Bogotá at 2253Z, a total flying time of 43 minutes. Evidently the two sets of information cannot be reconciled, since at 2227Z the TAO pilot reported 7 000 ft in VMC, estimating Cúcuta at 2235 hours, at which time the jet was flying at an altitude above 20 000 ft and was about to overfly Bucaramanga. The other eyewitnesses confirmed that the aircraft was flying in apparently normal conditions until it disappeared behind the mountain en route to Cúcuta; seconds afterwards they heard the collision and then saw smoke rising between the mountain, revealing that the aircraft had crashed and burned. These statements were acceptable and agreed with the facts.

2.2 Conclusions

a) The crew members held the appropriate licences and the pilot-in-command had sufficient flight experience.

The aircraft documents were in order and the aircraft had been correctly loaded. Shortcomings were found in the implementation of the maintenance plan for the aircraft, but this fact had no bearing on the accident.

An examination of the aircraft wreckage revealed that the upper flange of the left tailplane spar had sustained a fatigue fracture, two distinct areas being visible, namely the area of progressive fatigue and the area of instantaneous failure. This evidence obviously explained the accident, since the already weakened structure was not able to withstand the loads imposed when the aircraft entered an area of turbulence. Laboratory tests subsequently carried out confirmed the failure.

b) Cause or Probable cause(s)

Aircraft structure factor - tail unit, involving the failure in flight of the tailplane spar, so that the left tailplane and elevator became detached and control of the aircraft was lost.

ICAO Ref.: AIG/195/74

No. 15

British Airways, Boeing 747-136, G-AWNJ, incident at Nairobi, Kenya, on 3 September 1974. Report No. 14/75, dated 20 October 1976, published by the Department of Trade and Industry, United Kingdom.

1.- Investigation

1.1 History of the flight

The aircraft was operating British Airways flight BA-029, a scheduled service from London (Heathrow) Airport to Johannesburg with intermediate stops in Zurich and Nairobi. The flight from London to Zurich was uneventful and after a crew change the aircraft departed Zurich at 2136 hours on 2 September 1974, 11 minutes behind schedule, with an estimated time of arrival (ETA) at Nairobi of 0513 hours (0813 hours local Nairobi time).

The flight proceeded normally with the pilot-in-command in the left hand seat piloting the aircraft and the co-pilot in the right hand seat handling most of the air-to-ground communications. A flight engineer was operating the flight engineer's station. The aircraft flew at flight level (FL) 330 until about 2 1/2 hours before ETA when it was re-cleared to FL 370. No significant weather was encountered en route and sunrise occurred at about 0330 hours.

When the aircraft was approximately 150 nautical miles (NM) from Nairobi the pilot-in-command briefed the co-pilot and the flight engineer for the approach and landing. Following normal Company* procedures he reviewed the aerodrome approach charts and noted the height of Nairobi above sea level (5 327 ft) and the appropriate safety heights for the area. He also discussed the aerodromes available for diversion. Anticipating that Runway 06 would be in use and that procedure "A" would be followed for an approach using the Instrument Landing System (ILS) (see Appendix A), the pilot-in-command declared his intention of carrying out a coupled-approach on the ILS with a manual landing once the runway had been sighted. Having obtained the weather minima appropriate to both a manual approach and an auto-approach from the Company manual, the crew set the movable indices on the pressure altimeters appropriate to 5 627 ft (manual minimum altitude above sea level) and those on the radio altimeters to 200 ft (coupled-approach minimum height above aerodrome elevation).

Shortly after this briefing had been given, radio communications were established with the Nairobi radar controller on frequency 119.5 MHz and the aircraft was cleared to the "Golf Golf" non-directional beacon (NDB) at FL 150 with no delay expected for an ILS approach to Runway 06. The 0430 hours Nairobi weather observation reporting two oktas of cloud at 800 ft was also passed to the aircraft. At approximately 0455 hours, when the aircraft was about 90 NM from Nairobi, the descent to FL 150 was commenced. During the descent a message was received informing the aircraft that a pilot who had just landed at Nairobi had reported that the cloud base was then at 300 ft.

* Throughout this report the word "Company" refers to British Airways (Overseas Division).

The aircraft was recleared to FL 120 on a revised heading of 160°(M) after it had been positively identified by radar at a distance of 46 NM from Nairobi. After it levelled off at FL 120 at 0504:00 hours with 30 NM still to run to the "Golf Golf" beacon, it accelerated gradually to 338 kt Indicated Air Speed (IAS). At this time the skies were clear and the Ngong range of hills, on whose summit the "Golf Golf" beacon is installed, was clearly visible. Beyond the hills, however, the plateau surrounding the airport was covered by low cloud.

At 0505:47 hours, when the aircraft was about 16 NM from the "Golf Golf" beacon, it was recleared to descend to FL 100. This descent was made with the throttles closed and at a rate of about 1 000 ft per minute with the airspeed gradually reducing. At 0508:13 hours the aircraft was instructed by radar to turn left on to a heading of 105 degs(M). During this turn the aircraft reached FL 100 and began to level off automatically under the control of the autopilot. The speed at this stage was 263 kt IAS and still reducing. (NB: the maximum speed for lowering 1 degree of flap, i.e. the first increment, was 265 kt IAS and the minimum speed for zero flap at the aircraft's weight was 213 kt IAS.)

The turn on to 105°(M) was completed at 0508:49 hours, and the pilot-in-command engaged the autothrottle 7 seconds later when the speed was about 235 kt IAS.

The No. 1 very high frequency (VHF) navigation receiver had been set in the R/W 06 ILS frequency by this time and the Nairobi VOR frequency left on the No. 2 set. Both automatic direction finding (ADF) receivers were tuned to the "Golf Golf" beacon.

At 0508:59 hours the radar controller advised the flight: "SPEEDBIRD ZERO TWO NINE YOU ARE PASSING THE GOLF GOLF BEACON THIS TIME DESCEND SEVEN FIVE ZERO ZERO FEET THE QNH IS ONE ZERO TWO ZERO DECIMAL FIVE".

The crew noticed that they were passing the beacon both visually and by reference to the RMI needles. Neither pilot heard the clearance correctly and believed they had been cleared to descend to "five zero, zero, zero feet". The co-pilot accordingly read back without hesitation: "ROGER SPEEDBIRD ZERO TWO NINE CLEARED TO FIVE THOUSAND FEET ON ONE ZERO TWO ZERO DECIMAL FIVE". This message was not acknowledged by the radar controller. It was also missed by the flight engineer. He has stated that although he thought that the word SEVEN was indistinct, he was nevertheless in no doubt that the aircraft had been cleared to 7 500 ft, a height that he was expecting as it was given on the airfield approach chart as the intermediate approach altitude. However, he remained unaware that the pilots had interpreted the clearance differently.

A reconstruction of the events on the flight deck subsequent to this point has been made using the information obtained from the flight data recorder, the RTF transcript and recording, simulator studies and crew statements. No information was available from the cockpit voice recorder. The reconstruction is shown in diagrammatic form at Appendix B together with a vertical cross section of the flight at Appendix C and a plot of the aircraft's track at Appendix D. From these studies, it has been deduced that as soon the clearance was received, the pilot-in-command disconnected the auto-throttle and put the aircraft into a descent. At the same time, the co-pilot dialled 5000 in the Altitude Selector on the autopilot/flight director mode selector on the pilots' light shield. The flight engineer saw this action but did not see the altitude selected as he was engaged in checking the ILS coding at the time.

At 0509:07 hours, when the airspeed was 228 kt IAS, the pilot-in-command called for 1 degree of flap and whilst this was being selected by the co-pilot, the flight engineer started the approach check. This occupied him for well over a minute and whilst he was engaged in doing this, both pilots reset their pressure altimeters to the QNH of 1020.5. The pilot-in-command continued to control the aircraft through the autopilot whilst the co-pilot retuned both the ADFs to the outer and inner locators respectively. Both pilots then checked the locator beacon identifications. At this point, the co-pilot advised the pilot-in-command that in accordance with the airfield approach chart, it was permitted to descend to below the sector safe altitude as the aircraft's position had been positively established over the "Golf Golf" beacon by radar.

The flight engineer continued with the approach checks and encountered one short delay only when he found the pilots too pre-occupied with other duties to respond to his altimeter challenge until he had repeated it three times. As the aircraft passed through 8 600 ft AMSL he checked the cabin differential pressure in order to cross check the aircraft's altitude.

The aircraft continued descending at about 1 900 ft per minute and soon entered the bank of low cloud when all visual reference to the ground was lost. When it passed through 2 500 ft above ground level the terrain clearance audio warning sounded and was duly noted by the crew.

At 0509:26 hours, when the airspeed had been reduced to 220 kt, the co-pilot selected 5^{o} flap and this took 28 seconds to achieve. At 0509:53 hours the radar controller advised the aircraft that it had 15 NM to run to the runway and that it was cleared to lock on to the localizer which it was approaching and descend on the glide path. The pilot-in-command then selected the ILS frequency on the No. 2 VHF NAV receiver himself, set the inbound QDM and switched the navigation mode switch to LAND. He then engaged the Nos. 2 and 3 autopilots in preparation for a coupled approach and at 0510:20 hours he called for 10^{o} flap.

At 0510:38 hours the automatic capture of the localizer was initiated and the aircraft banked into a left turn. It was probably descending through about 7 700 ft AMSL at this time at a descent rate of about 2 000 ft per minute and with the airspeed temporarily steady at 225 kt. The aircraft passed through the localizer and had to continue the turn and make further adjustments in heading before it stabilized on the inbound course. At this stage the flight engineer made a further check on the aircraft's altitude by cross reference to the cabin differential pressure.

At 6 000 ft AMSL the co-pilot called "One thousand to go" and shortly afterwards there was an audio warning alerting the crew that they were approaching their selected altitude. The ILS deviation warning light on each pilot's instrument panel then came on but, because it was unexpected, the pilot-in-command's initial reaction was that the warning was probably false. The flight engineer also noticed the warning on resuming his instrument scan after checking the pressurization and when he saw that the aircraft was still descending with the glide slope pointers out of view in the up position although on the localizer centre line, he called "We have no glide slope". The pilot-in-command replied "We have". (Later he explained that he understood the flight engineer to mean that the glide slope had failed and that he could see no failure flag to confirm this.)

At 0511:42 hours, whilst the aircraft was still descending at 217 kt and at about 1 650 ft per minute, it reached 270 ft above ground level (AGL) and the Decision Height (DH) audio warning tone began to sound. A few seconds earlier, the ATC had advised the aircraft that it was 8 1/2 NM from touch down and that it was cleared to land. The co-pilot began to acknowledge this message but his transmission was abruptly cut off in mid-word. At this moment the flight engineer called: "Two hundred feet decision height" and almost immediately afterwards, the aircraft broke out of the bottom of the cloud. The flight engineer called "Give full power - give full power" followed by "Check height - check height". The pilot-in-command, on sighting the ground, checked the rate of descent on the elevators, disconnected the autopilots and applied power for the overshoot. The time was then 0511:50 hours. From the flight recorder read out, it was established that at its lowest point, the aircraft came to within 70 ft of the ground.

At 0512:26 the aircraft called ATC that it was overshooting and it was cleared to climb to 7 000 ft. As it had already passed 7 300 ft by this stage the radar controller amended the clearance to 7 500 ft. When the crew came to set this figure in the Altitude Selector they saw the figure 5 000 which had been previously set and realized the error that had caused the premature descent and near collision with the ground. The aircraft was subsequently given radar guidance back on to the ILS and made a successful automatic landing.

The pilot-in-command remained convinced that he had been cleared to 5 000 ft and after landing he went with his crew to air traffic control to find out why he had been given an incorrect clearance. This was denied by the controller and the flight crew were allowed to hear a replay of the ATC tape. This initially appeared to them to confirm that the figure 5 000 had been given in the descent clearance but after the third playback it was agreed that the words spoken by the radar controller were "seven five zero zero feet".

The pilot-in-command completed a Company incident report form which was immediately transmitted to the Company's base at London (Heathrow) Airport. The crew were suspended from flying duties and returned to London as passengers.

1.2 Injuries to persons

None.

1.3 Damage to aircraft

None.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Forewords refers).

2.- Analysis and Conclusions

2.1 Analysis

This was a very serious incident which only avoided becoming a major catastrophe by the narrowest of margins. Superficially, the incident occurred simply because both pilots misheard an ATC instruction to descend to 7 500 ft. In all probability, had they not done so, the approach and landing would have been a well-planned and well-executed manoeuvre involving the minimum wastage of time and fuel; or at least would have appeared so. But on closer examination it is apparent that there was present a number of interrelated factors, involving environmental conditions, sickness, operational procedures and flight deck management, which made it highly likely that the crew would not be alert to errors made by themselves or others.

Obviously the central question is why the mistake over the clearance was not noticed in good time by the crew or the ATC. This aspect will be fully explored later, but first, an attempt is made to establish the reason for the error itself.

Air Traffic Control

The way in which the clearance was given, that is "DESCEND SEVEN FIVE ZERO ZERO FEET" was quite correct and wholly in accordance with international procedures. Probably the pilots' hearing of the clearance as "five zero zero zero feet" was because the word "seven" was apparently received so indistinctly as to be unheard and the word "five" appeared to be given greater emphasis. By concentrating on the number of zeros being given in the clearance, the pilots obviously overlooked the first figure. The fact that the co-pilot's readback was unchallenged by the ATC may well have submerged any subconscious doubts that he may have had about the correctness of it.

According to the ICAO Annex 10, Volume II, the controller's instruction to the aircraft to descend was one for which a readback was required. This implies that the controller should therefore have listened for the readback and challenged it when he heard that it was incorrect. Equally the pilots should have also requested an acknowledgement if they were in any doubt. It is self-evident that had the controller picked up the incorrect readback, the incident would not have happened, but his failure to do so cannot be explained solely on the grounds that he was under training. He was, in fact, a fully qualified air traffic controller who was simply being checked out in that particular position. The most probable reason for his failure to pick up the incorrect readback was that at the time, he was talking to the tower on the internal intercom to report that the aircraft had left the "Golf Golf" beacon. Also as the readback was spoken confidently and without hesitation, there was nothing in the co-pilot's tone of voice to alert the controller that there was any doubt about the clearance.

Terrain awareness

The reason why the pilots saw nothing wrong with a supposed clearance to descend to 5 000 ft in the Nairobi area is more difficult to determine. Presumably they both believed that the aircraft had been cleared to descend to 5 000 ft above ground level. This could possibly have been because they momentarily overlooked that Nairobi is not a sea level airfield.

This possibility would have been considerably lessened, as would any possible confusion over altitude clearances, had the crew been provided with log sheets on which to record QNH and other ATC instructions in a way that would enable a direct comparison to be made with airfield elevation and local safety heights.

Environmental factors affecting the crew

By the time of the incident, the crew had been on duty for 9 hours during what was otherwise their normal sleep period. Moreover, at 0500 hours their biochemical, physiological and psychological functions would have been at their lowest point on the normal circadian rhythmic cycle. Thus each of them would have been in a lower state of arousal than normal and therefore less likely to notice errors, particularly if made by one of themselves.

In the case of the co-pilot, there were additional factors which undoubtedly would have affected his over-all performance, foremost among which was his state of health. It seems clear that he was more affected by his bowel infection than he himself realized, which, coupled with the medication he was taking, most probably lowered his general level of alertness and his ability to assimilate the normal amount of information. There is no doubt that the co-pilot should not have been flying in this condition, but the reason for his doing so can be appreciated. Not only did he believe that the infection was clearing up, but also he had been given no indication by his local doctor that he should not fly. When he was called out at the last moment over the weekend for the flight, which he was keen to make, he did not consider it necessary to let the Company know that he had been prescribed medication for his condition. It has since transpired that the drug he was using can have side effects, which the United States Federal Aviation Administration, for one, consider incompatible with flying duties.

Last but by no means least was the co-pilot's relationship with the pilot-in-command as an additional stress factor. They had not flown together before, and the co-pilot would therefore have been keen to make a good impression, particularly in view of the pilot-in-command's considerable seniority. As a consequence of this, it is likely that the co-pilot tried to convey the appearance of alertness by carrying out his duties briskly, but due to his physical condition did so without much thought as to the implications of what he was doing.

From the foregoing therefore, it is reasonable to deduce that the physical and mental state of the crew was such as to make them prone to error, especially when faced with a sudden demand for activity after a long period in a state of relatively low arousal. This would have been particularly so in the case of the co-pilot.

Crew activity

The clearance to descend from FL 100 appears to have triggered off a period of intense activity by all three crew members. This is illustrated in the diagram at Appendix B, which shows that the crew were left with a considerable amount to do in the time available. The result of this was that each crew member became wholly absorbed in his own task to the exclusion of all else. The flight engineer was engaged in reading out the approach check list, which not only occupied him for well over a minute, but also required him to turn away from the pilots' panels in order to attend to his own. The co-pilot also participated in the approach check as well as monitoring the extension of the flaps and talking to ATC. It was also at about this time that he inserted 5000 in the Altitude Selector. The pilot-in-command appears to have been mainly pre-occupied with initiating the descent. It therefore seems likely that he reacted as soon as he heard the word "Descend ...." and did not pay the same regard to the second part of the clearance. A further indication of the extent to which each crew member was occupied with his own tasks was when, a short while later, the pilot-in-command found it necessary to tune the No. 2 VHF Navigation Receiver to the ILS frequency himself, which he needed to do in order to engage Nos. 2 and 3 autopilots. Similarly the flight engineer states that he had repeatedly to request the pilots to check their altimeter settings.

Aircraft speed

The unusually high work load of the crew after the aircraft had passed "Golf Golf" was undoubtedly related to the speed of the aircraft during the descent from FL 100. This seems to have been unnecessarily high and considerably above the recommended speeds appropriate to each flap setting (though not, it should be said, in excess of the relevant limitations). The speed could in fact have been reduced progressively to 164 kt as the flap was lowered in stages to 10 degrees, but in fact the pilot-in-command never allowed it to fall below 210 kt IAS and most of the time it was higher than that. This resulted in the crew having considerably less time than they might otherwise have had for preparing the aircraft for the approach and monitoring the progress of the flight.

In view of the deteriorating weather conditions that were reported by the pilot of a preceding aircraft, it might have been expected that the pilot-in-command would have considered it prudent to have slowed the aircraft down and perhaps have started the approach check before reaching "Golf Golf". Admittedly this check would not have progressed beyond the altimeter check whilst the aircraft was still above FL 100, but at least it would have spread the work load and given the crew more time to monitor the progress of the flight after the aircraft had passed "Golf Golf". As it was, the pilot-in-command allowed the speed to build to as high as 338 kt when the aircraft levelled off at FL 120, so that when the aircraft reached "Golf Golf" at FL 100, he had only managed to reduce the speed to 235 kt. He then had to initiate the descent immediately at a fairly high rate, thus making any further speed reduction more difficult to achieve.

The pilot-in-command's decision to keep the speed higher than desirable appears to have been based on commercial considerations as it appeared to him that by so doing, the aircraft would arrive at Nairobi on or within five minutes of the scheduled time. It is not uncommon practice for commercial or ATC reasons for the speed to be kept close to the maximum for small flap extensions during the initial and intermediate approach phases. There can, of course, be no objection to this provided that the consequences in terms of increased workload on the flight deck are appreciated.

Monitoring procedures

The main reason why the pilot-in-command did not properly evaluate the supposed clearance to 5 000 ft seems to have been because he was attempting to do too much himself. He appears to have placed too much reliance on the system of monitoring used by the Company, not realizing that this system had in fact ceased to function during a period of increased crew activity. If any of the crew gave any thought as to who was monitoring the flight after it had passed the "Golf Golf" beacon, it can only be supposed that each thought the other was. The disturbing conclusion to be drawn from this is that there could well be other occasions when, without the crew realizing it, no monitoring takes place.

The Company lays great stress on monitoring and has gone to considerable lengths to ensure that its B-747 pilots and flight engineers operate as integrated crews. It must therefore be of some concern that the system of monitoring allowed a comparatively simple error to remain undetected whilst the crew was under pressure, especially as that pressure was neither exceptional nor sustained.

In the light of this incident, it would seem therefore that a re-examination by the Company of its monitoring procedures is called for, particularly to ascertain if any measures can be taken that would enable the pilot-in-command to devote more of his attention to his over-all supervision of the flight during an approach in instrument conditions.

The Company's decision, made since the incident, to introduce a procedure for monitoring all changes of setting to the Altitude Selector will obviously go a long way towards preventing a recurrence of this type of incident.

Failure of the crew to respond to warnings and other indications

The greater part of this analysis has of necessity been concerned with examining the possible reasons for the clearance being misheard and why it was not noticed by the crew. It is also necessary to examine why, once the error was made, various warnings and other indications did not alert them to the fact that the aircraft had been programmed to descend into the ground.

Firstly it is necessary to appreciate that most probably both pilots were utterly convinced of the correctness of their actions thus far. Their conviction was quite unshaken by the terrain audio warning which occurred at 2 500 ft above the ground (i.e. at an indicated altitude of 8 200 ft) and they did not in any way relate this warning to the intermediate approach altitude of 7 500 ft given on the approach chart and which they must have discussed at the top of the descent. It transpires that this warning makes comparatively little impact on crews, because it occurs on each approach at least once. In particular it appears to have little significance when it is heard at the time it is expected, as happened on this occasion. It is thus understandable why no action was taken when the warning sounded. However, from this point on, the radio altimeters were indicating but only the flight engineer appears to have paid them any attention. He states that though he was concerned by the aircraft's apparent deviation from its expected flight path, he could not see the reason for it. Subconsciously, he was probably trying to relate the inconsistency of the aircraft's low altitude with the fact the landing check had not been carried out and that the aircraft was not on the glide slope. His inability to understand what was happening was probably due to his having been out of the monitoring loop for a period of a minute or more whilst he was reading out the approach check. He was probably reluctant to communicate his unease to the pilot-in-command when he suspected that it may have been himself that was wrong and not the pilots. He clearly thought it best to say nothing until he had re-oriented himself to the approach.

The next two warnings came within two seconds of each other, namely the ILS deviation lights and the altitude alert. Also coincident with these warnings was a call from ATC clearing the aircraft to land. At this stage the aircraft was descending through 500 ft above the ground and it was also at this point that the flight engineer advised the pilot-in-command that there was no glide slope and received the pilot-in-command's denial of this.

The altitude alert does not indicate proximity to the ground but only that the aircraft is approaching the selected altitude, which in this case was 5 000 ft. As both pilots were convinced that there was nothing wrong with descending to 5 000 ft although it was in fact 327 ft below airport elevation, the warning that the aircraft was approaching that altitude clearly had no implications of danger for them. The pressure altimeter bug was similarly of no value, even though it had been set to the minimum decision height, as it can only be set to between 0 and 999 feet.

The ILS deviation lights light up when the aircraft is displaced from the localizer or glide slope and when it is below 500 ft above the ground, through terrain warning is not their function. The pilots' immediate reaction to the illumination of the ILS deviation lights was that it was a false warning. This was doubtless because it did not conform to what they believed the aircraft to be doing at this stage, namely, descending to the intermediate approach altitude. The co-pilot's reaction may well have been conditioned not only by the fact that there was very little time in which to determine the reason for the warning, but also because he had only once before seen the lights operate and that was at a very late stage in the approach during a simulator detail in circumstances totally different from that of the incident.

From the foregoing it can be seen that the reason why the crew apparently ignored the three indications of the aircraft's close proximity to the ground was because only one of these specifically related to aircraft height namely the terrain warning at 2 500 ft AGL and that this occurred when it was expected. The other two were not primarily intended to warn when the aircraft was coming close to the ground and therefore did not cause the crew any undue concern. When the minimum decision height (MDA) warning sounded at 270 ft AGL the flight engineer seemed to be the first to realize what was happening, probably because he had just previously been alerted by the operation of the ILS Deviation Lights. He immediately responded by calling that the aircraft was at a low altitude. Even then, it was only when the aircraft broke cloud that the pilot-in-command at last appreciated the aircraft's danger and took overshoot action.

Ground proximity warning system

Although no GPWS equipment had been approved for use at the time of the incident, it is instructive to consider what effect the equipment would have had on the outcome had it been available. As has been shown, even if the earlier type had been installed in the aircraft at the time of the incident it would probably have warned the crew of the hazardous situation that was developing as high as 700 ft AGL and certainly no later than 498 ft AGL. Although these warnings would only have occurred seconds before the existing warnings on the aircraft operated, they would have served to prompt the crew into immediate action. Thus the mental block that appeared to exist in the minds of all three crew members as to what was actually happening would have been broken much earlier than was the case, and the aircraft would not then have come so dangerously close to the ground. As it was, it required an actual sighting of the ground at the very last moment to persuade the pilot-in-command to take recovery action.

Notwithstanding the above, it should still be said that even if a GPWS had been installed in the aircraft and had operated correctly, a substantial departure from the intended flight path would still have occurred. The implications of this in terms of a failure of flight deck procedures would therefore have been no less serious.

Cockpit voice recorder (CVR)

The investigation would have been considerably aided had the CVR recording for the period of the incident not been subsequently lost due to the recorder being erased during the normal shut down procedure after the aircraft had landed. It is considered that every effort should be made to encourage crews when practicable to pull the CVR circuit breaker as soon as possible after an incident or accident when the aircraft is on the ground so that essential evidence may be preserved.

The effect on incident reporting of the action taken against the crew

The incident first came to light because the pilot-in-command reported it immediately. This was clearly a highly responsible action on his part and one which he took without thought of the possible consequences to himself. It is, of course, impossible to predict what effect the action taken against the crew will have on the future of incident reporting by flight crews, but it would seem likely that it may well be discouraging.

2.2 Conclusions and findings

a) Findings

i) The crew members were properly licensed.

ii) The aircraft was free of defects and its documentation was in order.

iii) The crew was properly rested prior to the flight and at the time of the incident had been on duty overnight for approximately 9 hours.

iv) The co-pilot had been suffering from a persistent bowel infection for five weeks and this had had a debilitating effect on him. He did not inform the Company that he had been prescribed medication for the complaint by his own doctor. The drug which the co-pilot was using may have had undesirable side effects on the performance of his duties and his general level of alertness.

v) The co-pilot's previous experience of seeing the ILS Deviation Lights operate was confined to one simulator detail and in circumstances totally different from that of the incident.

vi) The performance of the crew was partly affected by the loss of a night's sleep and the reduced physical and mental responses associated with the early hour of the morning.

vii) The word "seven" in the ATC clearance was received less distinctly than the remainder of the message and accordingly the pilots misheard the clearance as one to descend to 5 000 ft.

viii) The co-pilot's readback of 5 000 ft was not acknowledged or corrected by the trainee radar controller.

ix) Following the receipt of the clearance, the co-pilot inserted 5000 in the Altitude Selector and the pilot-in-command was aware that he had done so.

x) The flight engineer also had difficulty in hearing the clearance to descend, but he nevertheless interpreted it to mean that the aircraft was cleared to descend to 7 500 ft. However, he was unaware that the pilots had misheard the clearance and had interpreted it differently, nor did he see the altitude that was inserted in the Altitude Selector.

xi) The speed at which the aircraft was flown during the initial approach phase was greatly in excess of the recommended speeds. This resulted in a high work load on the crew and directly affected their ability to monitor the flight.

xii) The pilot-in-command initiated a descent which was continued at an average rate of 1 800 ft per minute to within sight of the ground at approximately 200 ft AGL.

xiii) During the subsequent overshoot manoeuvre, the aircraft came within 70 ft of the ground at a distance of approximately 6 3/4 NM from the airport on the localizer centre line.

xiv) The pilots believed that the altitude to which the aircraft was descending was an intermediate approach altitude prior to glide slope capture and had overlooked the fact that the altitude pre-selected by the co-pilot was below the elevation of the airfield.

xv) The flight deck instrumentation and warnings correctly indicated the aircraft's actual flight path towards the ground, but the significance of these was not appreciated by the crew.

xvi) No specific instructions were given in the Company Flying Manual, current at the time of the incident that the settings to the Altitude Selector should be cross checked, though it was stated in the Crew Training Manual Part I that the flight engineer should do so during the descent.

xvii) The pilots did not cross refer the altitude to which they believed the aircraft had been cleared to descend against the intermediate approach altitude published on the aerodrome approach chart for Nairobi.

xviii) There was no provision made by the Company for crews of the B747 fleet to record altitude clearances received during the approach phase to enable a direct comparison to be made with airfield elevation.

xix) Had an approved Ground Proximity Warning System been available at the time of the incident, it would probably have given a warning of the aircraft's proximity to the ground at a height of 700 ft AGL and certainly no lower than 498 ft.

xx) The pilot-in-command's planning and conduct of the approach gave himself and his crew too little time to monitor the progress of the flight properly.

xxi) The pilot-in-command's over-all supervision of the approach was adversely affected by his personal preoccupation with the control of the aircraft.

xxii) The system of monitoring used by the Company on its B747 fleet did not function properly during the aircraft's approach to Nairobi at a time when the cockpit workload was high.

b) Cause or Probable cause(s)

The incident was caused by the pilots' acceptance of a height to which they mistakenly believed the aircraft had been cleared by ATC to descend and which was below the level of the surrounding terrain. Contributory factors were: the failure of the ATC controller to challenge the incorrect readback of the descent clearance by the co-pilot; inadequate crew monitoring; the relatively high speed of the aircraft's approach; the crew's low arousal state and the ill health of the co-pilot.

3.- Recommendations

It is recommended that:

1) Consideration be given by the Company to a re-examination of its B747 flight deck procedures with particular regard to the allocation of crew duties and monitoring responsibilities during the descent and approach phases of flight so as to enable the pilot-in-command to exercise his supervisory function to greater effect.

2) Consideration be given to ensuring that settings to the Altitude Selector in the B747 and similar devices in other types of aircraft be cross checked by all flight crew members when descents to the sector safe altitude and below are involved.

3) Consideration be given by design and airworthiness authorities to the provision of a mechanical or electronic lock on the Altitude Select facility, which can be preset, so as to prevent the subsequent selection of heights to below a safe minimum.

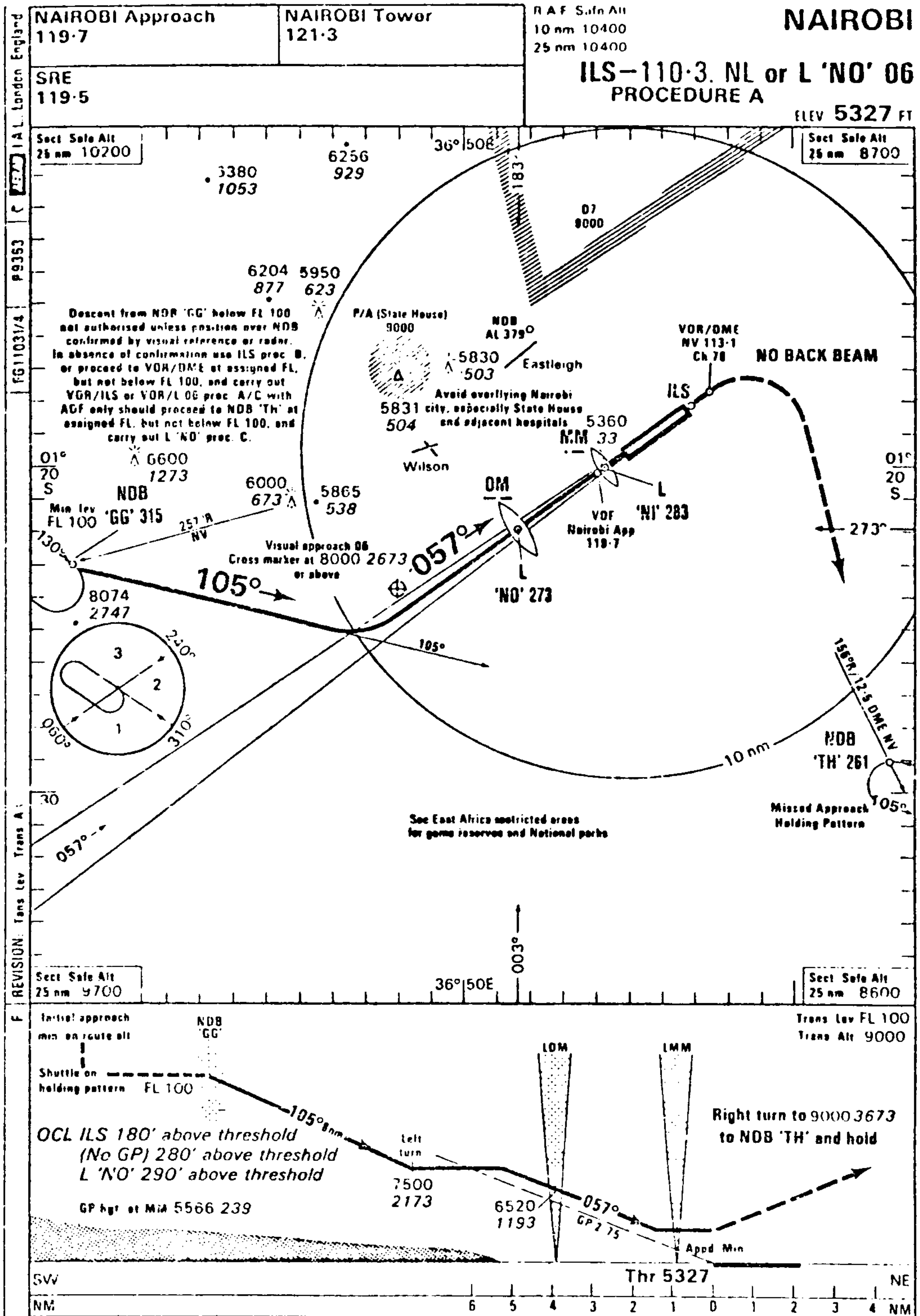
4) Flight crews be provided with log sheets on which altitude clearances can be recorded during the approach phase which will enable a direct comparison to be made with airfield elevation. Additionally provision should be made on the log sheets for recording ATC clearances during the approach phase.

5) Consideration be given by the Company to ensuring that crews of B747 aircraft receive adequate simulator refresher training in operating into high altitude airfields.

6) Consideration be given to requesting crews to switch off the Cockpit Voice Recorder as soon as possible after an incident or accident when the aircraft is on the ground so that essential evidence may be preserved.

ICAO Ref.: AIG/362/74

APPENDIX A

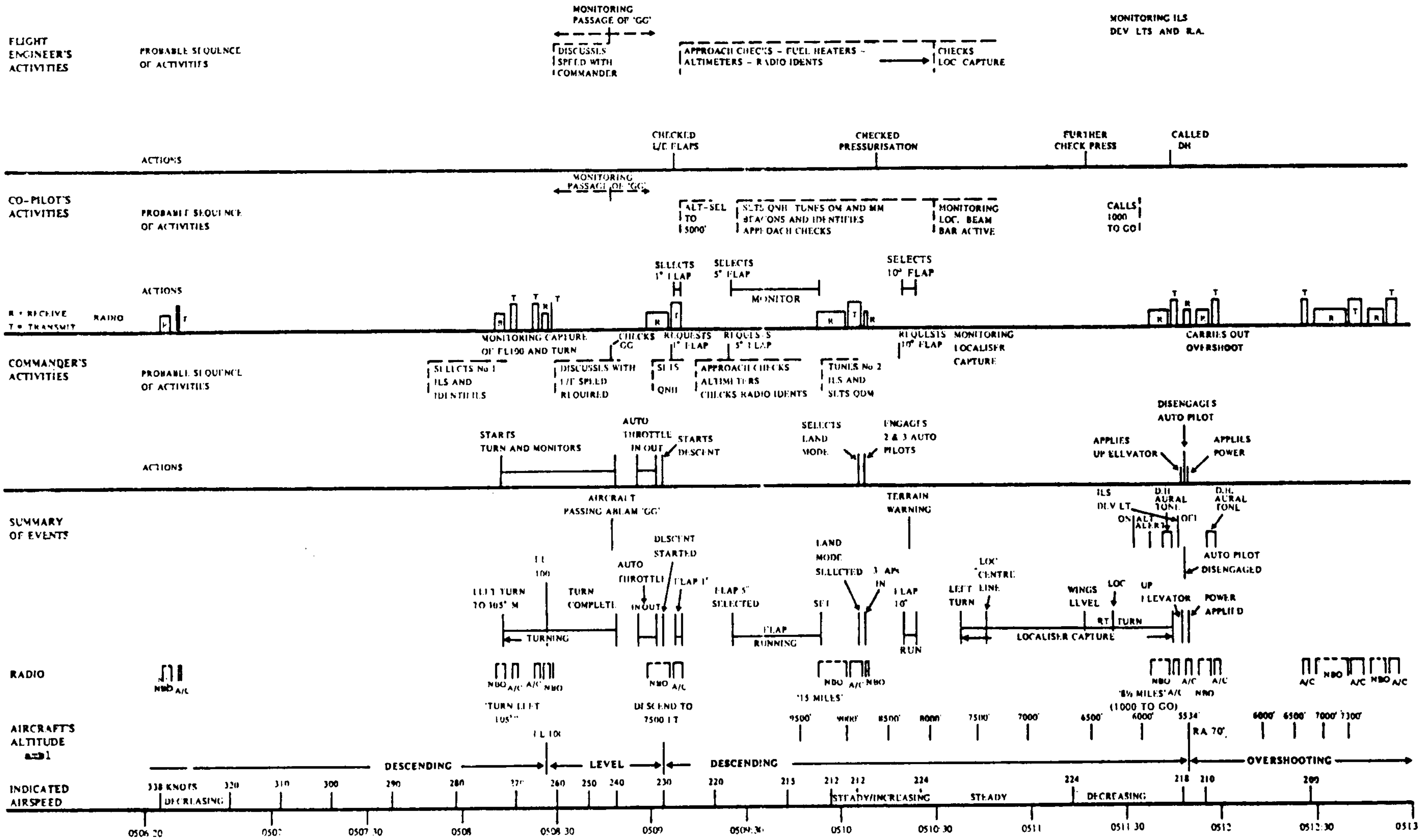


GROUND SPEED IN KNOTS		70	90	110	130	150	170	190	210
TIME FROM	NDB 'GG' TO TURN 8 nm	6 51	5 20	4 22	3 42	3 12	2 49	2 32	2 17
	LOM TO THRESHOLD 3·9 nm	3 21	2 36	2 08	1 48	1 34	1 23	1 14	1 07
GP 2·75°	FT PER MIN	340	438	535	632	729	827	924	1021

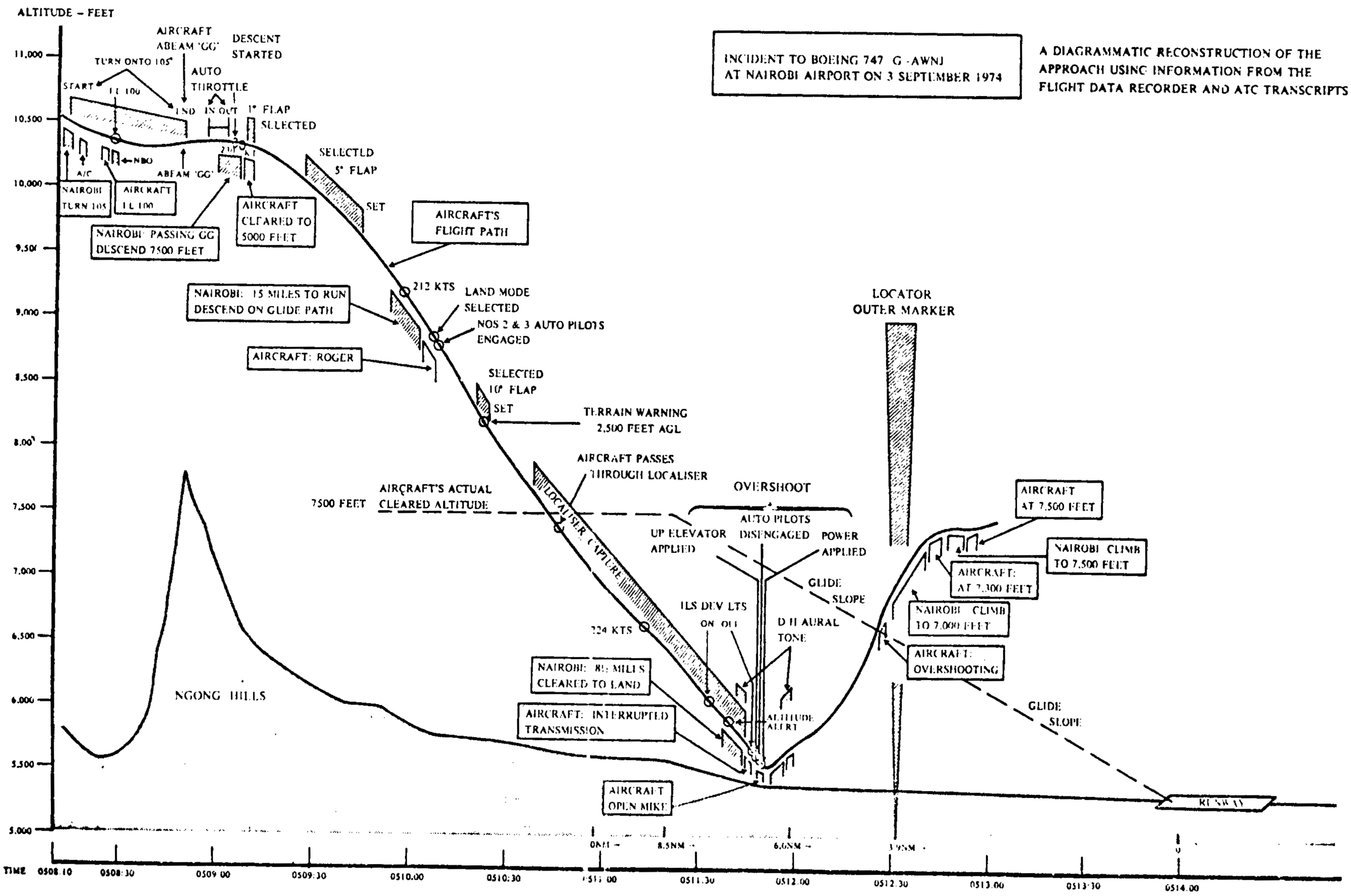
Bearings are magnetic Var 3°W
Elevations in feet AMSL 6600
Heights above threshold 06 1273

ILS—110·3. NL or L 'NO' 06 PROCEDURE A EFFECTIVE 1.8.74 B1 NAIROBI

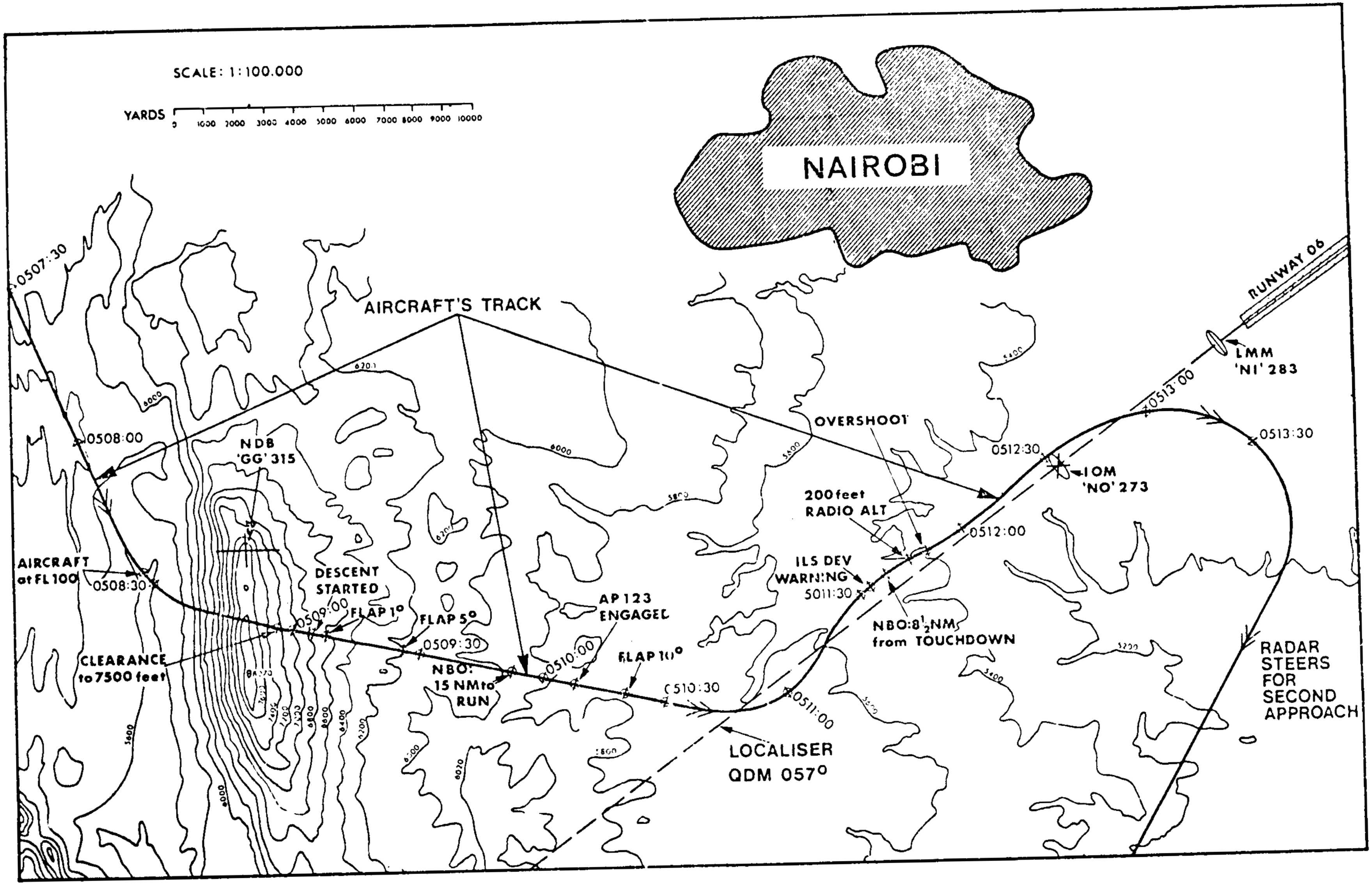
APPENDIX B - Crew Activities Diagram



APPENDIX C - Vertical Cross Section of Flight



APPENDIX D - Ground Plot



No. 16

Trans World Airlines, Boeing 707-331B, N-8734, accident in the Ionian Sea, on 8 September 1974. Report No. NTSB-AAR-75-7, dated 26 March 1975, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

Trans World Airlines (TWA) Flight 841, a Boeing 707-331B, N-8734, was a regularly scheduled international passenger and cargo flight from Ben Gurion International Airport, Tel Aviv, Israel, to John F. Kennedy International Airport, New York, New York. En-route stops were scheduled at Athenai Airport in Athens, Greece, and Leonardo Da Vinci Airport in Rome, Italy.

The flight departed Tel Aviv at 0613,[1/] 43 minutes late because it was delayed by passenger security procedures. There were 105 passengers, 9 crew members, and 5 186 lb of cargo aboard. The cargo consisted of mail, checked baggage, air freight, and company material; 3 875 lb was placed in the front cargo compartment and 1 311 lb was placed in the rear cargo compartment. No restricted articles were loaded.

At 0804, Flight 841 landed at Athens. The crew had not reported any mechanical difficulties while en route, nor was any maintenance required or accomplished at Athens. Fifty-six passengers deplaned and their baggage and some cargo was off-loaded.

Thirty passengers boarded the flight at Athens, bringing the number of passengers to 79. Most of the checked baggage for the boarding passengers was placed in the aircraft's forward cargo compartment. Some baggage and cargo were loaded in the rear cargo compartment where containers are not used. The rear compartment is normally used for cargo, mail, and the checked baggage of late arriving passengers.

According to TWA ground service personnel in Athens, one transit cargo container with bags destined for Rome was left unopened in the front cargo compartment. Four containers were off-loaded and emptied, and three were then refilled with originating bags. The four containers, including the empty one, were then placed aboard. The originating Athens mail was also loaded into the forward compartment. Baggage handlers stated that there were 30 to 35 passenger bags in the rear cargo compartment en route from Tel Aviv and destined for Rome or New York; however, they could not recall exactly how many pieces of checked baggage were loaded in that compartment at Athens.

Three thousand pounds of jet A-1 fuel was added at Athens; additional oil was not required. According to the TWA servicing crew, no unidentified or unknown personnel were seen in the loading area while TWA 841 was on the ground at Athens.

The flight filed an instrument flight plan with an estimated 1 hour 48 minutes flight time to Rome and requested a flight level of 35 000 ft (FL 350). Athens control cleared the flight to Rome, via Airway Green 8, at FL 140. After take-off, the flight was to proceed via Standard Instrument Departure No. 6, then to Korinthos (Corinth), to maintain FL 120 until given further clearance.

1/ All times herein are Greenwich Mean Time, based on the 24 hour clock.

At 0912, the flight departed Athens. At 0930, TWA 841 reported level at FL 280 and acknowledged ATC instructions to maintain that altitude and to report upon reaching the next Flight Information Region (FIR).2/ This was the last known radio transmission of the flight. All contacts had been routine flight reports.

At 0939, Pan American Flight 110 (Pan Am 110), eastbound from Rome, Italy, to Beirut, Lebanon, at FL 330 on Airway Green 8, entered the Athens FIR, reported to Athens ATC, and gave an estimated arrival time at Araxos of 0951. At 0940, the pilot-in-command of Flight 110 alerted Athens ATC that he had seen "a four-engine aircraft going down in flames" at their position, which was about 100 NM west of Araxos.

Communication between Pan Am 110 and Athens ATC was weak, so Olympic Airways Flight 201, which was flying in the area, relayed messages between Pan Am 110 and ATC. For the next several minutes, both Athens ATC and Olympic Flight 201 attempted to make radio contact with TWA 841 but were unsuccessful. At 0943, after Olympic Flight 201 asked Pan Am 110 what type aircraft was on fire, Pan Am 110 replied that there had been a mistake, since the aircraft was not burning. The Pan American pilot said that he thought the aeroplane was a B-707 and that it was a TWA aircraft. He also stated that it appeared that an engine had separated from the aircraft. When asked by Olympic Flight 201 if he saw the engine falling or the aircraft falling, the pilot said, "No, the aircraft is falling too. I saw an aircraft pitch up into a steep climb then roll over on its back and start in a dive, then a slow spiral ...".

Immediately after Pan Am 110 described the falling aircraft, Athens ATC telephoned Brindisi and other control centres, followed by inquiries to airports in the area of the TWA flight. The Greek Search and Rescue (SAR) Control Centre was notified and a Greek SAR C-47 aircraft was dispatched. About 2 1/2 hours after the accident, the crew of this aircraft reported debris and bodies at coordinates 38^{o} 25' north latitude and 19^{o} 22' east longitude.

Safety Board investigators interviewed the pilot-in-command, the co-pilot, the flight engineer, and two passengers of Pan Am 110, all of whom observed the TWA aircraft.

According to the Pan American crew, their flight was cruising at 33 000 ft on an easterly heading at Mach .806. 3/ The weather was good, and the visibility was unlimited, with scattered clouds at lower levels; the sea surface was visible, and the sun was at 3 o'clock; there was no turbulence. The crew did not recall seeing any condensation trails from other aircraft. The co-pilot was flying the aircraft on autopilot.

The pilot-in-command stated that he first saw Flight 841 at the 11 o'clock position, on a reciprocal heading, about 4 to 7 miles away, and about 4 000 ft below him. The aircraft appeared to be in level flight and in normal configuration. The pilot-in-command had no reason to be concerned about that aircraft and looked away for a few moments. When he saw the aircraft again it was in a steep climb attitude, which kept increasing. He also thought he saw an object behind the left wing of the aircraft, about a wingspan away. When the aircraft passed abeam, it had reached about the same altitude as Pan Am 110. It then rolled to the left into a steep descent, and was

2/ FIR - Airspaces of defined dimensions within which flight information service and alerting service are provided by the control centre designated on en-route flight charts. Green 8 ALPHA divided Athens FIR and Rome FIR.

3/ Mach Number - The ratio of true airspeed to the speed of sound.

rolling to the left as it disappeared from his view. At that time, he noticed that an engine was missing and speculated that the object he had seen when he first saw the aircraft in a steep climb might have been the No. 2 engine. He also was aware of a considerable amount of debris below his own flight level. He did not see any smoke; however, he did see a whitish vapour coming from the left wing and believed it to be fuel. He said that the debris he noted below Flight 841 looked like pieces of paper fluttering down. He indicated that there was one large rectangular piece and that the debris appeared to shine. He estimated that there were about 25 to 30 pieces of debris through which Flight 841 descended and thought that the debris was at Flight 841's original flight level. The pilot-in-command commented that he thought that no attempt was made to recover. He saw at least one full 360° roll as the aircraft went down. The pilot-in-command estimated that his observations lasted about 20 seconds.

The co-pilot said that the pilot-in-command drew his attention to the TWA aircraft. His observations of the aircraft's pitch-up were similar to those of the pilot-in-command. When the aircraft disappeared from his view, it was in a vertical roll to the left. He saw no debris, fire, smoke, or structural damage. He saw a brownish vapour coming from the middle of the left wing which extended about as far back as the horizontal stabilizer before dissipating. As the TWA aircraft passed abeam, it was 1 to 1 1/2 miles away from Pan Am 110. At no time was he concerned about the proximity of the TWA aircraft with regard to their own safety. He did not leave his seat, disconnect the auto-pilot, or make any flight path corrections.

When the flight engineer, who was standing with his face close to the left cockpit window, looked down on the aircraft he noticed debris, consisting of fluttering shiny objects that reflected the sunlight. He saw no colours in it. The debris was evenly dispersed, not clustered, and the individual pieces appeared to be of about the same size. He had the impression that the debris had come from the aircraft before, or at the point where, it stopped gaining altitude.

The two passengers aboard Pan Am 110 who observed Flight 841 were seated side by side on the left side of the first-class section. They saw the TWA aircraft several thousand feet below them and spinning at a high rate of speed.

None of the witnesses saw the aircraft strike the water. There were no reports of missile firings or military aircraft activities in the area.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	9	79	-
Non-fatal	-	-	-
None	-	-	

The bodies of 24 passengers were recovered from the sea.

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

Although most of the aircraft wreckage, including the flight data and cockpit voice recorders, was not recovered, sufficient evidence was obtained to analyse the probable sequence of events that led to the accident.

The witnesses' observations indicate that control of the aircraft was lost completely. The debris which witnesses saw during the pitch-up and subsequent descent of the aircraft is proof that some of the aircraft's structure, skin, interior furnishings, or cargo compartment contents separated during flight. Another indication of the violence of the occurrence is the fact that the Pan American pilot-in-command reported an engine separation and that he and other witnesses saw vapour from the left side of the aircraft. The absence of radio communication from the flight crew further indicates that a sudden catastrophe occurred aboard the aircraft. This evidence prompted the examination of a number of factors that could cause a sudden and complete loss of aircraft control.

First, the Safety Board considered the possibility that the flight crew initiated an evasive manoeuvre after sighting Pan Am 110 on an opposite flight path. According to the performance study, the steep pitch attitude and climb described by witnesses could have been produced by pilot action. However, such action would require about 100 lb of pilot effort. The pitch manoeuvre alone would not produce loads that would exceed structural limits. Therefore, after considering the altitude separation and relative positions of the two aircraft, the excellent visibility reported by the crew of Pan Am 110, the amount of pilot effort required, and the lack of evidence to suggest that a recovery was attempted, the Safety Board dismissed the possibility that the flight crew initiated an evasive manoeuvre.

Secondly, the Safety Board considered the possibility of a turbulence encounter. The weather in the vicinity of the accident area was reported to be fine to fair with light turbulence between 25 000 to 30 000 ft. The crew of Pan Am 110 encountered no turbulence at 33 000 ft. Therefore, the Safety Board concluded that in-flight turbulence was not a factor in this accident.

Thirdly, the Safety Board considered the possibility that either the aircraft's structure or one of its systems failed. Although insufficient physical evidence was recovered to determine precisely the integrity of the aircraft's structure or the functional status of its flight control systems, the five witnesses agreed that no major aerodynamic surfaces of the aircraft separated in flight. Since the pilot-in-command of Pan Am 110 saw that an engine was missing from the TWA aircraft, the Safety Board examined the possibility that the engine malfunctioned, separated in flight, and caused a subsequent loss of control of the aircraft. There have been eight incidents in which an engine has separated from a B-707 aircraft. Six of these separations resulted from excessive loads on the engine attachment structure; the loads were imposed by unco-ordinated training manoeuvres or by turbulence. The remaining two separations resulted from engine failure and subsequent fire. In no case did the separations produce uncontrollable pitch-ups. Therefore, the Safety Board does not believe that the engine separation caused a pitch-up manoeuvre.

With regard to the possibility that a system malfunction could have caused the pitch-up and uncontrollable descent, the performance study included a failure mode analysis of specific malfunctions of the flight control system which would have caused the observed manoeuvre. Autopilot "hardover", stabilizer trim "runaway", speed brake extension, and yaw damper failures were analysed. It was concluded that no known single failure could produce a pitch-up of sufficient violence to cause structural damage that would account for the debris and vapour described by witnesses. The study did show, however, that the observed events were compatible with nearly simultaneously applied elevator and rudder displacements.

The control cable systems which interconnect the pilot pitch and yaw controls with the respective control surface mechanisms are routed through the fuselage of the aircraft beneath the cabin flooring. Any mechanical interference with these control cables which would result in distortion, stretching, or unequal deflexion would, in turn, cause displacement of the respective control surfaces. The resultant combined pitch and side-slip manoeuvres could produce inertia and air loads which could fail the engine mounting structure.

Based on the abrupt initial change in Flight 841's flight path, the vapour from the left wing, and the probability that the No. 2 engine mounting structure was overloaded, the Safety Board believes that there were sudden and violent inputs into the rudder and elevator controls in excess of the crew's and the control system's capabilities. Simultaneous mechanical pitch and yaw inputs of that magnitude can be accounted for by the detonation of an explosive device. Therefore, based on the available evidence the Safety Board concludes that the detonation of such a device affected the elevator and rudder control cables which caused the pitch-up and uncontrollable descent.

The recovery of an explosively formed metal fragment from the foam liner of the aft cargo compartment door indicates that the detonation took place in that compartment. Since there is no pathological evidence to indicate that persons aboard the aircraft had been exposed to a detonating device, the Safety Board believes that the explosion took place below the cabin floor, which shielded the cabin occupants. The presence of an explosively formed fragment in one of the seat cushions proves that the floor had been penetrated or damaged. Finally, an incident on 26 August 1974 appears to have been an attempt at the same form of sabotage.

In conclusion, the Safety Board believes that the detonation of an explosive device in the aft cargo compartment buckled and damaged the cabin floor in such a manner that one or more of the elevator and rudder system control cables was stretched and, perhaps, broken. The resultant displacement of the control surfaces caused a violent pitch-up and yaw and made the aircraft uncontrollable. The No. 2 engine most likely separated at the nacelle structural attachment. The fuel released as a result of the engine separation was observed by the witnesses as a trail of vapour. Some of the floating debris may have been associated with the engine separation; however, the reference to "pieces of paper fluttering down" suggests strongly that some of the contents of the aft cargo compartment were expelled during the explosive decompression that undoubtedly occurred when the pressure hull of the aircraft was ruptured locally by the explosion. A damaged pressure hull and the limited penetration of the cabin floor suggest that the centre of the detonation was closer to the cargo compartment floor than the cabin floor.

2.2 Conclusions

a) Findings

1. All crew members were certificated and qualified for the flight.

2. The aircraft was certificated and maintained according to approved procedures.

3. The boarding passengers and luggage in Athens were processed in accordance with approved security procedures.

4. An explosive device was detonated within the aft cargo compartment while the aircraft was cruising at 28 000 ft.

5. The explosion disabled the control system of the aircraft.

b) Cause or
Probable Cause(s)

The National Transportation Safety Board determines that the probable cause of this accident was the detonation of an explosive device within the aft cargo compartment of the aircraft which rendered the aircraft uncontrollable.

3.- Recommendations

As the result of this accident, the Safety Board on 10 January 1975, submitted Safety Recommendations A-75-2 to 5 to the Administrator, Federal Aviation Administration. (See Appendix H.)

ICAO Note: Appendices not reproduced. The specific Recommendations were:

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Re-emphasize to the nations served by American flag carriers the importance of participating in the Aviation Security Technical Assistance Programme.

2. Establish an Aviation Security Office in the Federal Aviation Administration's Europe, Africa and Middle East Regional Headquarters in Brussels, Belgium.

3. Expedite the development and use of suitable explosives detection equipment to preclude the introduction of explosive devices on board an aircraft.

4. Ensure that the aircraft security programmes of U.S. air carriers, as prescribed by 14 CFR 121.538, contain provisions that are more responsive to high risk situations in international as well as domestic operations".

ICAO Ref.: AIG/311/74

No. 17

Panarctic Explorations, Lockheed L-188, CF-PAB, accident at Rea Point, Melville Island, Canada, on 30 October 1974. Report not dated, released by the Ministry of Transport, Canada.

ICAO Note: This report does not comply with Annex 13 Summary of Report format and therefore could not be abbreviated as other reports in this Digest. It has been included because of the unique circumstances of the accident and the findings of the investigation.

HISTORY OF THE FLIGHT

Lockheed L-188C Aircraft CF-PAB referred to as flight 416 departed Calgary International Airport at 1805 hours 29 October 1974. The aircraft was on a routine positioning flight to Edmonton with a pilot-in-command, co-pilot and flight engineer on board. The 30-minute flight was uneventful with no unserviceabilities reported by the crew. The aircraft was prepared for the continuing flight north with the loading of 20 000 lb of baggage and freight and 21 000 lb of jet B fuel. The aircraft pilot-in-command and flight engineer were replaced by those scheduled for the Edmonton to Rea Point leg.

The pilot-in-command received a weather briefing; an IFR flight plan was filed to Rea Point, via direct Fort Smith, direct Contwoyto Lake, direct Byron Bay, direct Rea Point at an initial cruising altitude of 18 000 ft with Pedder Point as the alternate. The estimated time en-route was 4 hours 12 minutes.

After loading 30 passengers and a fourth crew man, the loadmaster/flight attendant, the aircraft departed the Edmonton International Airport at 2004 hours. The flight proceeded uneventfully, cruising at 18 000 ft to Fort Smith where it was cleared to flight level 210. The aircraft reported over Byron Bay at 2304 hours with an estimated time of arrival at Rea Point of 0016. About 100 miles north of Byron Bay the aircraft was cleared to flight level 250.

Radio contact was established with Rea Point about 150 miles out and a descent was started for a straight-in VOR/DME approach to Runway 33. The descent was smooth except for some turbulence at 4 000 ft. The aircraft levelled at 17 miles DME from Rea Point at 2 000 ft for a period of 1 minute 45 seconds. The aircraft then slowly descended to about 875 ft ASL at 6 miles DME. A call was made to Rea Point advising them of the DME range on final. There was light turbulence. Fifteen hundred horsepower was selected on the engines; both the VHF navigation radios were selected to 111.2 MHz, the Rea Point VOR frequency; and both ADF's were selected to 396 KHz, the Rea Point OX nondirectional beacon frequency. Both cockpit barometric altimeters were set to 29.91 in of mercury, the latest Rea Point setting. The airspeed was indicating 150 kt which, with a 30 kt headwind component, resulted in a ground speed of 120 kt. The pre-landing check had been completed, 100 per cent flap selected and the landing gear was down. The landing lights were extended but were off; the wing leading edge lights as well as the alternate taxi lights were on. Glare had been experienced from external lights early in the descent from 10 000 ft, but not thereafter. There was no pre-landing briefing conducted by the pilot-in-command.

The flight engineer was able to see what appeared to be open water below with ice floes. The co-pilot set his radio altimeter warning to 450 ft and the pilot-in-command set his to 300 ft. When the warning light came on on the co-pilot's radio altimeter, he advised the pilot-in-command. As the descent continued through the minimum descent altitude of 450 ft, the co-pilot reset his radio altimeter to 300 ft and so advised the pilot-in-command. The aircraft was still in a shallow descent. At 300 ft radio altitude the co-pilot checked the DME reading as 3 miles, saw a dark area of open water and an ice line and reported to the pilot-in-command that they seemed to be approaching an ice ridge and that they had visual contact. The pilot-in-command reset his radio altimeter to about 150 ft. Also, close to this time the pilot-in-command said he believed they were on top of a layer of cloud, repeated the statement, following which he retarded the throttles and pushed forward on the control column with sufficient force to produce perceptable negative G.

Because of the small time frame, the sequence of events during the final descent could not be established with certainty. However, the rate of descent increased rapidly to between 1 700 and 2 000 ft a minute. The co-pilot recalled that he shouted at the pilot-in-command reporting their descent through 200 ft at 2 miles DME but there was no response. The flight engineer's recollection was that the co-pilot called through 100 ft and they both called through 50 ft without an observed reaction from the pilot-in-command. The co-pilot reached for the right side power levers and found the flight engineer's hands already on them. The co-pilot was observed to have his hands on the control wheel just prior to the impact.

On impact, the cockpit area broke away from the remainder of the fuselage and with the cargo continued along the ice surface for 900 ft. After the cockpit came to rest, the flight engineer, who did not remember the impact, undid his seat belt and saw both the pilot-in-command and co-pilot in their seats. The co-pilot although injured was able to undo his seat belt and the flight engineer pulled him on to the ice before the cockpit section sank completely. The flight engineer found a parka for the co-pilot and kept him awake until assistance arrived.

EVENTS ON THE GROUND AT REA POINT

At about 2330 hours the flight was in communication with Rea Point on 122.8 MHz concerning load and routing and confirming the arrival estimate of 0016 hours. The flight was provided traffic information and the 2400 hour weather observation which was: ceiling thin obscured, visibility 1 mile in blowing snow, temperature -11°F, wind 312° at 30 gusting to 38 mph, and the altimeter at 29.91 in of mercury. At 0015 hours the flight advised that it was 6 miles out on final approach and the radio operator gave the current wind and visibility. (It was later determined that the anemometer was in error and the actual wind speeds were 25 per cent lower than indicated.) One or two minutes later the radio operator's attention was attracted by sudden increases in wind velocity to over 50 mph. He observed the visibility to be less than one-eighth of a mile and occasionally less than 50 yards. This sudden reduction in visibility was transmitted but there was no response. Further contact with the aircraft was attempted on various frequencies but without success.

The senior company official at the site was advised by the radio operator that the aircraft was 11 minutes overdue and after consultation with the site foreman a decision was made to search for the aircraft. A Twin Otter pilot was alerted and briefed on the circumstances; he took off from Runway 33 at 0135 hours for a search of the approach area. The pilot reported that the visibility was about 1 mile in blowing snow during the take-off roll but was unlimited above the blowing snow. At 800 ft altitude during a left turn toward the approach area, he saw two small fires south of the airport. During a low pass with landing lights on, he saw a person standing in an area strewn with wreckage. After a brief aerial examination of the accident site 2 1/2 miles south on the extended centre line of Runway 33, he returned to the airstrip. A ground party departed the camp at about 0150 hours and guided by the Twin Otter circling over the accident site, arrived there in about 30 minutes. Three survivors, the co-pilot, flight engineer and a passenger were located and taken to the camp by about 0250 hours.

FINDINGS

The approach was continued below the company approved minimum descent altitude.

The pilot-in-command reacted inappropriately to a visual cue and suddenly initiated the final rapid descent.

Partial incapacitation of the pilot-in-command was a factor in the failure to recover from the high rate of descent.

Crew co-ordination in the cockpit in the final stages of the flight was inadequate.

No company Flight Operations Manual or similar document was available to adequately prescribe the aircraft crew's duties and responsibilities.

This operation was in the private category and was not operated or required to operate to the established commercial standards.

The established aerodrome emergency response procedures were inadequate.

CREW INFORMATION

Pilot-in-command

Flying history

The pilot-in-command, age 30, held a valid Airline Transport Pilot Licence endorsed for single and multi-engine land and sea up to a gross weight of 12 500 lb as well as Lockheed Electra aircraft. His class I instrument rating was valid to January 1975. He had accumulated a total of 8143 hours of which 3600 hours were flown on Twin Otters and 1792 on the Lockheed Electra including 907 hours as pilot-in-command.

The pilot-in-command obtained a commercial pilot's licence in 1964 and for the next 10 years progressed through various flying positions to that of pilot-in-command on a large 4-engine turbine aircraft. His first instrument rating, a Class II, was obtained in 1968. In January 1970 he began his employment with the Company as a pilot-in-command on Twin Otter aircraft. During 1971 he took his initial ground school and simulator training on Lockheed Electra aircraft at a commercial school. This was part of the upgrading process from a Twin Otter pilot-in-command to an Electra co-pilot. The training was completed in December 1971. Training reports indicate he experienced problems with IFR approaches and in adapting to the flight director system. After flying as co-pilot for about 7 months, he was given an instrument flight rating recheck by an MOT inspector who reported problems with cockpit management as well as the use of the ADF (Automatic Direction Finder). His next instrument check about 6 months later revealed only a problem in altitude control. In June of 1973, he took simulator and flight training for upgrading from co-pilot to pilot-in-command. During an MOT instrument flight rating check in the same month, his procedures were considered to be "somewhat unorthodox". In July 1973 he was upgraded to pilot-in-command on Lockheed Electra aircraft. In December 1973, he successfully passed a MOT instrument flight rating recheck, the report of which contained a comment of "some confusion" relating to the assigned runway for approach. Approximately 6 months later, an instrument flight rating recheck by an MOT approved Company check pilot reported that the pilot-in-command should give more attention to the detail of clearances and approach charts, but the test was successfully completed. His last proficiency check of any kind prior to the accident was on 24 August 1974, in a Lockheed Electra simulator. Comments included by the company check pilot were: preparation for ILS poor, not holding altitude to glide path intercept; slow initiating descent on ADF approach; speed high on missed approach. The pilot-in-command had not flown in the eleven days before the accident flight. During this period he worked as duty-pilot on normal working days.

Physiological aspects

Pathological evidence indicates possible extension of the left leg at impact. There was a fracture of the left hand of the type commonly associated with the hand being positioned on a control wheel at impact. There was a 50 per cent compression fracture of the L1 vertebrae indicating vertical acceleration in the area of 25 g with an onset rate of at least 300 g per second, and a duration of about 0.1 seconds.

The liver was found to be considerably enlarged with a very severe degree of fatty change. This condition is associated with metabolic disturbances such as a lowered amount of potassium in the blood as well as other blood chemistry changes including lowered blood sugar, changes in heart rhythm that could result in incapacitation and/or sudden death. The degree of fatty change noted in the liver, in an otherwise healthy individual, was considered by consulting pathologists to be almost certainly associated with the excessive intake of alcohol. Patients with fatty liver diseases but without clinical evidence of heart disease can exhibit an abnormal heart rhythm in response to stress and consequent incapacitation to any degree, including death. No evidence of recent alcohol or drug ingestion was found in the tissues. In addition, on 19 June 1974 a cardiological assessment was requested due to flattening of the T waves in the pilot-in-command's electrocardiogram. The cardiovascular report was negative although in retrospect it can be seen the T wave flattening may have been due to a lowered serum potassium.

A heterophoria (eye convergence or divergence) of between 6 to 8 diopters was noted on the pilot-in-command's medical records. While this condition would not normally be a problem it can result in an increase in the time of transition from instrument to visual reference under conditions of fatigue.

Psychological aspects

This pilot had spent most of his flying career on light aircraft up to and including Twin Otters. During all of this time he would have been the only pilot on board with no requirement for co-ordinated crew procedures. While he had held an instrument rating during the four years up to and including 1971, flight deck procedures during the approach phase would be markedly different from those employed in a high performance well-equipped, large, two-pilot aircraft. His total experience on two-pilot aircraft was in the Lockheed Electra starting in about January 1972 for 12 months as a co-pilot and the following 14 months to the time of the accident as a pilot-in-command. Many of the problems associated with proficiency checks on this pilot relate to flight deck management and instrument procedures.

The pilot-in-command had been initially well motivated towards flying but had been increasingly dissatisfied and frustrated during the year prior to the accident with this type of flying which he considered to be hazardous. The manifestation of his dissatisfaction included a desire to change jobs or to leave flying completely. There is evidence of chronic fatigue in the few months prior to the accident which may have been partially caused by his liver condition and amplified by the frustration and anxiety which was developing.

Co-pilot

Flying history

The co-pilot, age 32, held a valid Airline Transport Pilot licence endorsed for single and multi-engine aircraft up to a gross weight of 12 500 lb as well as helicopter and Lockheed Electra. His Class I instrument rating was valid to 1 March 1975. He had accumulated about 5100 hours of flying of which 1583 hours were on Twin Otters and 160 hours on the Lockheed Electra. Of the 1583 hours on the Twin Otter, 665 hours were experienced on Arctic operations out of Rea Point.

He commenced flying in 1966 and in 1970 obtained a Class II instrument flight rating. About 1 year later he had an instrument flight rating recheck by an MOT inspector which renewed the Class II rating with problems showing up in instrument procedures but one month later he was upgraded to a Class I. He continued to successfully pass instrument proficiency flying rechecks to a Class I standard with no outstanding problems. In July and August 1974 he successfully completed classroom, simulator training and a flying proficiency check on the Lockheed Electra aircraft and began flying in the capacity of a co-pilot. He had not flown during the six days preceding the accident and had not previously flown with this pilot-in-command.

Flight Engineer

The flight engineer, age 26, obtained a Private Pilot Licence in 1969. After serving an apprenticeship he received his Aircraft Maintenance Engineers Licence in 1972. In June 1973 he successfully completed flight engineer Lockheed Electra ground training and a service training course on Allison Turbine Engines in August of the same year. During the same month he successfully completed Lockheed Electra simulator and flight training and obtained a Flight Engineer's Licence.

Loadmaster/Flight attendent

The loadmaster, age 22, had been flying in this capacity with the company for about 1 year. During flight time he was to fill the role of a flight attendant combined with his pre- and post-flight loadmaster duties.

AIRCRAFT

The aircraft was a Lockheed Electra model L-188C, powered by four Allison 501-D13 engines driving constant speed Aeroproducts A6441 FN 606 hydromechanical propellers. The Federal Aviation Agency Type Certificate Data Sheet was issued 22 August 1958. The aircraft came to Canada in 1969 under an FAA Certificate of Airworthiness for Export issued 29 December 1969 when the airframe had accumulated 19133.4 hours. The Ministry of Transport issued a Certificate of Airworthiness for CF-PAB on 30 December 1969 and on 2 January 1972 reregistered for the company involved.

The form used to calculate the weight and balance position of each flight had been in use for only a few weeks prior to the accident. This form included aircraft compartments that were not in the basic weight and balance document.

The weight and balance form made up prior to the flight to show the load and C of G position at a maximum take-off weight of 114 580 lb was calculated on the basis of 20 009 lb of cargo and 5 270 lb for 31 male passengers. There were in fact 30 male passengers with a corresponding passenger load of 5 100 lb. The burn off or en-route fuel was calculated to be 18 930 lb to provide a maximum landing weight at Rea Point of 95 650 lb. The total fuel for take-off was indicated to be 26 530 lb and the C of G was shown as 26.7 per cent MAC. The flight engineer's fuel log from the aircraft showed the fuel at take-off to be 27 860 lb or 1 330 lb more than indicated on the weight and balance form which would have resulted in an overweight landing. Other discrepancies existed on the weight and balance sheet and despatch documentation; however none would have had a direct bearing on the accident circumstances.

Two significant points in the cockpit instrument presentation were noted. The altimeter, while of an approved type, was of the three-pointer type known to induce perception errors. The only DME read-out was on the pilot-in-command's panel even though it was used as a primary approach aid. The co-pilot would be hindered in his cross checking of this and other instruments with the DME read-out in this position.

OPERATIONAL CONTROL

When the Company proposed its L-188 operation it was ruled by the Canadian Transport Commission as non-commercial. The effect of this decision was to render the issuance of an Operating Certificate by MOT inapplicable, and consequently the Company became responsible for selecting and applying its own safety standards to some of its aviation operations. Although the MOT standards applicable to Companies holding Operating Certificates were available for guidance, the Company was under no obligation to apply them. Similarly, the application of some standard of safety to its air routes, navigation and communications facilities, aerodromes etc., is a Company responsibility.

The Company in response to these safety responsibilities created an Air Transportation Department embracing flight operations, aircraft maintenance and airlift co-ordination. The remaining aviation functions were not given department or section status in the Company's organization structure.

Thus this flight was conducted in accordance with a mixed set of standards: MOT standards for crew qualifications, aircraft certification, flight procedures (i.e. all those aspects covered by Air Regulations and Air Navigation Orders applicable to private operations), Company applied standards for flight despatch, flight following, crew procedures, passenger safety, facilities, aerodromes, air routes, etc. The items in the former group are subject to MOT routine surveillance for compliance but those in the latter group would not be, under the particular circumstances of this operation.

METEOROLOGICAL INFORMATION

Synoptic situation

The meteorological conditions over the Arctic Islands north of 70° latitude from 1700 hours on 29 October to 0500 hours on 30 October were influenced by a 978 millibar low that existed in Baffin Bay at 1700 hours on the 29 October and a ridge of high pressure extending from Gladman Point to Northern Banks Island with a surface low that moved to the vicinity of Thule by 2300 hours and began to fill. A new low pressure centre developed northeast of Alert by 0500 on 30 October. The ridge of high pressure remained stationary through the period. A broad cyclonic flow of continental arctic air prevailed over the arctic islands with the maximum northwesterly surface gradient occurring in a northwest/southeast band over eastern Melville Island.

There was a trough embedded in the northwesterly flow which moved southeastward at an estimated speed of 30 kt; passed Rea Point at 2000 hours on 29 October and Resolute Bay 3 hours later. Weather reports at Resolute and Rea Point indicate that overcast layer cloud prevailed ahead of the trough and decreased to scattered cloud one hour after the passage of the trough. The Resolute Bay radiosonde at 1700 hours on 29 October showed a saturated layer between 2 000 and 9 000 ft ASL. This indicates that sufficient moisture existed to create overcast merged layers ahead of the trough. However, the surface weather reports at Resolute Bay near 1700 hours indicated only scattered to thin broken layers. Rea Point reported overcast clouds ahead of the trough with an estimated base of 1 000 ft above ground level. One hour after the passage of the trough (at 2100 hours on 29 October) Rea Point reported 1/10 of altocumulus.

Maximum surface winds and the lowest visibility occurred ahead of the trough. Winds abated slightly and the visibility improved to 1 mile, behind the trough. However, the wind reached a second peak with gusts to 28 mph at 2400 hours on 29 October.

Forecast

The terminal forecast for Rea Point issued by the Arctic Weather Central forecast office in Edmonton at 1530 on 29 October valid for 12 hours from 1600 to 0400 hours on 30 October was included with the general weather information provided to the pilot-in-command prior to his departure from Edmonton. This forecast indicated: scattered clouds at 1 500 ft with a broken ceiling at 8 000 ft, conditions variable to partially obscured and a broken ceiling at 1 200 ft; a visibility of 3 miles obstructed in ice crystals and ice fog variable to 3/4 mile in light snow and ice fog; the surface wind 300° True at 25 mph with gusts. The surface weather observation at Rea Point taken at 2400 hours on the 29 October, about 16 minutes prior to the accident, was: a partially obscured condition of blowing snow with an opacity of 2/10; the visibility 1 mile in blowing snow and occasionally higher; the surface wind 312° True at 22 gusting to 28 mph.

Alternate

Pedder Point had been filed as the alternate although contrary to the requirement for filing alternate airports no terminal forecast was available. The only weather available for Pedder Point would have been the last hourly sequence which at 1800 hours was: sky clear, visibility 10 miles in ice crystals. Hourly weather observations continued to be taken with the 2400 and the 0100 observations missing. The 2300 hours observation was: "sky partly obscured in blowing snow with an opacity of 2/10 with scattered altostratus clouds at 10 000 ft; visibility 3 miles in blowing snow; wind 320° True at 17 mph".

Observations

The weather observed by the surviving crew members included moderate turbulence at 4 000 ft and turbulence again at 300 ft; some surface detail was visible vertically up to and during the early stage of the approach and just prior to the sudden descent; no lights on the ground were observed at any time. When the Twin Otter took off from Rea Point at 0135 to search for the aircraft the pilot observed the weather to be: visibility of about 1 mile in blowing snow up to about 100 ft above ground and unlimited conditions above. Very low fog of perhaps 10 ft in height appeared to be streaming out over the open water caused by the wind blowing off the ice.

Facilities

The observing stations at Rea Point and Pedder Point as well as other arctic sites that are primarily used by private oil drilling operations are manned by radio operators employed by the drilling company involved but under contract to the Department of the Environment on a no cost mutual benefit basis. As well as taking weather observations these operators have other duties including communication with aircraft and ground stations. They are not required to take special weather observations. Six days after the accident the weather observing equipment and capability were examined by an inspector of the Department of the Environment. The inspection revealed that the observations were satisfactory with one exception, the wind speed detector was found in error and consequently all measured wind speeds required a correction factor of -25 per cent.

Micro-meteorological considerations

There was a strip of open water of at least several miles width over which the aircraft flew immediately prior to the accident. An atmospheric structure analysis based on physical modelling and numerical computation indicates:

1) the extreme contrast in temperature as the airflow from the land and sea ice moved over the open water creates an internal boundary layer;

2) within the internal layer the flow would have an increased turbulence due to the convection originating from the "hot" open lead;

3) development of sea smoke mixed with ice crystals from blowing snow originating several hundreds of metres from the edge of the shore-fast ice and the open water, thickening with distance to dimensions suggested on the diagram; and

4) the position of the aircraft at the point where an abrupt descent was initiated corresponds closely to a position where optical shifting of surface images (mirage effect, foreshortening) would have been at a maximum.

AIDS TO NAVIGATION

A non-directional beacon, OX (Rea Point) on 396 KHz is located 0.79 nautical miles from the threshold on the extended centre line of Runway 33. A VOR/DME located on the same extended centre line 0.19 nautical miles from the end of the runway. There was no indication of an unserviceability at the time of the accident.

COMMUNICATIONS

The radio operator at Rea Point did not hold a licence as required by the Radio Regulations of the Department of Communications. He was communicating with the flight on 122.8 MHz. There were no indications that any problems existed in the ground or aircraft installations. However, due to the multiplicity of communication duties he could not give full attention to the inbound flight. Apparently, priorities had not been well established.

AERODROME AND GROUND FACILITIES

The airstrip at Rea Point oriented 333° True is located on Melville Island (75° 22'N, 105° 42'W) about 1 mile from the shoreline of Byam Channel. It is a firm level sand surface 200 ft wide and 6 300 ft long. There were 2 standard red obstruction lights on top of the NDB and VOR towers with a "T" pattern approach lighting system. This comprised nine 50 Watt amber lights across the runway direction followed by 4 similar amber lights leading into the runway threshold spaced about 200 ft apart. The threshold was marked with 10 green lights of 50 Watts with white runway lights of 50 Watts spaced at 200 ft intervals. If this lighting system met MOT or ICAO standards it would have extended at least 400 ft further from the threshold.

The fire fighting equipment consisted of four 350 lb dry chemical reel type extinguishers; two positioned on the aircraft ramp, one in the main garage and one in a heated area. There are also numerous small fire extinguishers located throughout the camp. The reel type extinguishers are mounted on elevated platforms to provide for mobility by use of a pickup truck.

The planning for a disastrous aircraft accident was inadequate and there was no off-airport vehicle on stand by for emergency use.

FLIGHT RECORDERS

The aircraft was equipped with a Fairchild A-100 cockpit voice recorder serial #1698 and a Fairchild 5424-221 flight data recorder serial #1301 although carriage of Flight Recorders is not required of a private operator. The rear section of the aircraft containing both recorders sank to the bottom of Byam Channel in about 100 ft of water. The recorders were subsequently recovered without any damage from the accident or the immersion in sea water. However, the cockpit voice recorder was found to be unserviceable due to a failure of an incorrect tape splice and the data recorder was found to have an inoperative heading stylus and reversed Pitot and static pressure connexions. The company had been advised of the reversed connexions subsequent to a previous accident. Time histories of altitudes and airspeeds were derived but with a reduced accuracy that resulted from the reversed connexions. The accuracy of the acceleration data was poor in the final stages of the approach due to vibration from turbulence. The data derived for the last 10 minutes of flight as well as an expanded version of the last 100 seconds is included.

The fluctuations in the derived pressure altitude over the last 40 seconds of the accident flight were studied in order to try and explain their presence and resolve why the final recorded altitude was at least 110 ft above sea level. It was obvious that the fluctuations were too rapid to represent genuine flight variations. However, there is no obvious explanation for the variations and no satisfactory corrections could be found to reduce them to a more realistic value. Since the altitude had to be derived from a combination of the altitude and air speed stylus positions, there is a combination of measurement errors that degrades the accuracy.

WRECKAGE

All major surface wreckage was located and identified. The major portions of the wreckage underwater were located and identified with the use of underwater video and divers. Without exception the fracture characteristics of the identified items were typical of instantaneous overload failure. Some 200 other unidentifiable fragments also showed instantaneous overload characteristics.

The aircraft struck the 8-in thick sea ice on a heading of about 321° True with about a 2° crab angle to port. The wings were level or slightly left wing low with a nose-down attitude in the order of 7°. The break-up sequence is shown on the following page.

The burnt part of the upper rear portion of the fuselage indicates that it was partially immersed in water for some time prior to sinking. The rear main passenger door was in the open position during the time the surface fire was burning. Underwater examination showed that the emergency recessed T-handle used to operate the door manually had been pulled and the door was moved to a nearly fully open position. No satisfactory explanation was found for the position of the door and emergency handle as all passenger seats had been ejected through the front of the passenger compartment at the time of the aircraft break-up. This resulted from the passenger compartments being exposed to decelerations in the order of 16 to 20 g.

The examination of pressure sensitive instruments did not reveal any significant witness marks or indications; however, both altimeters were set at the latest altimeter setting provided by the ground station of 29.91 in of mercury. Significant electrical instrument indications included the single DME indicator on the pilot-in-command's side showing 2.3 nautical miles and the radio altimeter also on the pilot-in-command's side indicating 27 ft with the altitude warning set at 160 ft (it is believed the intended selection was 150 ft). The co-pilot's radio altimeter was indicating 35 ft and the altitude warning was set at 290 ft (intended selection 300 ft).

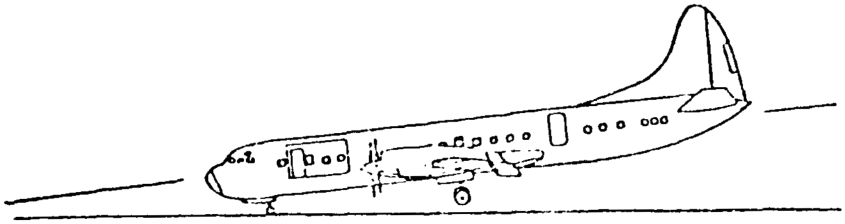
The engine power indications showed turbine inlet temperatures of 742, 755, 748 and 718 degrees centigrade, and horsepowers of 2 835, 2 725, 2 720 and 2 445 for engines 1 to 4 respectively. The oil pressures and fuel flows showed appropriately similar indications. The fuel quantity gauges read 3 210, 3 680, 1 790 and 1 930 pounds at impact.

The warning light bulb indications of the aircraft's major systems of hydraulics, electrical and fuel as well as control boost were examined. With the exception of the landing gear down indicator bulbs which were on at impact, all warning indicator bulbs were found to be off.

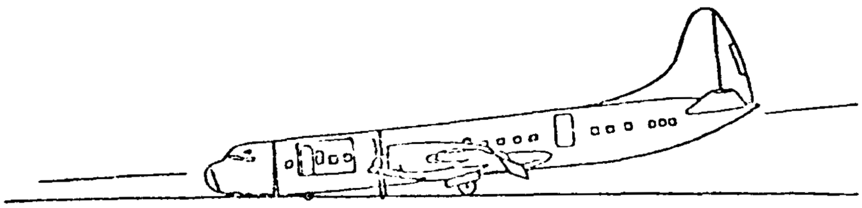
The number 1 engine was found on the ice surface and examination showed it to have been functioning normally at the time of impact. The fuel co-ordinator was found to have been set at 70 degrees at impact and the test of another engine with a similar setting, revealed a turbine inlet temperature of 756 and a horsepower of 2 300. The remaining 3 engines sank to the bottom and although observed on an underwater video camera, were not recovered for more detailed examination. However, all propellers indicated substantial power was being developed at impact. Fuel samples taken from No. 1 engine showed that the fuel met the specific gravity and distillation range requirements for jet B type fuel. Neither the previous history nor the Flight Engineer's operating log recovered from the wreckage showed any major problems associated with engine operation.

TEST AND RESEARCH

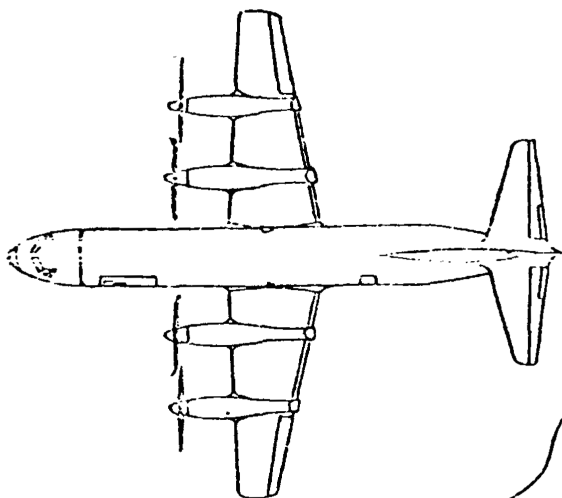
A test flight was conducted on a similar aircraft with similar loading and centre of gravity positions. The purpose was twofold: a) to determine what effect if any, changes in power had on the static system as a result of changing airflows over the static port caused by the number 2 and 3 propellers, b) to determine trim, power and pilot control input to achieve conditions similar to those in the accident.

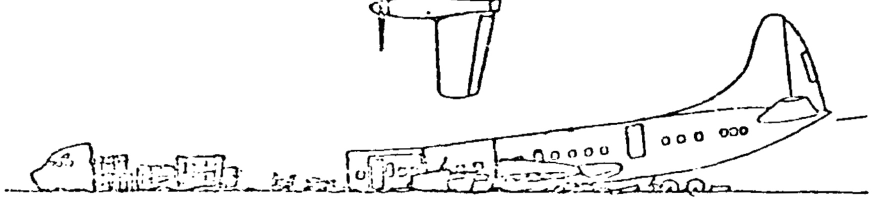


The Electra at impact with nose oleo fully compressed and about to punch through the ice.

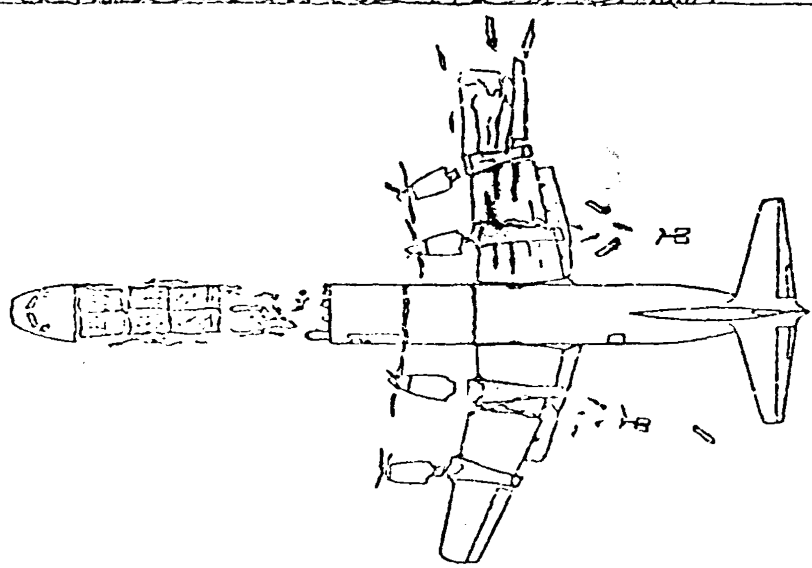


The main gear penetrates the ice, the outboard propellers begin to slash the ice and the nose gear truss girders and shock tube tear out with the fuselage rupturing at FS 200.





The nacelles and wing centre box contact the ice, the propellers, gearbox and engines separate from the wings, the fuselage ruptured at FS 570, the right wing exploded outboard of WS 170, the left wing separated intact outboard of WS 170 and the centre wing box disintegrated. The cockpit and bulk cargo slid ahead of the decelerating structure, and the passengers, seats and emergency gear cabinet broke free within the aft fuselage.



Flight profiles similar to those provided by the information from the flight data recorder and witnesses' testimony were flown with the following results: no significant effect of changing thrust on the aircraft could be associated with responses on any pressure instrument during flight. From a normal power setting to maintain level flight a reduction to 200 horsepower on all engines and a control input to achieve about a 7 degree nose-down attitude resulted in a "hands off" stabilized descent without changes of trim with a vertical velocity of about 2 000 ft a minute.

FIRE

There was no indication of any in-flight pre-impact fire. Post-impact fire from burning fuel was evident. The post-crash fire did not spread on a large scale until about 15 minutes after impact.

SURVIVAL ASPECTS

The injury to the pilot-in-command and co-pilot of compression factors of L1 vertebrae indicate the greatest impact of the decelerative force was directed upwards. The high peak G loading appeared to be the result of the use of thick elastic non-energy - absorbing type seat cushions as well as the dynamic failure of the vertical adjustment seat friction clamp mechanisms. The fact that the flight engineer did not have a compression fracture can be explained by the hunched forward posture that would be required to operate the throttle from the flight engineer's seat.

The occupants in the passenger compartment in the rear of the aircraft were exposed to substantial horizontal deceleration forces; however, 50 per cent had potentially survivable injuries. As the passenger restraint systems were not designed to withstand the deceleration forces, the passengers were subjected to secondary impact. In all cases the seat mountings came loose from the floor track. A number of these were broken indicating they had pulled through the floor tracks and a number showed no witness marks, indicating that the floor tracks separated releasing the seats. The seat pans of the canvas type were intact except in cases where burning occurred. Some of the seat belts were of the fabric pull-through lift-latch type where the evidence confirmed previous experience of inadvertent release. Chafing on the fabric showed that the belt pulled through the latch and allowed the passenger to fly free.

The three crew seats were equipped with 5 point harnesses with a single release and the shoulder harnesses with an inertia reel of the rate of extension type. None of the crew had elected to wear shoulder harnesses nor was this a practice with Panarctic crews nor a requirement of the company. As it was established that the pilot-in-command died from drowning, probably while unconscious, utilization of the shoulder harnesses could have contributed to his survival.

Of the four crew and thirty passengers on board, only the co-pilot and flight engineer survived. One passenger survived initially but succumbed to haemorrhagic shock while en route to Edmonton on an air medical evacuation flight. Of the remaining 31 occupants of the aircraft, 16 had potentially survivable injuries. Of these with survivable injuries, it is estimated that five survived for longer than 15 minutes, four survived for ten to 15 minutes and seven survived for less than 10 minutes. Of those who survived for less than ten minutes, six were found on the ocean floor and probably succumbed to drowning.

ANALYSIS

The flight from Edmonton to Rea Point was routine for the type of operation involved until the aircraft had descended to about 875 ft above sea level and 6 miles from the DME. The pilot-in-command made the decision to descend to 300 ft before reaching the minimum descent altitude of 450 ft; the co-pilot accepted the pilot-in-command's action. While the co-pilot reset his radio altimeter warning to the minimum descent altitude of 450 ft, the pilot-in-command set his to 300 ft. Considering the runway elevation of 50 ft the radio altimeter selection of 300 ft would provide for a warning light when the barometric altimeter indicated an altitude of 350 ft above sea level over the runway or 100 ft below the minimum authorized altitude. When they descended through 450 ft, the co-pilot reset his radio altimeter warning to 300 ft and advised the pilot-in-command.

The statements of the pilot-in-command that he believed they were on top of a layer of cloud at 300 ft just prior to the sudden steep descent is significant. This signifies that the pilot-in-command may have been using outside visual reference. Normally, the pilot flying maintains instrument reference until the other pilot indicates he has sight of the runway or approach lights. The pilot-in-command's selection of 150 ft on the radio altimeter would be consistent with an intent to try to descend below cloud.

The co-pilot observed an ice/water line and advised the pilot-in-command he had visual contact. With this observation being made through the forward windshield, the pilot-in-command should have been able to see the same ice/water line. However, the reaction of the pilot-in-command would be based on what he perceived. A rapid descent was initiated very quickly with a large control input causing a marked feeling of negative "G". The interpretation of sensory stimuli is dependent upon many complex variables including both psychological and physiological, factors. Identical stimuli may be perceived by different people in different ways or interpreted differently by the same person at different times. In this case there were a number of factors that could possibly have degraded the pilot-in-command's perceptual state including:

a) fatty liver disease possibly causing low blood sugar and deteriorating performance,

b) a degree of fatigue,

c) the movement of the ice/water line seaward from the position observed by the pilot-in-command on previous flights,

d) stress from flying with a new co-pilot under marginal weather conditions,

e) the stress of continuing to fly in an operation of which he was apprehensive.

In his perceptual state the pilot-in-command interpreted the visual information as requiring an immediate steep descent. Misinterpretations could include: the ice/water line location; pitch-up from the dark/light difference; the ice being a cloud layer; or variations in light intensity and/or image shifting.

After the steep descent was established the pilot-in-command did not respond to the warnings of the co-pilot and flight engineer. He also failed to respond to the instrumentation that showed a hazardous rate of descent at low level three miles from the airstrip. This failure to respond indicates a degree of incapacitation.

While the pilot-in-command's actions may have been influenced by perceptual problems the factors that predisposed him to be affected by these problems are significant. The descent to 300 ft on the radio altimeter put the aircraft 150 ft below the minimum authorized altitude. It was done in an apparently routine manner without discussion with the co-pilot. This disregard of approach criteria was accepted by the co-pilot as it had happened before on at least one previous flight with another pilot-in-command. It can be concluded that this procedure was either acceptable to those in control of the company flying operation or that they did not have an effective system for detecting operational deficiencies.

The omission of a pre-landing briefing of the flight crew denied the pilot-in-command the safety factor inherent in cross monitoring by the crew. Both the co-pilot and flight engineer were restricted in their capacity to monitor the approach due to a lack of information. Standardized procedures were not followed nor were procedures promulgated in a Flight Operations Manual or similar document. The pilot-in-command's past experience flying single pilot aircraft was probably a factor in his actions.

After the abrupt descent was initiated the pilot-in-command failed to respond to shouted warnings and instrument indications. The ice impact at about seven degrees indicates that there was little or no rotation of the aircraft in an attempt to arrest the descent. Despite concern and shouted warnings from the co-pilot and flight engineer the co-pilot did not take over the control of the aircraft. There was no company procedure established whereby the pilot not flying would detect subtle incapacitation and take over control in the case of any incapacitation. However, when the high descent rate in the order of 2 000 ft per minute was established below 300 ft the possibility of a safe recovery was remote.

Undoubtedly the pilot-in-command was incapacitated to some degree. The evidence of his left leg being extended with the slight yaw to the left and being slightly right of the centre line indicates a remaining ability to recognize and react. However, the possibility of a serious debilitating condition brought about by metabolic change cannot be discounted.

From the time of the crash until rescue crews reached the scene about 2 hours had elapsed even though the crash site was 2 1/2 miles from the end of the runway. The delay occurred due to an inadequately defined response procedure. There was no off-airport vehicle on a stand-by basis and indecisive action followed the loss of communication with the aircraft. It is unlikely that a more rapid response in this instance would have affected the outcome.

ICAO Ref.: AIG/372/74

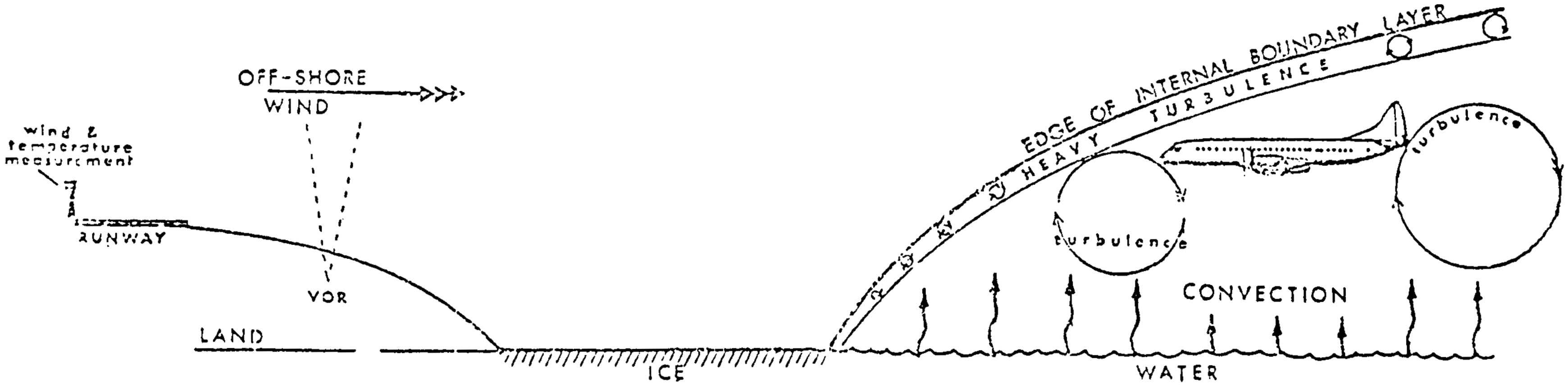


Figure 17-1.- Cross-section of local meteorological situation (or internal boundary layer) associated with cold flow from land over "warm" open lead offshore

(Prepared by Dept. of Environment)

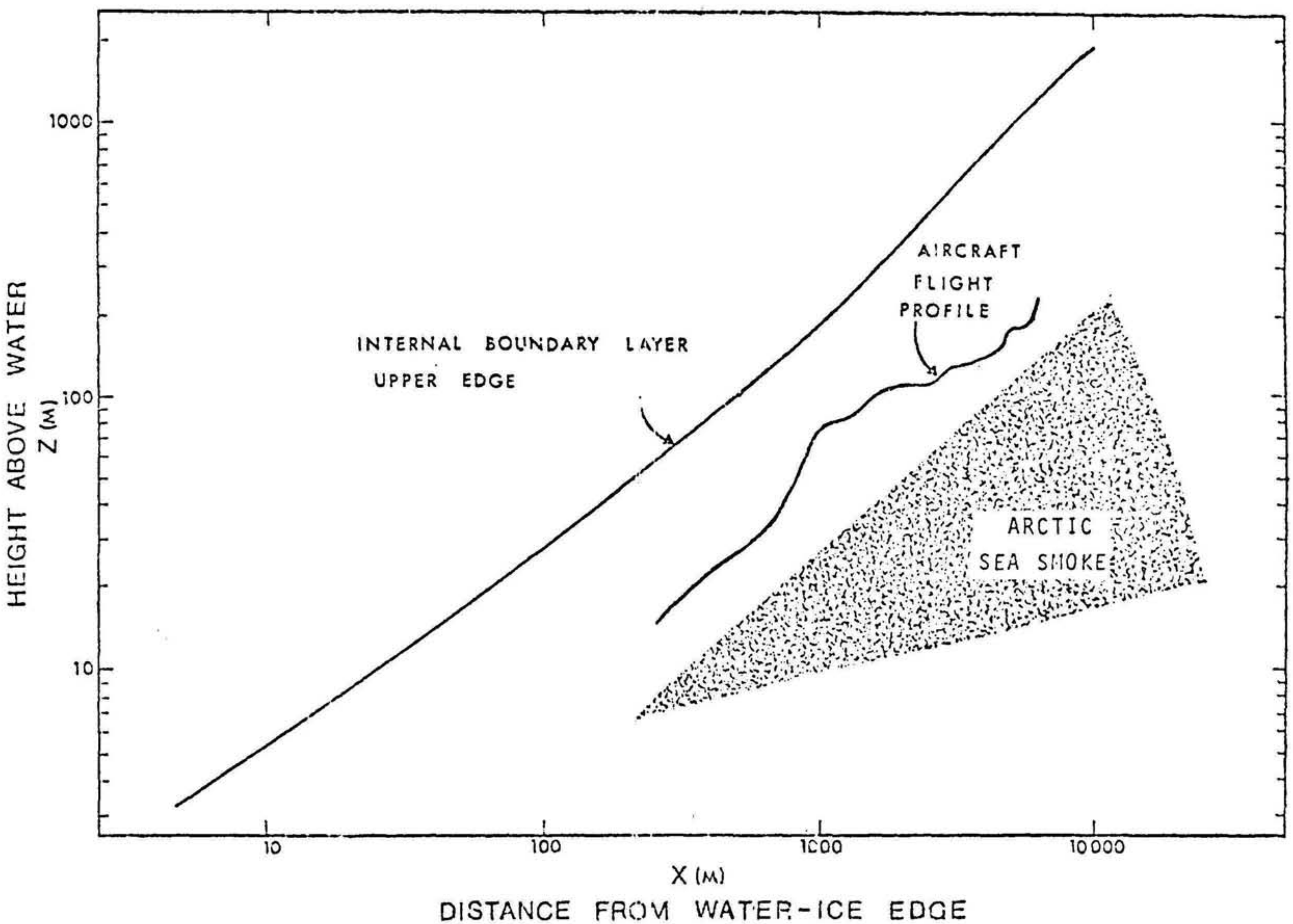


Figure 17-2.- Position of aircraft and of upper edge of internal boundary layer

(Prepared by Dept. of Environment)

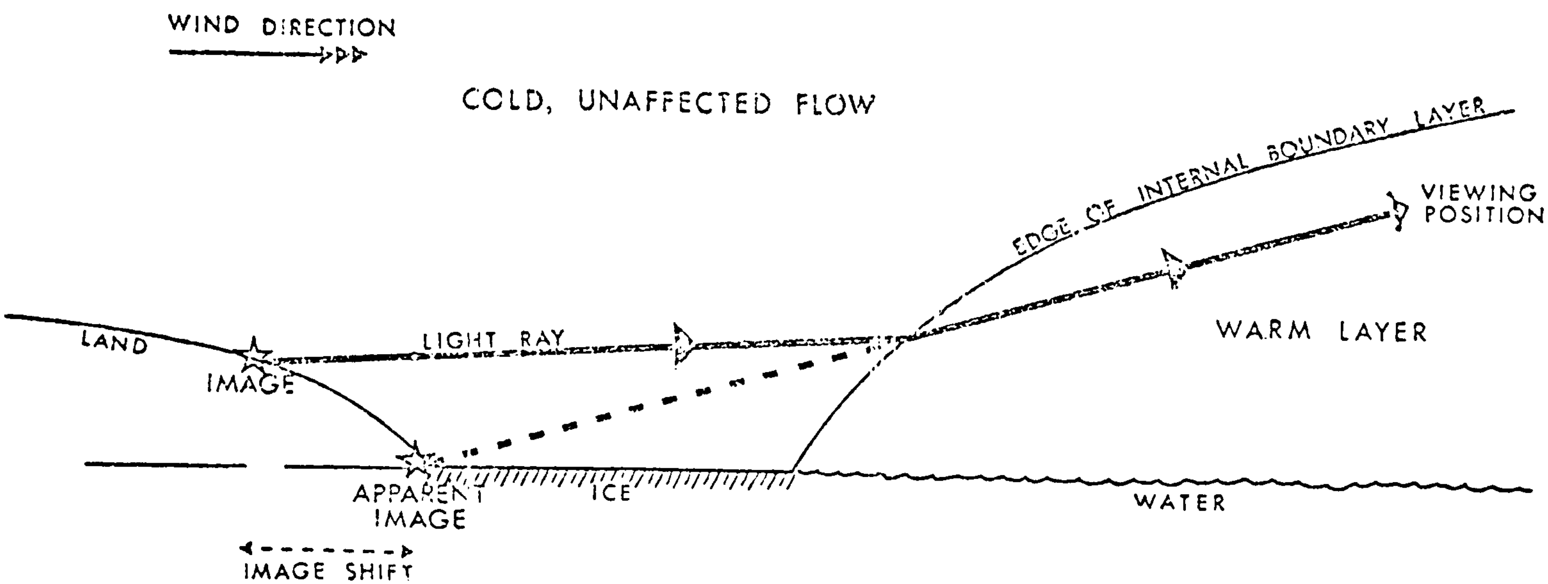


Figure 17-3.- Pictorial demonstration of image shifting due to internal boundary layer

(Prepared by Dept. of Environment)

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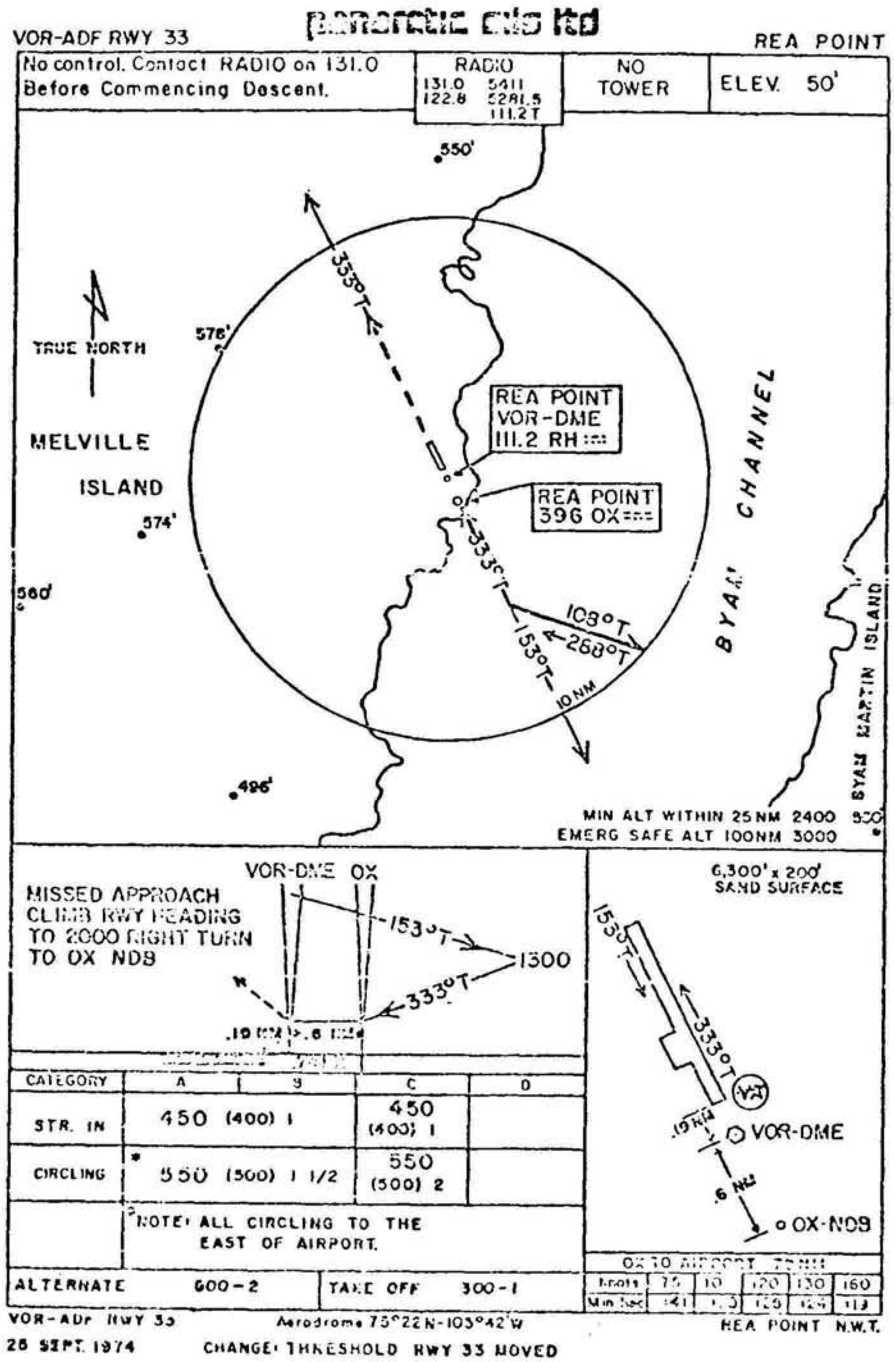


Figure 17-4

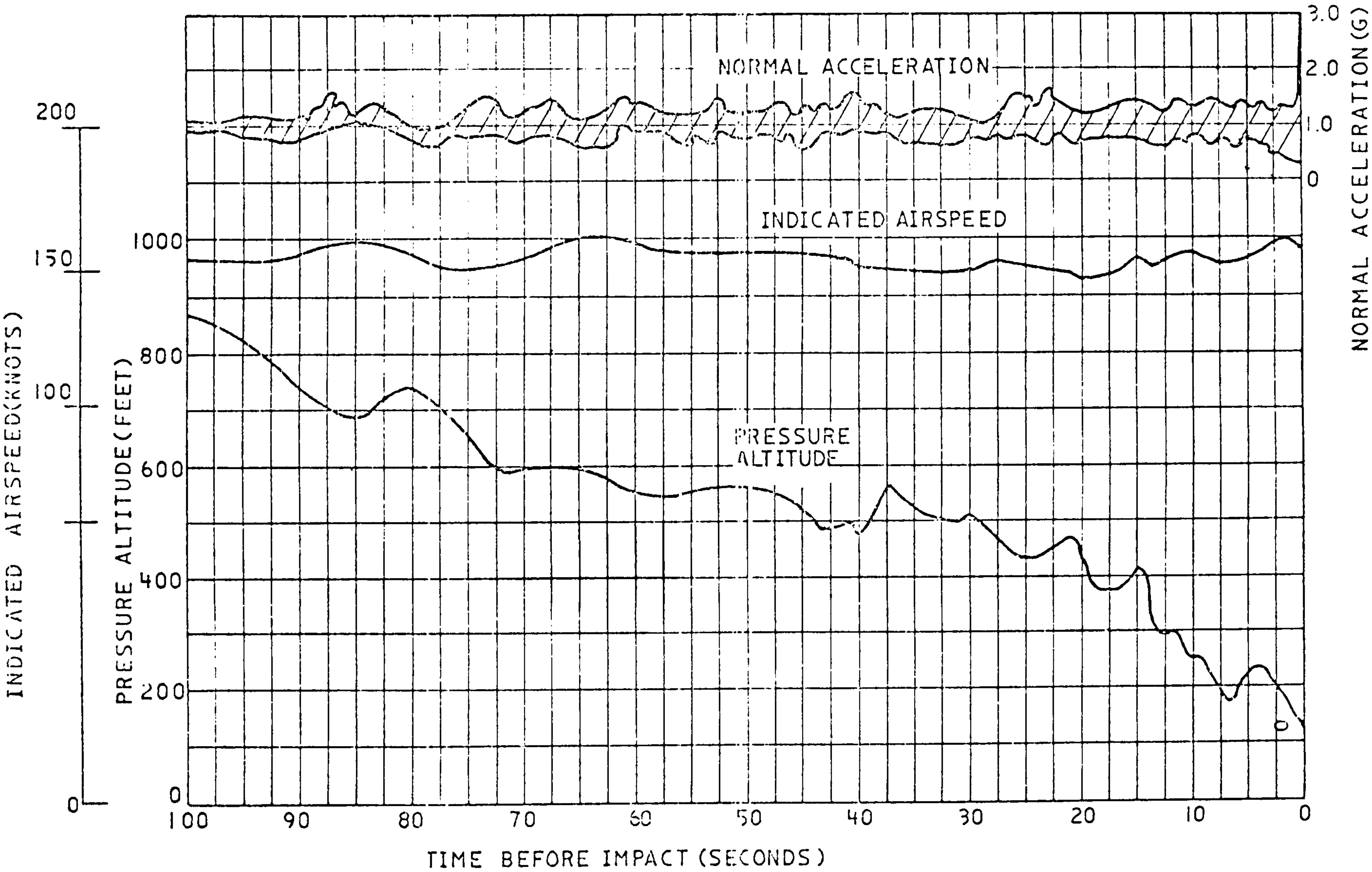


Figure 17-5.- Time histories of flight recorder data over last 100 seconds

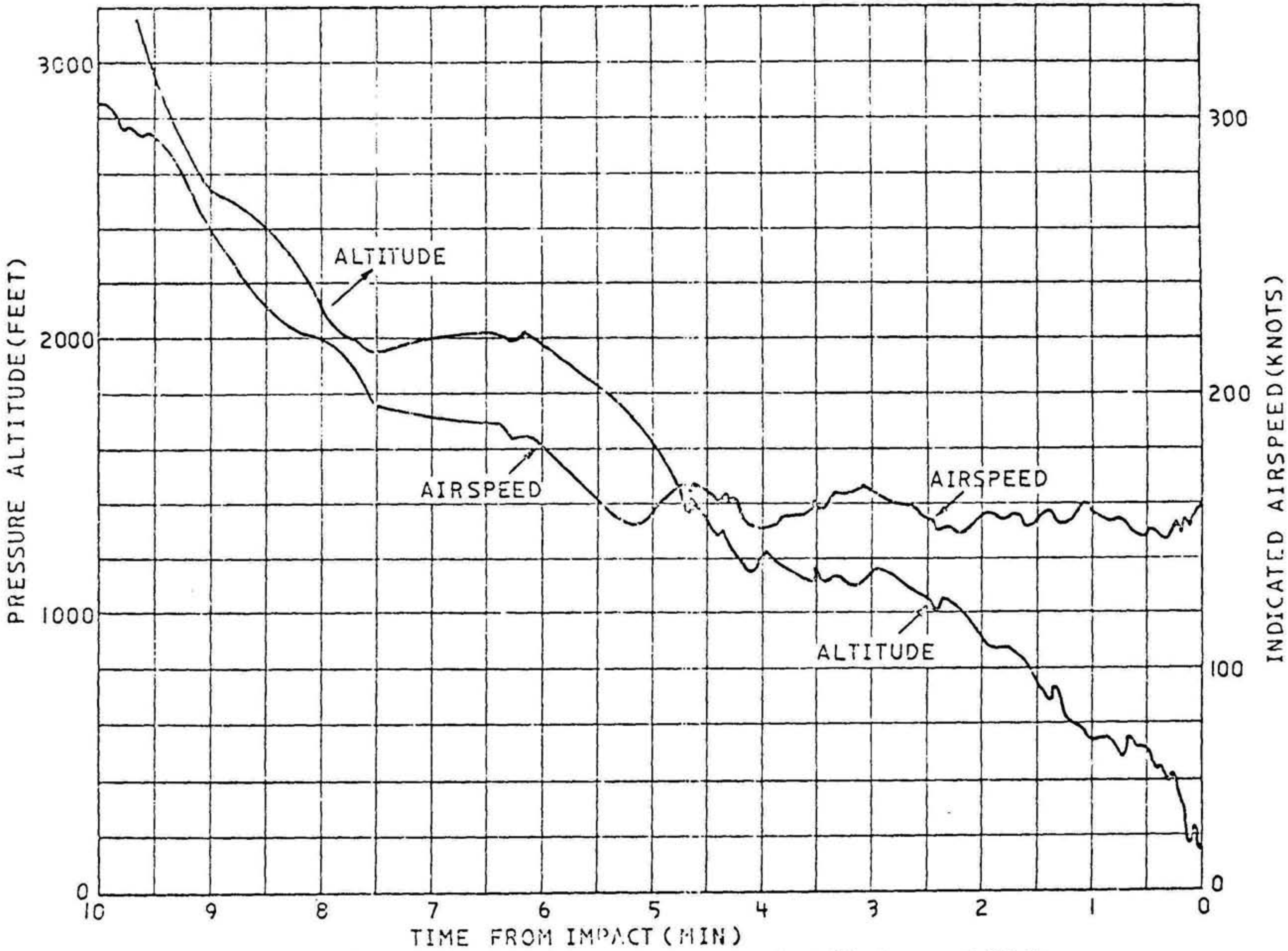


Figure 17-6.- Altitude and airspeed data over last 10 minutes of flight

No. 18

Lufthansa, Boeing 747, D-ABYD, accident at Nairobi, Kenya, on 20 November 1974.
Report No. CAV/ACC/26/74, dated July 1976, released by the
Accident Investigation Branch, East African Community.

1.- Investigation

1.1 History of the flight

Introduction

The aircraft was on a scheduled international passenger and cargo flight (LH 540/19) originating in Frankfurt, Federal Republic of Germany, and with intended stops at Nairobi, Kenya, and Johannesburg, South Africa. A change of flight deck and cabin crew was scheduled at Nairobi.

The flight from Frankfurt was routine, and the aircraft arrived at Nairobi at 0357 hours. The crew reported there were no defects, and in due course went off duty.

Pre-flight phase

The aircraft was refuelled up to 61 000 kg of fuel, resulting in an estimated take-off weight of 254 576 kg. Because this figure was well below the maximum authorized for the forecast take-off conditions, the take-off from Nairobi was planned on a reduced engine power basis ("-3A power"), using the following parameters:

Runway in use	06
V_1	125 kt IAS
V_R	138 kt IAS
V_2	148 kt IAS
Stabilizer trim setting	5.2
Rotation target attitude	14^o
Take-off EPR (-3A power)	1.46
Take-off EPR (-7 power)	1.51*

*This figure is routinely calculated and is available for use in case of engine failure or other emergency when extra power is required. During the Before Start checks it is set on the No. 4 EPR gauge bug.

The Pilot-in-command of the relieving crew designated his co-pilot as handling pilot for the sector. In due course the co-pilot, sitting in the right hand pilot's seat, read the Cockpit Checklist and the Before Start Checklist, with the appropriate crew member responding. The flight crew spoke amongst themselves without the use of the aircraft's intercommunication (interphone) system. For radio (RTF) communications they used their head-sets and hand-held microphones. At 0442 hours the engines were started in accordance with a revised procedure introduced by the Company the previous year. This required that the bleed air valve switches which control the aircraft's pneumatic system supply remain in the closed position until after the engines had been started. When the starting sequence was complete the co-pilot read the After-Start Checklist, which contained, *inter alia*, specific reference to confirmation that the bleed valves switches had been selected OPEN. The crew afterwards stated that up to this time, and indeed throughout the flight, the checklists were accomplished correctly and without undue haste.

The taxiing phase

At 0447 hours, the co-pilot requested taxi clearance, and the control tower cleared the aircraft to Runway 06.

Shortly afterwards the tower controller called the flight again, offering a choice of Runways 24 or 06. As he was aware that the aircraft was well below its limiting take-off weight for either runway and that the wind was light, the Pilot-in-command elected to use Runway 24, which would give a shorter flight path to intercept the initial track to Johannesburg. The crew considered that the change of runway would not materially alter their take-off data and they therefore did not recalculate it.

In order to reach the Runway 24 take-off point the Pilot-in-command had to taxi the aircraft down taxiway "C" and back-track the runway in use (see Appendix 1). Whilst the aircraft was on Taxiway "C" the co-pilot selected the flaps to the 10^{o} take-off position. Shortly afterwards the flight engineer started to read the taxiing Checklist sitting facing forwards and with his seat in the forward position. At 0451 hours, just after the checklist had been completed, the control tower passed the flight its Air Traffic Control (ATC) clearance. At the same time the Pilot-in-command turned the aircraft at the end of the runway. The flight engineer then read the Take-off Checklist. At 0452 hours, take-off clearance was received from the control tower, the surface wind being reported as calm.

The take-off run

The Pilot-in-command partially opened the throttles to initiate the take-off and the co-pilot took control of the nose-wheel steering. The flight engineer then adjusted the throttles to set the correct, -3A, take-off power of 1.46 EPR. At the call of "80" (80 kt IAS) he relinquished control of the throttles to the Pilot-in-command but continued to face forwards whilst monitoring the engine instruments on the pilots' centre panel. The co-pilot stated that shortly before target rotation speed (V_R) he released his forward pressure on the control column and then commenced the initial rotation to approximately 10^{o}. Flight recorder data indicates that rotation commenced at 135-136 kt and that rotation rate appeared to be normal. Eyewitnesses estimated the rotation point at between 2 165 and 2 400 m from the beginning of the runway.

During the rotation phase the acceleration, which up to that time had been normal, ceased abruptly. Lift-off occurred at approximately 145 kt, some 35 seconds before the time of first main impact, i.e. I-35. The observed lift-off point was between 2 305 and 2 500 m from the beginning of the runway. As the aircraft was lifting off, all three crew members noticed birds passing by the nose.

The airborne phase

Very shortly afterwards buffeting or "vibration" was experienced and the Pilot-in-command turned to the flight engineer to ask him if there were any indications of abnormal engine vibration. The flight engineer looked back at his panel to check the engine vibration meters and warning lights and confirmed that all was normal. On hearing this the Pilot-in-command thought that the vibration might be the result of unbalanced wheels. He therefore checked that a positive rate of climb was indicated and (at I-21) selected GEAR UP. The co-pilot reported that after becoming airborne he lost all feeling of acceleration such as during the normal take-off, and that he had to lower the nose and gradually descend in order to prevent the airspeed from deteriorating. At no time, in his opinion, had the pitch attitude exceeded approximately 12^{o}.

The flight recorder trace indicates that at I-19 when the aircraft reached approximately 100 ft above ground level, the rate of climb, which had initially been 400-500 ft per minute, fell rapidly to zero, and the aircraft started a gradual descent.

The recording also shows that after reaching a maximum value of some 146 kt just before lift-off, the airspeed thereafter fell slightly, remaining within the range 145 to 140 kt IAS until just before impact*. At I-15 the flight engineer again confirmed that the engines were running normally. At I-8, as the speed decayed to 140 kt, the stick shaker operated for three seconds. The Pilot-in-command immediately put his hands on the control column to lower the nose, but was unable to lower it appreciably because of the proximity of the ground. After a 2 second pause the stick shaker recommended operation, and at I-1 the landing gear warning horn sounded. Subsequent investigation indicated that the horn had been activated by the action of the co-pilot in closing all four throttles when he realized that impact with the ground was imminent.

The crew stated that, due to anxiety about engine vibration, power was never increased beyond the initial (reduced) take-off power setting. A former airline pilot who was sitting in the left hand window seat at row 16 stated that the take-off run, rotation and lift-off appeared normal. After lift-off, he felt the aircraft shaking and, on looking out of the window, noticed that the wing leading edge flaps were not extended.

Ground impact

The first point of impact occurred when the tail of the aircraft grazed bushes and grass located 1 120 m from the departure end of Runway 24, and some 33 m to the south of the extended centre line. The aircraft continued in a partially airborne condition for an additional 114 m with its tail scraping the ground. It then struck an access road running at right angles to the flight path and protruding to a height of some 8 ft above the surrounding terrain. On impact the tail structure began to disintegrate, but the major part of the aircraft skidded a further 340 m, during the course of which it turned to the left and came to rest facing in the opposite direction. Fire broke out in the left wing and the separated tail section. Shortly afterwards an explosion in the left inner wing spread the flames to the fuselage.

As the aircraft came to a halt the Pilot-in-command pulled the four engine fire switches. After an unsuccessful attempt to open the overhead escape hatch he and the flight engineer eventually escaped through holes in the fuselage side. The co-pilot finally succeeded in opening the escape hatch and lowered himself to the ground by means of the emergency escape reel. He and the Pilot-in-command assisted passengers to escape until forced to leave the main wreckage area by explosions. Due to injury the flight engineer was unable to assist in rescue attempts.

Due to the development of events and the rapid disintegration of the aircraft immediately following initial impact, no evacuation command was heard in the cabin. Accordingly every cabin crew member acted independently on the basis of their instructions at the time of training.

Escape from the left hand side of the cabin was impossible on account of the fierce fire that had developed, but evacuation through doors Nos. 2 and 3 on the right hand side was accomplished. The automatic action of both these doors and the deployment of both escape chutes functioned correctly.

*Note: Airspeed values observed by the crew during the flight were generally several knots higher than those obtained from the flight recorder.

A number of passengers and some cabin crew were thrown out of the cabin as it disintegrated, and some left through fractured openings after the aircraft came to rest. It was reported that determined efforts to open doors Nos. 1 and 4 on the right hand side of the cabin were unsuccessful. During the evacuation the cabin crew continued to assist passengers to leave the wreckage until forced away by the fierceness of the fire.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	55	-
Non-fatal	9	45	-
None	4	39	

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

Introduction

Soon after the accident had occurred, it became apparent that the leading edge flaps were in the fully retracted position at impact. Further investigation suggested the probability that these flaps were incorrectly positioned prior to take-off because the pneumatic supply which powers the leading edge flap units was switched off at the time the flaps were selected to the take-off position.

Apart from the incorrect leading edge flap configuration, there was no evidence of any other primary causal factor.

Crew activities

There seems little doubt that, at the time of the introduction by a number of operators of the revised engine starting procedure which required the pneumatic system bleed valves to be switched to the closed position, the essential role played by these valves in the sequencing of the leading edge flaps was to a certain extent overlooked.

Although the operator's checklists, in common with those of other ATLAS Operators, were amended to include a requirement for the bleed valve switches to be re-opened, and for a check that the VALVE CLOSED indication lights were extinguished, no specific check of pneumatic system pressure was included. In view of the intermittent illumination of the VALVE CLOSED indication lights at low power settings even though the associated bleed valve switches are open, they cannot be regarded as a reliable indication of switch position. Therefore an independent check of system pressure should have been included. However, an experienced crew member, such as the flight engineer of D-ABYB on the accident flight, could have been expected automatically to check system pressure in the normal course of events.

There is no doubt that the flight engineer believed that he had selected the bleed valves OPEN during the After-Start Checks, and he certainly gave the correct response. Nevertheless, in view of the evidence it is difficult to come to any conclusions other than that he must inadvertently have failed to open them.

If he had opened them he must have closed them again within the next two minutes in order to have shut off the pneumatic air supply before the flaps were selected to TAKE-OFF, for the leading edge flap units to be found in the position they were in at impact. In view of the fact that during this time there are no particular actions which have to be carried out by the flight engineer which could be confused with the operation of the four bleed valve switches, this seems unlikely. If one accepts this assumption, it follows that he must also have failed to notice that the four "VALVE CLOSED" amber lights were continuously illuminated and the pneumatic gauge indication of zero duct pressure.

All three crew members presumably believed that they had seen the correct number of leading edge green lights at the time of the Taxiing Checks prior to take-off. In view of the findings of the system analyses that certain single failures could produce an incorrect illumination of the green light on the pilots' panel, sometimes accompanied by one or more of the lights on the flight engineer's annunciator panel, the possibility that each crew member did see at least one green light cannot be excluded. However, the chance of a faulty indication occurring prior to take-off flap selection and not being noticed, or alternatively of its occurring coincidentally with, or just after flap selection, but before the checklist call "FLAPS", must be extremely small. There does nevertheless exist the previous report of just such a case which, however, could not be reproduced. However, if a single fault had existed, the manufacturer's analyses show that a fully correct indication of leading edge flap extension (8 green, no amber lights) could not have been present on the flight engineer's annuciator panel prior to the take-off. It is relevant to note that at this stage the flight engineer would be reading the checklists with his seat in a forward position, following Company practice. His angle of view of the leading edge flap indications at the rear of his panel is such that it is possible to be misled by a quick glance into believing that all eight green lights are on, when in fact they are not ALL on.

The cockpit voice recording confirms that one of the pilots, probably the Pilot-in-command, responded to the call FLAPS, by the words "TEN TEN" followed by another word which could not be understood but which might have been "GREEN". Any other response would have been abnormal and therefore the occasion for comment by other crew members. No response can be heard from the flight engineer, but due to the limitations of the voice recording system the fact that a word or phrase from the checklist cannot be heard in the recording does not necessarily mean that it has not been spoken. It must equally be appreciated that because a correct response to a checklist item has been heard, this cannot be taken as definite confirmation that the check has been physically completed.

At this point, it should be mentioned that although the two pilots are expected to cross-check each other's panels wherever possible, the company manuals made no suggestion of the need for the Pilot-in-command to check any items on the flight engineer's panel before take-off. Therefore on the accident flight the flight engineer had no "back-up" monitoring. Although this philosophy is common to many operators, and is probably acceptable when adequate monitoring facilities of all vital parameters are provided on pilots' panels, in the light of this accident it is suggested that operators should re-examine the validity of their policies in this respect.

Performance considerations

The Pilot-in-command followed normal practice in planning the take-off using reduced engine power in conditions when an adequate performance margin exists. Under the accident conditions the take-off field length available in either runway direction was ample.

Acceleration during the take-off run was normal; there was no evidence of lack of thrust or excessive drag during this phase, and as far as performance was concerned there would have been no indication to the crew that all was not well.

The disparity between eyewitness reports and estimates of the rotation and lift-off points is not considered a significant feature. The probability is that several seconds would have elapsed between the initiation of the manoeuvres and their observation by witnesses situated some distance away, during which time the aircraft would have travelled an appreciable distance.

Analysis of the available data indicates that virtually the whole of the 35-second flight took place in a condition of abnormally high drag and well into the presence of substantial airflow separation; the aircraft was in a condition which can best be described as "partially stalled". It never reached the fully stalled state, which would have been characterized by a greater rate of descent, a lower airspeed reading and, possibly, a change of attitude.

The loss of acceleration during rotation and the subsequent minimal rate of climb resulted from the considerable increase in drag caused by the proximity to the stall of the incorrectly configured aircraft. The discrepancy between recorded airspeed values and those indicated to the pilots could have been due to system errors and would not normally have been significant. However, if the recorded values are correct, they indicate that rotation was initiated slightly early with the result that acceleration ceased at a correspondingly lower value than it would otherwise have done. A study of the low speed characteristics of the aircraft with the leading edge flaps retracted makes clear the extreme sensitivity of rate of climb to airspeed, and in particular that, assuming power and attitude remained unchanged, the aircraft was incapable of emerging from ground effect at any speed below 146 kt IAS. After rotation, the entire flight took place at a recorded airspeed just below this figure. As the aircraft climbed out of ground effect, the handling pilot attempted to maintain or increase airspeed by lowering the nose, but his action was largely ineffective. This may have been partially due to the presence of slightly adverse wind sheer during the climb-out. However, any corrective action he may have taken was nullified by the severity of the drag rise which occurred at about this time (between I-21 and I-10), and which was probably largely due to a further separation of the airflow as the speed fell slightly and the aircraft lost the benefit of ground effect. In addition there was an adverse contribution, believed to be small, from the opening of the landing gear doors during the retraction cycle initiated by the Pilot-in-command at I-21. The possibility cannot be entirely ruled out that in the aircraft's already critical aerodynamic condition the effect on drag of the gear doors was larger than predicted. It was perhaps remarkable that the gear was not fully retracted at the time of impact, 21 seconds later, but tests have shown that without the assistance of the air driven pumps, as would be the case if the pneumatic system was not switched on, this time was not exceptional.

The crew spent the short time available to them in unsuccessfully attempting to diagnose the situation. In view of the two pilots' previous training in approaches to the stall, it seems surprising that they did not recognize the pre-stall buffet for what it was. However, the non-standard configuration and the presence of ground effect may have modified its extent and characteristics compared with those encountered in their normal flight and simulator training. Moreover, they were almost certainly misled by the fact that their attitude and airspeed indications were close to the values they would have expected to see at this stage of the flight. Their target V_2 speed, which included a 20 per margin above the normal configuration stalling speed, was 148 kt. Remembering the birds seen a few seconds earlier, and confronted with vibration and a low rate of climb, they assumed an engine malfunction and made no move to alter the power settings while trying to locate the fault. In spite of their anxiety about engine trouble, it might have been expected that, when the aircraft started to descend, all available power would have been applied. On evidence from the engine manufacturer this would not seriously have affected the engines for at least five minutes. However, analysis of possible recovery actions suggests that even in the first ten seconds of the flight, a decrease in pitch attitude would have been required in addition to an increase in power. This type of reaction was unlikely to have been forthcoming unless the pilots had appreciated that their airspeed was in fact dangerously low. During the succeeding 10-15 seconds, up to approximately I-10, the situation could only have been retrieved by a "stall recovery" type of manoeuvre involving a deliberate loss of height to just above the ground - a desperate action which would only have been attempted if the semi-stalled situation had been identified.

By the time that the stall warning system began to operate (I-8) as the airspeed fell to 140 kt, it was too late to take effective action. This system met the requirements of the Certificating Authority to provide adequate warning of an approaching stall in any standard configuration. It is unreasonable to expect the certification of non-standard configurations. Nevertheless it remains true that had the system installed on the 747 included an input from the leading edge flap position it would on this occasion have operated at about the time of lift-off and should have alerted the crew to the true nature of their problem in time for an effective recovery to be made.

The discrepancy between the onset of stall warning as measured during flight test in free air in the accident configuration and that recorded on the accident flight could be due to several factors including system tolerances, differing rates of approach to the stall, and the presence of ground effect during the relevant part of the accident flight.

The elevated access road could by no means be categorized as an obstruction to the normal take-off flight path, being only 8 ft high and over 1 200 m from the aerodrome; nevertheless the severity of the accident was considerably increased by the aircraft's collision with a protruding obstacle at right angles to the flight path rather than with the otherwise comparatively flat surrounding country.

Historical background

A striking feature of this accident is the number of previous incidents involving the leading edge flaps which are now known to have occurred and which for one reason or another failed to alert the manufacturer, the regulatory authorities or, with very few exceptions, the airlines concerned.

The first Boeing 747 operator to have reported a take-off with the leading edge flaps partially retracted, in August 1972, realized the potential danger sufficiently to alert the manufacturer and the Certificating Authority, and to initiate, in conjunction with the manufacturer, a modification to its own aircraft to include the leading edge flap position in the take-off configuration aural warning system. Both the Certificating Authority and the manufacturer took the view that this was a report of an isolated incident which did not call for any action on their parts because, provided crew drills were correctly followed, there should be no recurrence. In coming to this conclusion they perhaps overlooked the fact that it is the isolated incident which often gives warning of a potentially serious hazard. They must have reached it in the full knowledge that an aircraft with leading edge flaps retracted, taking off at its normal target speed, would have its speed safety margin eroded to the extent that it would be very close to the stall at an altitude where stall recovery was improbable.

Before deciding that no further action was required of them, the manufacturer and the authority concerned should therefore have satisfied themselves beyond all reasonable doubt of the adequacy of the leading edge flap configuration warning system. They should have taken into account, amongst other factors, the fallibility of human beings and the integrity of the system against failure of which they were providing a warning. The fact that the Boeing 747 leading edge flaps are pneumatically powered via electrical sequencing from the hydraulically operated trailing edge flaps might suggest increased possibilities of incorrect operation, compared with a more straightforward arrangement. Following the first reported incident, there occurred eight known incidents involving whole or partial deactivation of the leading edge flap system. In three cases the indication system did alert the crew prior to take-off. However, the continuing recurrence of incidents in spite of warning bulletins from the manufacturer and, no doubt, operators, only emphasized the human fallibility factor and the necessity for an effective warning system as a back-up.

The manufacturer obviously considered the existing warning system to be adequate, because whilst agreeing to the modification proposed by the operator involved in the first reported incident, to include the leading edge flap configuration in the take-off aural warning system, they did not officially mention its existence to other Boeing 747 operators. On all "standard" 747 aircraft, therefore, up to the time of the accident, the only warning of incorrectly positioned leading edge flaps was provided by the absence of a green light on the pilot's centre panel and the absence of one or more of the 8 green lights on the flight engineer's annunciator panel, with the possible addition of amber lights on the engineer's and pilot's panel if the flaps were partially extended.

As a result of the November, 1972, incident in which the crew reported the illumination of the leading edge green light on the pilot's panel although the leading edge flaps has not extended, a study undertaken by the manufacturer showed that this condition could be caused by any one of six separate faults.

Nevertheless, the most recent guidance from the manufacturer on the subject of leading edge flap configuration warning, generally available to operators at the time of the accident, was that contained in the Field Service Memorandum and the subsequent Bulletin of November 1972. These described the incident which had just occurred, and mentioned that the flight engineer's annunciator panel lights had correctly indicated the flap position. The Operations Manual Bulletin merely emphasized cockpit procedural steps, circuit-breaker engagement checks and that the flight engineer's annunciator panel was available "as a supplementary check if desired."

Further evidence relevant to the inadequacy of the leading edge flap indication system as a warning was provided by the series of incidents, reports of which, for one reason or another, never reached the Certificating Authority or the manufacturer until after the accident. It appears that in some cases the operators either did not realize the serious implications of the particular incidents, or else were too embarrassed to report what they perhaps considered as a breakdown in their operating procedures. In other cases the crew themselves were presumably too embarrassed or too afraid of the consequences of reporting their mistakes. It is significant that, after the accident, three reports of successful take-offs with the leading edge flaps retracted filtered through from crews of one operator in a state where mandatory incident reporting is in force. Apparently the mere legal introduction of mandatory reporting of operational incidents is in itself not necessarily effective. Much greater inducements are needed to ensure that crews and operators are not deterred either through embarrassment or fear of the consequences from reporting all incidents which might provide a warning indication for the future. A necessary corollary is that operators, manufacturers and regulatory authorities must have both the will and the capability to sift through the inevitably large number of incoming reports in order to identify potentially hazardous items. Having done so, nothing should be allowed to stand in the way of effective remedial action.

It was unfortunate that the efforts of the operator who reacted positively to the report of a second take-off, where the leading edge flaps were retracted, by attempting to alert the Certificating Authority, were nullified. However, had the warning contained in their letter of August 1974, reached the Certificating Authority, it seems unlikely, in view of their previous somewhat negative attitude to the matter, that action would have been taken in time to affect the course of the accident.

After the report of "incident 3" in November, 1972, Lufthansa, in common with other 747 operators, followed the manufacturer's recommendation to emphasize to crews the necessity to check circuit breaker engagement and adhere to the correct drills. In addition they included in their checklists a check, after flap selection, on the status of the flight engineer's leading edge flap annunciator panel. Unfortunately, due to the inadequacy of the international incident reporting system, operators as well as the manufacturer and the Certificating Authority, were largely unaware of a number of leading edge flap incidents that had occurred subsequently.

The fact that a number of 747 aircraft had previously accomplished successful take-offs with the leading edge flaps wholly or in part retracted is believed to be due to a combination of a number of factors:

1. The effect of altitude, which would be to reduce total engine thrust, and therefore acceleration, at whatever power setting was used. It is believed that the successful take-offs in this configuration were all accomplished at lower altitude airfields than Nairobi.

2. The take-off at Nairobi was made using a reduced engine power setting. This inevitably resulted in a reduced acceleration compared with a take-off using the normal maximum (-7) power setting. However, it has not been possible definitely to establish what levels of power were used on the successful take-offs. The fact that on this occasion the correct reduced power setting was used in accordance with normal procedures, and with an ample power margin for all reasonable contingencies, does not appear to justify a re-examination of the philosophy of carefully regulated use of reduced power settings for take-off.

3. The probable presence of slight adverse wind sheer, i.e. increasing tail-wind component, during the climb-out.

Adequacy of warning/indication systems

Although it seems difficult to believe that the accident take-off could have been made with the bleed valves switched off, necessarily involving failure to notice continuous illumination of the amber bleed valve lights and the lack of pneumatic duct pressure, direct confirmation of this possibility was provided by the incident which occurred exactly seven days before the accident. It is now clear that the indication lights and the positions of the leading edge flaps could be and, on occasion, were being missed. This was because the vital importance of the leading edge flaps and their associated systems had not been sufficiently stressed on the lines of "if these indications are ignored the aircraft could stall on take-off", and above all because the warning of unsafe configuration basically consisted of the ABSENCE of lights. It is recognized that the Boeing 747 has an excellent safety record. Also that, as designed and installed, the leading edge flap lights were only intended to be position indicators, and as such were not included in the master warning or caution panels. However, the correct positioning of the leading edge flaps is almost essential to a successful take-off. In the light of experience it is now clear that correct leading edge flap positioning could not be guaranteed, and therefore that unmistakable warning of an incorrect setting was required. The history of previous incidents in which crews failed to notice that the leading edge flaps were incorrectly positioned confirms that the indication system as fitted to the aircraft at the time of the accident did not meet this requirement, and therefore needed supplementing with a more positive warning device.

When taken in conjunction with agreed improvements to the indication system, the modification endorsed by the Certificating Authority involving the inclusion of the leading edge flap position in the take-off configuration aural warning system, would appear to meet the requirement for an adequate system. However, its effectiveness will on occasion be nullified unless operators remove the take-off warning system from the list of allowable deficiencies, that is to say, make it a "no go" item. In view of the frequency of previous incidents this change is considered essential.

As a further measure, consideration should also be given to the inclusion of leading edge flap position in the stall warning system programme and to the inclusion of a warning, on the pilots' annunciator panel, of low pneumatic duct pressure.

Flight data recorder

Although the accident aircraft's five parameter engraved foil recorder met the current requirements of the state of registry, the quality and quantity of information it provided was not in keeping with the standards expected of aircraft of the Boeing 747 category. On this occasion, other evidence was fortunately available so that the Inquiry was not greatly impeded. However, there is no doubt that for accident investigation purposes the minimum satisfactory standard for all Boeing 747 and similar category aircraft is a multi-channel recorder compatible with ARINC 573 or a similar characteristic.

Cockpit voice recorder

Because the crew did not use the aircraft's intercommunication system for cockpit conversation, three out of the four recorder channels were rendered ineffective and possibly important evidence was lost. Apart from any improvement to the quality of the transcription obtainable from the area microphone channel it appears to be essential that the other three channels should be more fully utilized; for instance by a requirement for the crew to use a "hot microphone" cockpit voice recorder circuit during the take-off, approach and landing phases.

2.2 Conclusions

a) Findings

i) The crew were properly licensed and experienced.

ii) The aircraft had been maintained in accordance with an approved maintenance schedule and its Certificate of Airworthiness was valid.

iii) The weight of the aircraft and its centre of gravity were within the prescribed limits.

iv) The aircraft took off with the leading edge flaps in the retracted position, with the result that it became airborne in a high drag, partially stalled condition.

v) The loss of ground effect during the climb-out together with the probable presence of slight adverse wind sheer and the opening of the landing gear doors during the retraction cycle contributed to a further reduction in performance with the result that the aircraft descended and struck the ground.

vi) Following the introduction of a modified procedure which involved the closing of the pneumatic system bleed valves, the revision of the cockpit checklist after starting was completed did include a requirement for checking the re-opening of the bleed air valve switches but did not specifically call for a check on the pneumatic system.

vii) After the engines had been started the flight engineer omitted to open the bleed valves, thereby rendering inoperative the pneumatic system which powered the leading edge flap units.

viii) The indications of leading edge flap position prior to take-off could not be positively established. However, it is extremely unlikely that the flight engineer's annunciator panel indicated that all the leading edge flap units were in the correct take-off position.

ix) In view of the inherent possibilities of incorrect leading edge flap operation and the critical nature of leading edge position during the take-off phase, adequate warning of incorrect position should have been provided. The existing indication system in use at the time of the accident did not meet this requirement.

x) Cockpit procedures did not call for any cross checking by the Pilot-in-command of items on the flight engineer's panel.

xi) The accident could probably have been averted had the pitch angle been reduced and power been increased sufficiently early in the flight.

xii) The pilots did not take effective recovery action in the short time available to them because they did not identify the semi-stalled condition of the aircraft until alerted by the stall warning system shortly before the aircraft struck the ground.

xiii) The stall warning system did not give adequate warning of the critical condition of the aircraft because it was not programmed to take account of leading edge flap position. Had it been so programmed, its operation at lift-off might have alerted the crew in time to affect a recovery.

xiv) This accident was preventable. Inadequacies in international incident reporting procedures and effective follow-up action could be considered a contributory factor.

b) Cause or
Probable cause(s)

The accident was caused by the crew initiating a take-off with the leading edge flaps retracted, because the pneumatic system which operates them had not been switched on. This resulted in the aircraft becoming airborne in a partially stalled condition which the pilots were unable to identify in the short time available to them for recovery.

Major contributory factors were:

1) the lack of warning of a critical condition of leading edge flap position;

2) the failure of the crew to satisfactorily complete their checklist items.

3.- Recommendations

It is recommended that:

1) The take-off configuration aural warning system programme on Boeing 747 aircraft should be modified to include leading edge flap position.

2) The take-off configuration aural warning system on Boeing 747 aircraft should be excluded from the list of allowable deficiencies.

3) Consideration be given to the incorporation of leading edge flap position in the aircraft's stall warning programme.

4) Consideration be given to the inclusion of a pneumatic duct low pressure warning of the Pilot's Annunciator Panel.

5) Consideration be given to amending operating procedures where necessary to include a cross-check by the Pilot-in-command of important items on the flight engineer's panel.

6) In Boeing 747 and similar aircraft, States of Registry should require the carriage of a multi-channel flight data recorder compatible with ARINC 573 or equivalent characteristic.

7) In Boeing 747 and similar aircraft, consideration should be given by States of Registry to require the installation and use of hot microphone cockpit voice recorder circuits during the take-off, approach and landing phases.

8) Implementation of adequate international incident reporting procedures, as initiated in the Accident/Incident Reporting System (ADREP) of ICAO, including effective follow-up action, should be enforced.

4.- Action taken

The following is a summary of the principal preventative measures taken since the date of the accident:

a) On 23 November 1974, at the request of the Chief Inspector of Accidents, East African Community, and the United States National Transportation Safety Board, the Federal Aviation Administration (FAA) recommended an interim flap inspection procedure. This was to the effect that all Boeing 747 operators should ensure that, prior to leaving the ramp, the flaps should be extended to the normal take-off position and visual confirmation be obtained from a qualified ground observer that all wing leading edge devices were fully extended.

b) On 6 December 1974, the manufacturer telexed all Boeing 747 operators briefly describing the circumstances of the accident and re-emphasizing the necessity for checks on bleed valve switches, leading edge flap circuit breakers and alternate system switches.

c) On 11 December 1974, the FAA issued a "Notice of Proposed Rule Making" proposing an Airworthiness Directive (AD) which would require modifications to the existing leading edge flap indication system and the addition to the take-off aural warning system of an input from the leading edge flap logic unit.

d) On 16 December 1974, the manufacturer suggested alternative modification proposals, as follows:

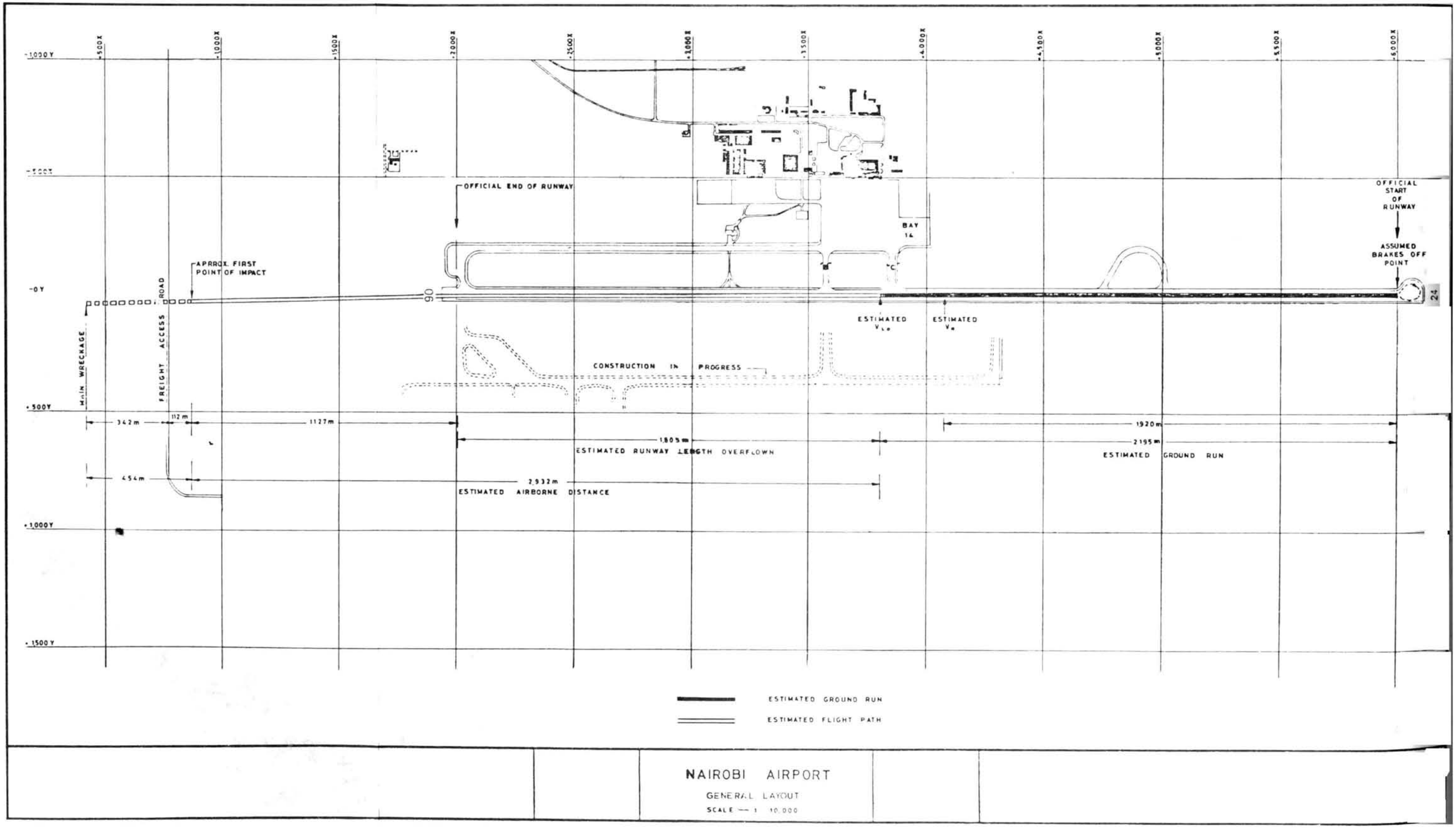
   i) that the amber light on the pilot's panel would light up when any one leading edge flap unit is not fully extended and the trailing edge flaps are at a take-off setting.

   ii) that limit switches in the leading edge flap motors would cause inputs to the take-off aural warning system when any flap unit is not fully extended and the trailing edge flaps are at a take-off setting.

The FAA accepted these proposals and issued an Airworthiness Directive covering the modifications effective 24 March 1975, to be complied with within five months.

ICAO Ref.: AIG/413/74

APPENDIX 1


OFFICIAL END OF RUNWAY
OFFICIAL START OF RUNWAY
ASSUMED BRAKES OFF POINT
APPROX. FIRST POINT OF IMPACT
MAIN WRECKAGE
FREIGHT ACCESS ROAD
BAY 14
ESTIMATED V1.0
ESTIMATED VR
CONSTRUCTION IN PROGRESS
342 m
112 m
1127 m
1920 m
1,805 m
ESTIMATED RUNWAY LENGTH OVERFLOWN
2195 m
ESTIMATED GROUND RUN
454 m
2,932 m
ESTIMATED AIRBORNE DISTANCE
ESTIMATED GROUND RUN
ESTIMATED FLIGHT PATH
NAIROBI AIRPORT
GENERAL LAYOUT
SCALE — 1 : 10,000

No. 19

Trans World Airlines, Boeing 727-231, N-54328, accident at Berryville, U.S.A., on 1 December 1974. Report No. NTSB-AAR-75-16, dated 26 November 1975, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

Trans World Airlines, Inc., Flight 514 was a regularly scheduled flight from Indianapolis, Indiana, to Washington, D.C., with an intermediate stop at Columbus, Ohio. There were 85 passengers and 7 crew members aboard the aircraft when it departed Columbus.

The flight was dispatched by TWA's dispatch office in New York through the operations office in Indianapolis. The pilot-in-command received a dispatch package which included en-route and destination weather information. The flight operated under a computer-stored instrument flight rules (IFR) flight plan.

Flight 514 departed Indianapolis at 0853 EST[1/] and arrived in Columbus at 0932. The crew obtained weather and aircraft load information. The flight departed Columbus at 1024, 11 minutes late.

At 1036, the Cleveland Air Route Traffic Control Center (ARTCC) informed the crew of Flight 514 that no landings were being made at Washington National Airport because of high cross-winds, and that flights destined for that airport were either being held or being diverted to Dulles International Airport.

At 1038, the pilot-in-command of Flight 514 communicated with the dispatcher in New York and advised him of the information he had received. The dispatcher, with the pilot-in-command's concurrence, subsequently amended Flight 514's release to allow the flight to proceed to Dulles.

At 1042, Cleveland ARTCC cleared Flight 514 to Dulles Airport via the Front Royal VOR, and to maintain flight level (FL) 290.[2/] At 1043, the controller cleared the flight to descend to FL 230 and to cross a point 40 miles west of Front Royal at that altitude. Control of the flight was then transferred to the Washington ARTCC and communications were established with that facility at 1048.

During the period between receipt of the amended flight release and the transfer of control to Washington ARTCC, the flight crew discussed the instrument approach to Runway 12, the navigational aids, and the runways at Dulles, and the pilot-in-command turned the flight controls over to the co-pilot.

1/ All times are eastern standard times expressed on 24-hour clock.
2/ Altitude reference used above 18 000 ft MSL, using an altimeter setting of 29.92.

When radio communications were established with Washington ARTCC, the controller affirmed that he knew the flight was proceeding to Dulles. Following this contact, the cockpit voice recorder (CVR) indicated that the crew discussed the various routings they might receive to conduct a VOR/DME approach to Runway 12 at Dulles. They considered the possibilities of proceeding via Front Royal VOR, via Martinsburg VOR, or proceeding on a "straight-in" clearance.

At 1051, the Washington ARTCC controller requested the flight's heading. After being told that the flight was on a heading of 100°, the controller cleared the crew to change to a heading of 090°, to intercept the 300° radial of the Armel VOR, to cross a point 25 miles northwest of Armel, to maintain 8 000 ft,[3/] and "... the 300° radial will be for a VOR approach to Runway 12 at Dulles". He gave the crew an altimeter setting of 29.74 for Dulles. The crew acknowledged this clearance. The CVR recording indicated that the Armel VOR was then tuned on a navigational receiver. The pilots again discussed the VOR/DME approach to Runway 12 at Dulles.

At 1055, the landing preliminary check list was read by the flight engineer and the other crew members responded to the calls. A reference speed of 127 kt was calculated and set on the airspeed indicator reference pointers. The altimeters were set at 29.74.

At 1057, the crew again discussed items on the instrument approach chart including the Round Hill intersection, the final approach fix, the visual approach slope indicator and runway lights, and the airport diagram.

At 1059, the pilot-in-command commented that the flight was descending from 11 000 ft to 8 000 ft. He then asked the controller if there were any weather obstructions between the flight and the airport. The controller replied that he did not see any significant weather along the route. The pilot-in-command replied that the crew also did not see any weather on the aircraft weather radar. The CVR recording indicated that the pilot-in-command then turned on the anti-icing system.

At 1101, the controller cleared the flight to descend to and maintain 7 000 ft and to contact Dulles approach control. Twenty-six seconds later, the pilot-in-command initiated a conversation with Dulles approach control and reported that the aircraft was descending from 10 000 ft to maintain 7 000 ft. He also reported having received the information "Charlie" transmitted on the ATIS broadcast.[4/]

The controller replied with a clearance to proceed inbound to Armel and to expect a VOR/DME approach to Runway 12. The controller then informed the crew that ATIS information Delta was current and read the data to them. The crew determined that the difference between information Charlie and Delta was the altimeter setting which was given in Delta as 29.70. There was no information on the CVR to indicate that the pilots reset their altimeters from 29.74.

At 1104, the flight reported it was level at 7 000 ft. Five seconds after receiving that report, the controller said, "TWA 514, you're cleared for a VOR/DME approach to Runway 12". This clearance was acknowledged by the pilot-in-command. The CVR recorder the sound of the landing gear warning horn followed by a comment from the

3/ All altitudes and elevations are expressed in feet above mean sea level unless otherwise noted.

4/ ATIS - Automatic Terminal Information Service.

pilot-in-command that "Eighteen hundred is the bottom". The co-pilot then said, "Start down". The flight engineer said, "We're out here quite a ways. I better turn the heat down".

At 1105:06, the pilot-in-command reviewed the field elevation, the minimum descent altitude, and the final approach fix and discussed the reason that no time to the missed approach point was published. At 1106:15, the co-pilot commented that, "I hate the altitude jumping around". Then he commented that the instrument panel was bouncing around. At 1106:15, the pilot-in-command said, "We have a discrepancy in our VOR's, a little but not much". He continued, "Fly yours, not mine". At 1106:27, the pilot-in-command discussed the last reported ceiling and minimum descent altitude. He concluded, "... should break out".

At 1106:42, the co-pilot said, "Gives you a headache after a while, watching this jumping around like that". At 1107:27, he said, "... you can feel that wind down here now". A few seconds later, the pilot-in-command said, "You know, according to this dumb sheet it says thirty-four hundred to Round Hill --- is our minimum altitude". The flight engineer then asked where the pilot-in-command saw that and the pilot-in-command replied, "Well, here. Round Hill is eleven and a half DME". The co-pilot said, "Well, but ---" and the pilot-in-command replied, "When he clears you, that means you can go to your ---". An unidentified voice said, "Initial approach", and another unidentified voice said, "Yeah!". Then the pilot-in-command said "Initial approach altitude". The flight engineer then said, "We're out a --- twenty-eight for eighteen". An unidentified voice said, "Right", and someone said, "One to go".

At 1108:14, the flight engineer said, "Dark in here", and the co-pilot stated, "And bumpy too". At 1108:25, the sound of an altitude alert horn was recorded. The pilot-in-command said, "I had ground contact a minute ago", and the co-pilot replied, "Yeah, I did too". At 1108:29, the co-pilot said, "*power on this #".5/ The pilot-in-command said "Yeah --- you got a high sink rate". The co-pilot replied, "Yeah". An unidentified voice said, "We're going uphill", and the flight engineer replied, "We're right there, we're on course". Two voices responded "Yeah!". The pilot-in-command then said, "You ought to see ground outside in just a minute. -- Hang in there boy". The flight engineer said, "We're getting seasick".

At 1108:57, the altitude alert sounded. Then the co-pilot said, "Boy, it was --- wanted to go right down through there, man", to which an unidentified voice replied, "Yeah!". Then the co-pilot said, "Must have had a # of a downdraught".

At 1109:14, the radio altimeter warning horn sounded and stopped. The co-pilot said, "Boy!". At 1109:20, the pilot-in-command said, "Get some power on". The radio altimeter warning horn sounded again and stopped. At 1109:22, the sound of impact was recorded.

At 1109:54, the approach controller called Flight 514 and said, "TWA 514, say your altitude". There was no response to this or subsequent calls.

The controller subsequently testified that he noticed on the radar scope that the flight's altitude was about 2 000 ft just before he called them.

5/ * Indicates unintelligible word(s); # indicates non-pertinent word(s).

The flight data recorder (FDR) readout indicated that after the aircraft left 7 000 ft, the descent was continuous with little rate variation until the indicated altitude was about 1 750 ft. The altitude increased about 150 ft over a 15-second period and then decreased about 200 ft during a 20-second period. The recorded altitude remained about 1 750 ft until impact.

During that same portion of the flight, the indicated airspeed varied from 240 kt to 230 kt until the altitude trace levelled off about 1 750 ft after which the airspeed decreased and fluctuated between 222 kt to 248 kt. Some of the fluctuations occurred within short time spans while others were within longer spans.

The heading trace showed little variation during the latter portion of the flight. As the aircraft left 7 000 ft, the heading changed from an indication of 112° to about 120° in about 2.5 minutes. The heading did not vary more than 2° to 4° from that indication until impact.

As the aircraft left 7 000 ft, the vertical acceleration (g) trace was smooth with little fluctuation. After 40 seconds, the g trace activity increased to about ±0.1 g. This continued for about 1 minute and then increased in amplitude to about ±0.2 g for about 70 seconds. At this point there was a blank in the g trace. When the trace reappeared, it was still active, with variations in indicated g ranging from ±0.2 to 0.5 g, until impact.

The accident occurred on the west slope of Mount Weather, Virginia, about 25 NM from Dulles, at an elevation of about 1 670 ft. The latitude was 39° 04.6' N and the longitude was 77° 52.9' W.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	7	85	-
Non-fatal	-	-	-
None	-	-	

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Foreword refers). Reconstruction of the "Descent profile" is shown at Appendix A.

2.- Analysis and Conclusions

2.1 Analysis

There was no evidence that any malfunction of the aircraft, aircraft systems, powerplants, or the flight control system contributed to the cause of the accident. The aircraft had been maintained in accordance with the FAA-approved procedures and was certificated properly.

The flight crew and the involved air traffic controller were qualified to perform their assigned duties. There was no evidence that any medical factors played a part in this accident.

The flight crew was provided with the necessary dispatch data and weather information before their departure from Indianapolis and these data were updated in Columbus. The flight was routine until the crew was advised by ATC that National Airport was not accepting landing traffic and that they would either have to hold until they could land at National or they could divert to Dulles. After consultation with the dispatcher, the pilot-in-command elected to proceed to Dulles and the dispatch release was amended accordingly. During their conversations with ATC the crew was advised to expect an instrument approach to Runway 12 at Dulles.

The crew reviewed the approach chart for the VOR/DME approach to Runway 12 shortly after they confirmed their plan to divert. Their next clearance was to "... Dulles via direct to Front Royal, direct Dulles". At 1043, the pilot-in-command's radio receiver was tuned to the Dulles ATIS and the ATIS information was recorded three times on the CVR. After a discussion of the weather, the control of the aircraft was given to the co-pilot. The flight crew then discussed the different transition routes that they might use to get to Dulles. The crew referred to the approach chart and the area chart in planning their approach. (See Appendix B.)

At 1051, ATC instructed the pilot to fly a heading of 090° to intercept the 300° radial of the Armel VOR and to cross 25 miles northwest of Armel at 8 000 ft and to maintain that altitude. This clearance was followed by a conversation between the pilots which again indicated that they were referring to the approach chart for a VOR/DME approach to Runway 12 at Dulles.

At 1055, the landing preliminary check-list was initiated and completed at about 1056. About 1 minute later, the crew again reviewed the approach chart and referred to the Round Hill intersection and the 6 NM DME fix. The altitude at the DME fix was announced properly as 1 800 ft. They then discussed the runway and the runway lighting including the VASI.

About 1101, Flight 514 was cleared to descend to and maintain 7 000 ft and to contact Dulles approach control. They were then advised by approach control to expect a VOR/DME approach to Runway 12. They were also given the new altimeter setting of 29.70. The flight reported level at 7 000 ft at 1104 and 5 seconds later was cleared for a VOR/DME approach to Runway 12. The pilot-in-command announced that 1 800 (feet) was "the bottom" or, the altitude to which the flight was to descend. The co-pilot initiated an immediate descent. The crew again reviewed the approach chart.

At 1106, there was mention of a discrepancy between the two VOR indicators in the cockpit. The investigation indicated that the co-pilot's VOR receiver was tuned to the Front Royal VOR. The tuning of the pilot-in-command's VOR receiver could not be determined, but the Board believes that it was tuned to the Armel VOR. Apparently the discrepancy was of no navigational significance since the aircraft was following the prescribed inbound track.

Shortly after 1107, the pilot-in-command first expressed doubt concerning the action he should be taking and the minimum altitude to which he was descending. He noted that the minimum altitude to Round Hill (from Front Royal) was 3 400 ft. He discussed the chart with the crew and again decided that the flight was authorized to descend to 1 800 ft, the intermediate approach segment altitude. Seconds later the altitude alert system warning sounded indicating that the flight was approaching 1 800 ft and the pilot-in-command stated that he had seen the ground "a minute ago". The co-pilot indicated that he had seen the ground also. Apparently they had only fleeting glimpses of the ground and did not derive any relative altitude information from what they saw. The co-pilot mentioned the power and the pilot-in-command noted that they had a high sink rate. Then the pilot-in-command said that the ground should be visible in just a minute. At 1108:57 the altitude alert sounded again. This sound may have been caused by a pilot positioning the altitude alert control to cancel further warnings. This is a normal TWA procedure once cleared to descend below the initial approach altitude. In this particular case the aircraft had arrived at the altitude the pilot-in-command had determined to be the initial approach altitude, and clearance for the approach had been received. Subsequent altitude information was provided by the barometric altimeter and height-above-the-ground information was provided by the radio altimeter. There was some conversation regarding a downdraught and the radio altimeter warning horn sounded, then stopped. The pilot-in-command said at 1109:20, "Get some power on". The radio altimeter warning horn sounded again and at 1109:22, the sound of impact was recorded.

The first radio altimeter warning was activated by the aircraft coming within 500 ft of the terrain, the designated altitude where the radio altimeter will begin to indicate the altitude. The second radio altimeter warning sounded as the aircraft approached 100 ft above the terrain. TWA's procedure, when conducting a non-precision approach, requires that the radio altimeter be set to provide a warning at 100 ft above the terrain. The first warning came 7 seconds before impact and the second warning about 1 second before impact, after the pilot-in-command ordered the co-pilot to "get some power on". The crew should have realized that the aircraft should not have been that close to the ground at that point in the approach. However, their reaction to the warning probably could not have been faster than it was.

A review of the flight data recorder graph indicates that at the times when the recorded altitude can be cross-cehcked against other altitude data sources within the aircraft, the aircraft was near the altitudes recorded. This indicates that the altimeter system was operating properly. The elevation at impact was about 1 675 ft. The altimeter was set at 29.70, the last altimeter setting given to the crew.

Two reasons why the aircraft might have been below its target altitude of 1 800 ft are evident. First, the aircraft was entering ground effect as it got closer to the ground and this may have caused an error in the Pitot static system which caused the altimeter to indicate an altitude higher than the actual aircraft altitude. Second, it is possible that the high winds blowing over the rough terrain in the accident area may have caused a pressure change which affected the altimeter indication. However, the crew's evident concern about the altitude was indicated by the pilot-in-command's order regarding the power and the co-pilot's comments about the downdraught when the aircraft went below the target altitude. Based on the evidence available, the Safety Board concludes that there was no significant error in the altitude information presented to the pilots by their instruments.

The crew's comments regarding the altitude and the power indicate that the co-pilot was not flying the aircraft at the target altitude of 1 800 ft. The Board examined the flight data recorder trace and found that while there was evidence of moderate turbulence, it was probably not of sufficient magnitude to prevent the co-pilot from maintaining the desired altitude. There was also no evidence that there was any problem within the aircraft that would have prevented the pilot from staying at 1 800 ft. Therefore, the Board concludes that the deviation below the target altitude was probably a result of the combination of the co-pilot's flying techniques and the turbulence.

From the above, it is clear that this was an operational accident and that the crew knowingly descended to approximately 1 800 ft after being cleared for the approach. The basic questions requiring resolution are 1) why did the crew knowingly descend to 1 800 ft in an area where the terrain obstacles extended almost up to that altitude; and 2) why did the approach clearance not include an altitude restriction under the circumstances of this case.

Our review of the record supports the conclusion that the pilot-in-command believed that when he approached the airport in a radar environment for a non-precision approach he would not be "cleared for the approach" without an altitude restriction unless he could make an unrestricted descent to the final approach fix altitude. In attempting to determine the reasons for the pilot-in-command's belief in this regard, a brief description of the development of the usage of radar and its impact on pilot responsibilities is required.

Before the advent of radar, the pilot alone was responsible at all times for knowing the position of his aircraft with regard to the terrain. The pilot kept the controller informed of the aircraft's position and of the pilot's intentions. Typically, during an instrument approach, numerous radio calls were made as the pilot reported his position, altitude, and intentions.

With the advent of radar, the controller was able to observe the aircraft in two dimensions -- range and azimuth -- and was able to vector flights to arrive over geographical positions. By issuing headings the controller could prevent the tracks of known IFR traffic from converging if the danger of a collision existed. However, it was still necessary for the pilot to advise the controller of the flight's altitude. As experience was gained in the use of radar, a new language was introduced to pilots and controllers and new procedures were instituted to provide for the control of IFR traffic in the terminal area. The controller played a greater role in manoeuvring the aircraft by providing headings and altitudes to pilots. As traffic became heavier and aircraft became faster, the controller played a greater role in the movement of the traffic in an effort to provide an uninterrupted flow of traffic to the runway. In an effort to improve his ability to move traffic, he was assigned blocks of airspace and minimum vector altitude information, which was not known to the pilot, to be used in moving traffic off the published approach routes.

The advent of the ARTS III radar system and similar systems now provides the controller with information on properly equipped aircraft in three dimensions -- aircraft altitude, range, and azimuth, as well as ground speed.

The volume of terminal air traffic has grown to the point that the FAA has frequently found it necessary to divert flights away from published instrument approach routes in order to improve the flow of traffic. In addition, it has become commonplace to clear pilots to descend below the altitudes published on the terminal area charts and instrument approach charts. Pilots in turn have tended to become more and more dependent on the air traffic controller to control their flight's altitudes, headings, and airspeed. Concurrent with this increasing dependency has been 1) a lessened ability to know the type of terrain over which the aircraft is flying, and 2) in some cases, limited information regarding the position of the aircraft relative to the airport and obstacles on the ground.

Controllers are trained in the air traffic control procedures and the terminology associated with IFR navigation. Pilots, on the other hand, are trained in the operation of the aircraft, air traffic control procedures, and terminology essential to safe operation of aircraft in the airspace system. However, as this case demonstrates, imprecise terminology, unresolved differences of opinion, and unnoticed changes in the definitions and procedures can result in an inadequate understanding on the part of one or both of the participants in the air traffic control situation.

At the Safety Board's public hearing, FAA witnesses testified that they were not aware that there was any potential misunderstanding on the part of pilots as to the meaning of the term "cleared for the approach", in a case where a non-precision approach is made, particularly when the clearance was issued a long distance from the airport. The evidence, however, does not support this conclusion, since, for several years prior to this accident, various organizations had perceived a problem in the use of the term "cleared for the approach".

Ironically, approximately 6 weeks before the TWA accident an air carrier flight, after being "cleared for the approach", descended to 1 800 ft while outside of the Round Hill intersection during a VOR/DME approach to Runway 12 at Dulles. The carrier involved had implemented an anonymous safety awareness programme, was in fact made aware of the occurrence, and subsequently issued a notice to its flight crews to preclude the recurrence of a near-fatal misinterpretation of an approach clearance. The Board is encouraged that such safety awareness programmes have been initiated. It is through such conscientious safety management that the expected high level of safety in air carrier operations can be obtained. In retrospect, the Board finds it most unfortunate that an incident of this nature was not, at the time of its occurrence, subject to uninhibited reporting and subsequent investigation which might have resulted in broad and timely dissemination of the safety message issued by the carrier to its own flight crews.

Both the USAF and TWA had pointed out to the FAA that the terminology "cleared for the approach" could be misinterpreted and that pilots might understand that they could descend unrestricted unless a specific altitude restriction was included in the clearance. With respect to the crew of TWA 514, the conversation in the cockpit as reflected in the CVR transcript permits no other conclusions than that they assumed the clearance received permitted an unrestricted descent to 1 800 ft. Subquestions requiring discussion are whether other available information should have indicated to the crew the unsafe nature of such a descent and why the crew was not alerted at least to the point of making inquiry to ATC.

Considering the number of times the pilot-in-command examined his chart after being informed that he was to divert to Dulles, he should have realized that the minimum altitude of 1 800 ft might not be a safe altitude. Although the pilot-in-command did not know his exact position relative to the terrain when he received the approach clearance, the Board believes that with his VOR tuned to Armel and with the information provided by that navigational aid, he should have been able to read his DME range from Armel. At the time he received the clearance, he was about 44 NM from Armel on the 300° radial inbound to the station. By reference to the approach chart, he should also have been able to identify the high obstacles between that position and the Round Hill intersection. With that information, he should have been able to determine that 1 800 ft was not an adequate altitude to provide terrain clearance of 2 000 ft in this designated mountainous area. If he did not realize that he was over a designated mountainous area, he should have applied terrain clearance of 1 000 ft as prescribed for non-mountainous areas. He did notice the 3 400 ft associated with the course between Front Royal and Round Hill. That should have suggested that he should re-examine his decision regarding the descent to 1 800 ft. If he had questioned the controller regarding the minimum altitude in the area of his aircraft, he should have received information that would have alerted him that he could not descend to 1 800 ft until after he passed Round Hill.

The information available to the pilot, including the approach chart, should have alerted the crew that an unrestricted descent would be unsafe. It does appear to the Board that there was a deficiency in the chart. This particular approach chart depicted the profile view from the final approach fix to the airport. It did not depict the intermediate fix, Round Hill, with its associated minimum altitudes. This information was available from the plan view of the chart, but it appears that the crew gave their primary attention to the profile. If this was the case, it may have led the crew to discount the other information available on the chart and to continue their descent on the assumption that it was permissible by reason of the clearance they received.

The second major question deserving consideration is the role of the ATC system in this accident, specifically why TWA 514 was not given an altitude restriction in its approach clearance. The testimony of all FAA witnesses, including the controller, was consistent in stating that Flight 514 was not a "radar arrival"; that because of this fact the controller was not required to implement the provisions of paragraph 1360 of the FAA Handbook 7110.8C; and that they considered TWA 514, after intercepting the 300° radial of Armel, as proceeding on its own navigation and as being responsible for its own obstacle clearance.

The FAA witnesses stated that Flight 514 was not a radar arrival because it had not been vectored to the final approach course. They did not consider the vector of Flight 514 by the Washington Center to intercept the 300° radial as being a vector to the final approach course, even though the VOR/DME approach procedure utilizes the 300° radial inbound from Round Hill. Particular emphasis was made by FAA that the vector to the 300° radial occurred when the flight was approximately 80 miles from the airport and that it was vectored by the centre on to an en-route course. Operational advantage was indicated by the controllers as the reason for the vector to the 300° radial rather than to an initial approach fix on the approach procedure.

The counterposition is that Flight 514 was operating in a radar environment, was receiving at least one type of radar service, and was on a course which would lead directly to the Round Hill intermediate approach fix. Furthermore it had been advised that the reason for the vector to the 300° radial was for a VOR/DME approach for Runway 12. Consequently, it should have received services, including altitude restrictions, as set forth in paragraph 1360 of 7110.8C.

In evaluating these facts, the one issue present is whether the handling of Flight 514 required the provision of an altitude restriction. FAA witnesses agreed that, had Flight 514 been classified as a radar arrival within the meaning of the handbook, the flight would have been given an altitude restriction until it reached Round Hill. In resolving this issue, the Board has been troubled by the fact that ATC procedures are almost always dependent upon the usage of certain specified phrases and terms, many of which have no established definitions and mean different things to controllers and pilots.

The term "radar control" is an example. The pilot witnesses believed that, when they were operating in a traffic control radar environment, they were being controlled by radar. The controller group was aware that this was not always the case, but the FAA apparently did not perceive the difference of understanding, and the efforts made by the FAA to clarify when an aircraft was or was not radar controlled did not eliminate the confusion.

The Board concludes that based on the criteria in 7110.8C the system allowed for the classification and handling of Flight 514 as a non-radar arrival. The Board, however, believes that the flight should have been classified and handled as a "radar arrival".

This, however, does not dispose of the issue of whether the ATC system should have provided for a redundancy that would have prevented or consequently identified and corrected a deviation of an aircraft from a clearance which was not followed as the controller expected it to be.

The system should clearly require controllers to give the pilots specific information regarding their positions relative to the approach fix and a minimum altitude to which the flight could descend before arriving at that fix. Pilots should not be faced with the necessity of choosing from among several courses of action to comply with a clearance.

The Board believes that the clearance, under these circumstances, should have included an altitude restriction until the aircraft had reached a segment of the published approach procedure or the issuance of the approach clearance should have been deferred until the flight reached such segment. Therefore, the Safety Board concludes that the clearance was inadequate and its issuance and acceptance was the result of a misunderstanding between the pilot and the controller.

The Board believes that there is a general lack of understanding between pilots and controllers in their interpretations of air traffic control procedures. There is also a lack of understanding about the meaning of some words and phrases used by both the controller and pilot in the handling of IFR traffic in the terminal area.

In this case, there was no definition of the term "radar arrival" or "final approach course", nor, as indicated earlier, did there seem to be common understanding between pilots and controllers as to the meaning of "radar control".

Therefore, the Safety Board concludes that it is essential that a lexicon of air traffic control words and phrases be developed and made available to all controllers and pilots who operate within the National Airspace System. Additionally, there should be one book of procedures for use by both pilots and controllers so that each will understand what to expect of the other in all air traffic control situations. This manual must be used in the training of all pilots and controllers.

The need for such a lexicon and procedures manual is evident from the circumstances of this accident. Flight 514 was vectored to intercept the 300° radial of Armel, the reciprocal course of which coincides with the course for the intermediate and final approach segments of the published instrument approach procedure. The vector was given when the flight was more that 80 miles from the airport and at a point where the 300° radial of Armel was not a part of the published instrument approach procedure. While proceeding inbound on the 300° radial of Armel, the flight would not have reached a segment of the published approach procedure until it arrived at Round Hill.

However, there was some testimony contending that Flight 514 was on its final approach course when the flight intercepted and was inbound on the 300° radial, and accordingly it was permissible for the pilot to descend to the minimum altitude of 1 800 ft prescribed for crossing the final approach fix of the VOR/DME instrument approach procedure. Qualified instrument pilots and air traffic controllers should know and understand beyond equivocation that the coincidence of the inbound course being an extension of the final instrument approach course does not permit descent to altitudes lower than those published for that air space segment unless specifically authorized by ATC.

A clear, precise definition of final approach course and final instrument approach course should preclude future misunderstandings. Neither of these terms was defined in the AIM at the time of this accident. However, the AIM glossary did contain a definition of "Final Approach - IFR" wherein the final instrument approach course is shown to be confined to the final approach segment of the instrument approach procedure and that it begins at the final approach fix.

The issue of when flights are or are not radar arrivals must also be resolved. It is difficult for a pilot who is operating in a radar environment and communicating with a radar controller to realize that, under some circumstances, his flight is, without formal notification, considered to be a non-radar arrival and subject to a different ATC procedure. Specifically, he may not realize that the responsibility for obstacle clearance shifts from the controller to the pilot under some circumstances without the pilot being specifically informed. While the Safety Board recognizes that the FAA is concerned about radio frequency congestion in busy terminal areas, any control procedure which effects a change in the responsibility for providing terrain clearance must be communicated and clearly understood by both pilots and controllers. If radar service is terminated, the crew should be so informed. Then they will be prepared to resume the responsibility for navigation which was vested in the controller while the flight was classified and handled as a radar arrival.

The ARTS III system provides, as previously noted, information capability not formerly available to controllers. The Safety Board has previously recommended that the altitude information capability of this equipment be used as an additional safety factor in the terminal area to help prevent controlled flight into the ground. In the case of Flight 514, the controller testified that he could not clearly see the target associated with the flight until he noted that the altitude was 2 000 ft. Immediately thereafter, he attempted to contact the flight to verify its altitude, but impact had already occurred. The FAA has taken action to install an altitude deviation warning in the ARTS III system which should be beneficial in alerting controllers to altitude deviations in the terminal area.

Although the record of this investigation shows that the weather was a factor in the occurrence of the accident, it was not of such nature as to have made the accident inevitable. The icing encountered by the aircraft in the descent was apparently eliminated by the anti-icing systems. The intensity of the turbulence may have been sufficient to make the control of the aircraft somewhat difficult. The excursions of the traces on the flight data recorder are indicative of light to moderate turbulence. The possible effect of the high winds on the indicated altitude has been discussed previously. While the evidence does not indicate whether the crew was aware of the SIGMETS issued for the Washington area, there is no evidence to indicate that knowledge of the SIGMETS would have caused the crew to operate any differently than they did.

The CVR indicates that the crew did encounter considerable turbulence during the descent. However, the record also indicates that they were able to read the altimeters well enough to know that they had descended below their target altitude of 1 800 ft. The Safety Board believes that the effect of turbulence was not critical but could not determine positively why the descent was not arrested at 1 800 ft.

In summary, this accident resulted from a combination of conditions which included a lack of understanding between the controller and the pilot as to which air traffic control criteria were being applied to the flight while it was operating in instrument meteorological conditions in the terminal area. Neither the pilot nor the controller understood what the other was thinking or planning when the approach clearance was issued. The pilot-in-command did not react correctly to his own doubt about the line of action he had selected because he did not contact the controller for clarification. The action of the other air carrier pilot who questioned the clearance he received about half an hour before the accident is the kind of reaction that should be expected of a pilot suddenly confronted with uncertainty about the altitude at which he should operate his aircraft.

The Board again stresses that it is incumbent upon air carrier management to ensure the highest possible degree of safety through an assertive exercise of its operational control responsibility. This management function must ensure that flight crews are provided with all information essential to the safe conduct of flight operations. Furthermore, the air carrier must ensure that its flight crews are indoctrinated in the operational control precept and that during flight the final and absolute responsibility for the safe conduct of the flight rests solely with the captain as pilot-in-command regardless of mitigating influences which may appear to dilute or derogate this authority.

Whereas the air carriers and the pilots are expected to perform their services with the highest degree of care and safety, this same high level of performance must be expected from the management of the air traffic control system and the controller. The present case provides a classic and tragic example of a pilot and controller who did not fully comprehend the seriousness of the issuance and acceptance of a clearance which was not precise or definitive. The pilot should question a clearance which leaves any doubt as to what course of action should be followed.[6/] The Board also believes that it is incumbent upon the controller to ascertain beyond a doubt that the terminology of a clearance conveys the intent to the pilot, and to question the pilot if there is any doubt that he has understood it and is initiating actions compatible with the intent of the clearance.

Since, as FAA witnesses testified, the ATC system is a co-operative system, it is imperative that pilots and controllers fully understand the intent and execution of clearances to the extent that one is able to back up the other whenever there is doubt that the clearance or the execution of it may be unsafe or is likely to lead to an unsafe situation.

2.2 Conclusions

a) Findings

1. The flight operated without reported difficulty and in a routine manner until the diversion to Dulles Airport from Washington National Airport was approved.

2. The crew of Flight 514 reviewed the approach chart for the VOR/DME approach to Runway 12 at Dulles several times before beginning the approach.

3. The Washington Air Route Traffic Control Center controller vectored the flight to intercept the 300° radial of the Armel VOR at a point about 80 NM from the VOR. This portion of the radial was not part of the published instrument approach.

4. The crew of Flight 514 intercepted the radial and tracked inbound on it, and control of the flight was passed to the Dulles approach controller.

6/ Subsequent to the accident the FAA amended 14 CFR 91.75(a) to re-emphasize that "If a pilot is uncertain of the meaning of an ATC clearance, he shall immediately request clarification from ATC".

5. The Dulles approach controller cleared the flight for a VOR/DME approach to Runway 12 when the aircraft was about 44 NM from the airport. The clearance contained no altitude restrictions.

6. The pilot-in-command assumed that the flight could descend to 1 800 ft, immediately. The co-pilot, who was flying the aircraft, initiated an immediate descent to 1 800 ft.

7. The flight encountered icing and turbulence during the descent. Neither of these conditions should have appreciably endangered or restricted the control of the aircraft, but contributed to the apparent inability of the crew to arrest the descent at 1 800 ft.

8. The co-pilot allowed the aircraft to descend below the target altitude of 1 800 ft and did not take sufficient corrective action to regain and maintain that altitude.

9. The co-pilot's altimeter was set properly.

10. It is possible that wind velocity over the hilly terrain may have induced an altimeter error which could have caused the instrument to indicate that the aircraft was higher than its actual altitude. However, the crew's last comments regarding altitude indicated that they knew they were below 1 800 ft.

11. The altitude alerting system and the radio altimeter aural warnings sounded at appropriate altitudes to indicate to the pilots that the aircraft was below 1 800 ft and that the aircraft was within 500 ft and 100 ft of the ground. These latter warnings occurred 7 seconds and 1 second, respectively, before impact.

12. The flight crew apparently did not have sufficient time to avoid the accident after these warnings.

13. The approach clearance was given to the flight without altitude restrictions because the flight was not being handled as a radar arrival and because the controller expected the crew to conduct the approach as it was depicted on the approach chart.

14. Procedures contained in FAA's Terminal Air Traffic Control Handbook were not clear and resulted in the classification and handling of TWA 514 as a "non-radar" arrival. The terms "radar arrival" and "non-radar arrival" were not defined.

15. In view of the available ATC facilities and services and since the flight was receiving radar service in the form of radar monitoring while under the jurisdiction of a radar approach control facility, the procedure should have provided for giving altitude restrictions in an approach clearance for an aircraft operating on an unpublished route prior to its entering a segment of the published approach procedure.

16. The ATC system was deficient in that the procedures were not clear as to the services the controllers were to provide under the circumstances of this flight.

17. The flight crew believed that the controller would not clear them for an approach until they were clear of all obstructions.

18. The depiction on the profile view of the approach charts neither indicated the position of Round Hill intersection nor did it contain all minimum altitudes associated with the approach procedure. This information was available on the plan view of the approach chart.

19. The pilot-in-command noticed the minimum altitude associated with the approach segment from Front Royal to Round Hill but he decided that the flight could descend to 1 800 ft without regard for the 3 400 ft minimum altitude depicted on the chart because he was not on that segment.

20. The pilot-in-command of Flight 514 did not question the controller after receiving the approach clearance, regarding the action the flight crew was expected to take. Another crew that questioned a similar clearance received further instructions and information which resulted in their accepting a radar surveillance approach to Dulles.

21. Both military and civil aviation officials for several years had indicated concern regarding a lack of understanding on their part of what the Air Traffic Control procedures and terminology were intended to convey to the pilots. They were also concerned about the possibility of misunderstandings which could result in pilots descending prematurely.

22. The FAA was not responsive to the long-standing, expressed needs and concerns of the users of the Air Traffic Control System with regard to pilot/controller responsibilities pursuant to the issuance of an approach clearance for a non-precision approach. Furthermore, the FAA did not provide users of the Air Traffic Control System with sufficient information regarding the services provided by the system under specific conditions.

23. The FAA did not utilize the capability of the ARTS III system to ensure terrain clearance for descending aircraft conducting non-precision instrument approaches in instrument meteorological conditions.

24. The flight crew of Flight 514 was not familar with the terrain west and northwest of Dulles. However, they did have information regarding the elevation of obstacles west of Round Hill intersection depicted on the plan view of the approach procedure.

b) Cause or
Probable cause(s)

The National Transportation Safety Board determines that the probable cause of the accident was the crew's decision to descend to 1 800 ft before the aircraft had reached the approach segment where that minimum altitude applied. The crew's decision to descend was a result of inadequacies and lack of clarity in the air traffic control procedures which led to a misunderstanding on the part of the pilots and of the controllers regarding each other's responsibilities during operations in terminal areas under instrument meteorological conditions. Nevertheless, the examination of the plan view of the approach chart should have disclosed to the pilot-in-command that a minimum altitude of 1 800 ft was not a safe altitude.

Contributing factors were:

1) The failure of the FAA to take timely action to resolve the confusion and misinterpretation of air traffic terminology although the Agency had been aware of the problem for several years;

2) The issuance of the approach clearance when the flight was 44 miles from the airport on an unpublished route without clearly defined minimum altitudes; and

3) Inadequate depiction of altitude restrictions on the profile view of the approach chart for the VOR/DME approach to Runway 12 at Dulles International Airport.

3.- Recommendations

As a result of the accident, the Safety Board submitted 14 recommendations to the Administrator of the Federal Aviation Administration. (See Appendix I.)

ICAO Note: Appendix I not reproduced. The specific recommendations were:

Safety Recommendations A-75-45 and 46

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Relocate the Armel, Virginia, distance measuring equipment monitor from the Washington, D.C. flight service station to the Dulles terminal air traffic control facility. (Class II)

2. Conduct a review of all terminal air traffic control facilities to ensure that controllers at each facility serviced by a navigational aid will have direct access to the associated monitor for that navigational aid. (Class III)"

Safety Recommendation A-75-52

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

Revise FAA Handbook 7110.8D and FAA Handbook 7110.9D to make the issuance of a safety advisory mandatory. (Class II)"

Safety Recommendations A-75-54 and 55

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Require that In-flight Advisories (SIGMETS and AIRMETS) be taped on receipt, for subsequent broadcast via navigational aid voice frequency and ensure that they are, and continue to be, broadcast in accordance with current procedures. (Class II)

2. Require that Principal Air Carrier Operations Inspectors survey all air carrier dispatch departments to ensure that adequate standard procedures are in use to provide pilots in flight with SIGMET and other meteorological information in accordance with 14 CFR 121.601(b). (Class II)"

Safety Recommendation A-75-56

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

Publish a comprehensive lexicon of ATC terms and provide for its use by all pilots and ATC specialists. (Class II)"

Safety Recommendations A-75-58 and 59

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Define the term "radar arrival" and assign an equal weight of controller responsibility to all arrivals receiving radar service, regardless of the kind of radar service. (Class II)

2. Discontinue automatic termination of radar service in accordance with paragraph 1212c of Handbook 7110.8D, dated 1 January 1975, and paragraph 662b of Handbook 7110.9D, dated 1 January 1975, except after the aircraft has been visually sighted by a local controller. (Class II)"

Safety Recommendation A-75-62

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

Designate a specific authority to have final responsibility, both editorially and technically, for the content of the Airman's Information Manual. (Class III)"

Safety Recommendations A-75-74 through 77

"The National Transportation Safety Board recommends that the Federal Aviation Administration:

1. In concert with the two other IACC Members (Department of Commerce and Department of Defense) and the Jeppesen Company, conduct a study of the cartographic techniques and specifications used throughout the aviation industry for approach charts for the purpose of identifying those techniques and specifications that best lend themselves to uniformity and standardization.

2. Based on the above study, initiate steps to revise the IACC manual to include those techniques and specifications that best lend themselves to uniformity and standardization and to which there is unanimous agreement by the parties engaged in the study.

3. Require that the IACC manual be used as the minimum standards for cartographic presentation of specified data on all instrument approach charts used in U.S. civil and military aviation.

4. Require that the revised IACC manual be used as a mandatory reference by FAA personnel whenever a new instrument approach procedure is developed or whenever an existing procedure is modified.

Subsequent to the accident, the FAA has taken several actions in an effort to prevent recurrence of this type of accident.

1. The FAA had directed that all air carrier aircraft be equipped with a ground proximity warning system by December 1975.

2. The FAA has revised the provisions of 14 CFR 91 with regard to pilot responsibilities and actions after receiving a clearance for a non-precision approach.

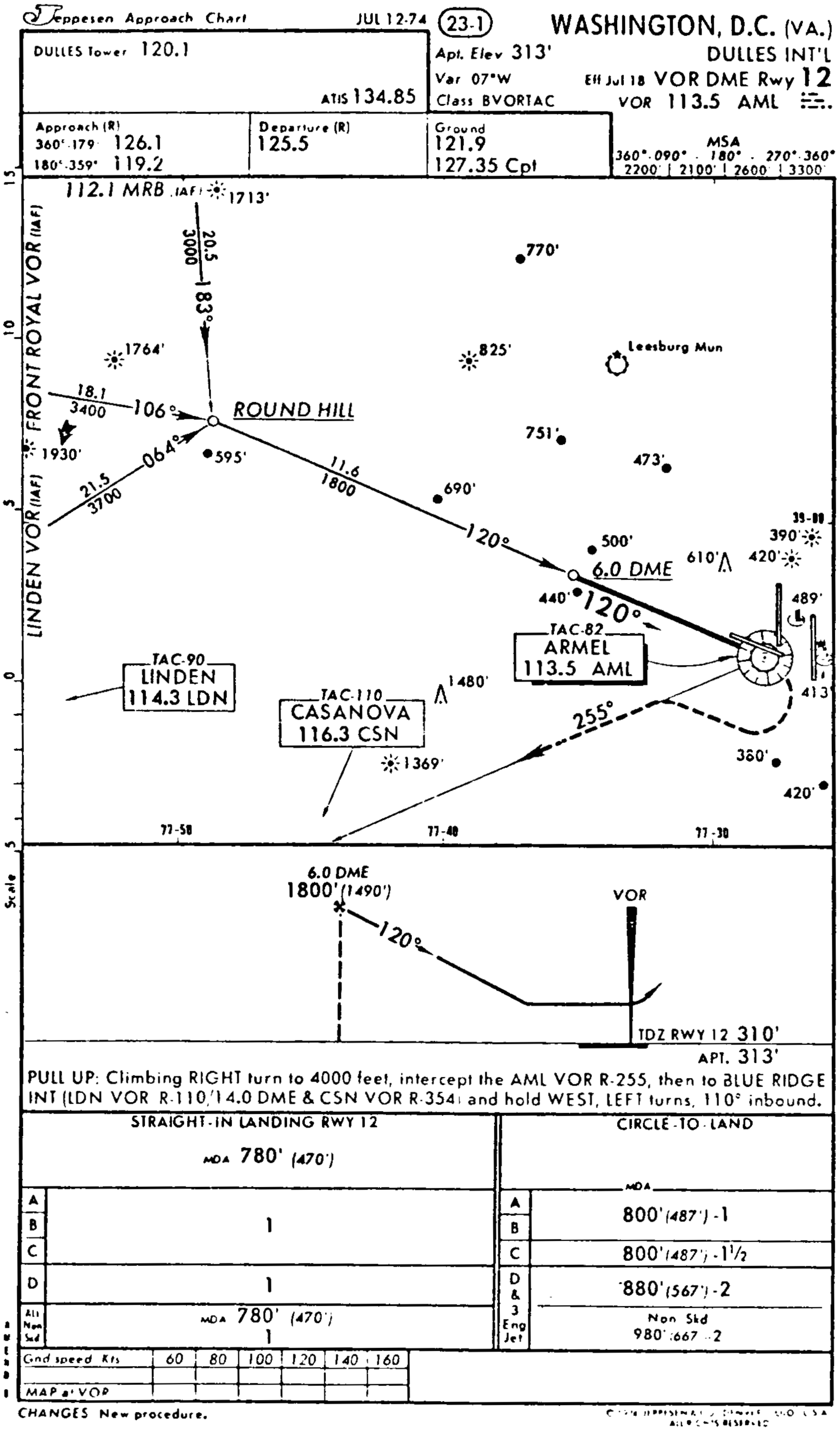
3. The FAA has established an incident reporting system which is intended to identify unsafe operating conditions in order that they can be corrected before an accident occurs.

4. The FAA has changed its air traffic control procedures to provide for the issuance of altitude restrictions during non-precision instrument approaches.

5. The FAA is installing a modification to the ARTS III system that will alert air traffic controllers when aircraft deviate from predetermined altitudes while operating in the terminal area.

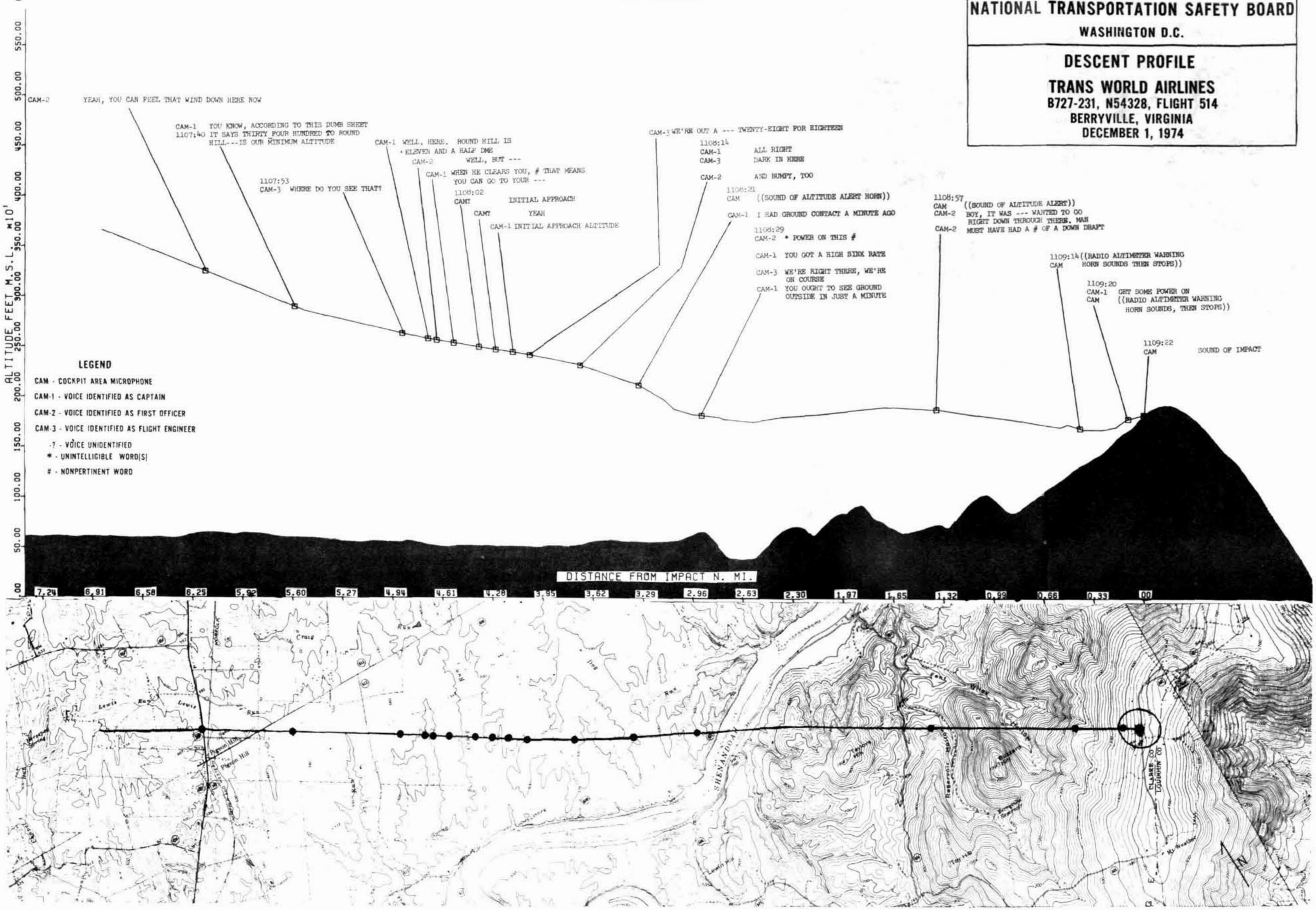
ICAO Ref.: AIG/442/74

APPENDIX B



"ILLUSTRATION ONLY - NOT TO BE USED FOR NAVIGATIONAL PURPOSES"

APPENDIX A


NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON D.C.
DESCENT PROFILE
TRANS WORLD AIRLINES
B727-231, N54328, FLIGHT 514
BERRYVILLE, VIRGINIA
DECEMBER 1, 1974
ALTITUDE FEET M.S.L. x10'
600
550.00
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
00
CAM-2 YEAH, YOU CAN FEEL THAT WIND DOWN HERE NOW
CAM-1 YOU KNOW, ACCORDING TO THIS DUMB SHEET
1107:40 IT SAYS THIRTY FOUR HUNDRED TO ROUND HILL---IS OUR MINIMUM ALTITUDE
1107:53
CAM-3 WHERE DO YOU SEE THAT?
CAM-1 WELL, HERE. ROUND HILL IS ELEVEN AND A HALF DME
CAM-2 WELL, BUT ---
CAM-1 WHEN HE CLEARS YOU, # THAT MEANS YOU CAN GO TO YOUR ---
1108:02
CAM? INITIAL APPROACH
CAM? YEAH
CAM-1 INITIAL APPROACH ALTITUDE
CAM-3 WE'RE OUT A --- TWENTY-EIGHT FOR EIGHTEEN
1108:14
CAM-1 ALL RIGHT
CAM-3 DARK IN HERE
CAM-2 AND BUMPY, TOO
1108:21
CAM ((SOUND OF ALTITUDE ALERT HORN))
CAM-1 I HAD GROUND CONTACT A MINUTE AGO
1108:29
CAM-2 * POWER ON THIS #
CAM-1 YOU GOT A HIGH SINK RATE
CAM-3 WE'RE RIGHT THERE, WE'RE ON COURSE
CAM-1 YOU OUGHT TO SEE GROUND OUTSIDE IN JUST A MINUTE
1108:57
CAM ((SOUND OF ALTITUDE ALERT))
CAM-2 BOY, IT WAS --- WANTED TO GO RIGHT DOWN THROUGH THERE, MAN
CAM-2 MUST HAVE HAD A # OF A DOWN DRAFT
1109:14 ((RADIO ALTIMETER WARNING
CAM HORN SOUNDS THEN STOPS))
1109:20
CAM-1 GET SOME POWER ON
CAM ((RADIO ALTIMETER WARNING HORN SOUNDS, THEN STOPS))
1109:22
CAM SOUND OF IMPACT
LEGEND
CAM - COCKPIT AREA MICROPHONE
CAM-1 - VOICE IDENTIFIED AS CAPTAIN
CAM-2 - VOICE IDENTIFIED AS FIRST OFFICER
CAM-3 - VOICE IDENTIFIED AS FLIGHT ENGINEER
-? - VOICE UNIDENTIFIED
* - UNINTELLIGIBLE WORD(S)
# - NONPERTINENT WORD
DISTANCE FROM IMPACT N. MI.
7.24
6.91
6.58
6.25
5.92
5.60
5.27
4.94
4.61
4.28
3.95
3.62
3.29
2.96
2.63
2.30
1.97
1.65
1.32
0.99
0.66
0.33
00
SHENANDOAH
Pigeon Hill

No. 20

Northwest Airlines, Boeing 727-251, N-274US, accident near Thiells, U.S.A., on 1 December 1974. Report No. NTSB-AAR-75-13, dated 13 August 1975, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

On 1 December 1974, Northwest Airlines, Inc., Flight 6231, a Boeing 727-251, N-274US, was a ferry flight from John F. Kennedy International Airport (JFK), Jamaica, New York, to Buffalo, New York. Three crew members were the only persons aboard the aircraft.

Flight 6231 departed JFK about 1914[1/] on a standard instrument departure. After take-off, Kennedy departure control cleared the flight to climb to 14 000 ft.[2/] At 1920:21, New York air route traffic control centre (ZNY) assumed radar control of the flight, and at 1921:07, ZNY cleared the flight to climb to flight level 310.[3/]

Flight 6231 proceeded without reported difficulty until 1924:42, when a crew member transmitted, "Mayday, mayday ..." on ZNY frequency. The ZNY controller responded, "... go ahead", and the crew member said, "Roger, we're out of control, descending through 20 000 ft".

After giving interim altitude clearances, at 1925:21, the ZNY controller asked Flight 6231 what their problem was, and a crew member responded, "We're descending through 12, we're in a stall". The sound of an active radio transmitter was recorded at 1925:38. There were no further transmissions from Flight 6231.

At 1925:57, Flight 6231 crashed in a forest in the Harriman State Park, about 3.2 NM west of Thiells, New York. No one witnessed the crash.

The accident occurred during hours of darkness.

The geographic coordinates of the accident site are 41° 12' 53" N. latitude and 74° 5' 40" W. longitude.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3	-	-
Non-fatal	-	-	-
None	-	-	

1/ All times herein are eastern standard, based on the 24-hour clock.
2/ All altitudes herein are mean sea level, unless otherwise indicated.
3/ An altitude of 31 000 ft which is maintained with an altimeter setting of 29.92 in.

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

Trees and bushes were either damaged or destroyed.

1.5 Crew information

The crew members were qualified and certificated for the flight. The three crew members had off-duty periods of 15 hours 31 minutes during the 24-hour period preceding the flight. (See Appendix B.)

In October 1974, the first officer advanced from second officer in B-707 aircraft to first officer in B-727 aircraft; he had flown about 46 hours in the latter capacity.

1.6 Aircraft information

N-274US was owned and operated by Northwest Airlines, Inc. It was certificated and maintained in accordance with Federal Aviation Administration (FAA) regulations and requirements. (See Appendix C.)

N-274US was loaded with 48 500 lb of Jet A fuel. The gross weight at take-off was about 147 000 lb. The weight and centre of gravity (c.g.) were within prescribed limits. The aircraft was in compliance with all pertinent airworthiness directives.

In the Boeing 727 aircraft, the Pitot-static instruments on the pilot-in-command's panel, the Pitot-static instruments on the co-pilot's panel, and the Pitot-static instrumentation in the flight data recorder (FDR) are connected to separate Pitot and static sources. The three Pitot systems have no common elements and are completely independent. The three static systems are also independent except for manual selector valves in both the pilot-in-command's and co-pilot's systems which provide for selection of the FDR static system as an alternate pressure source if either primary source malfunctions.

The co-pilot's Pitot and static systems are connected to a Mach airspeed warning switch. The switch activates a warning horn when it senses a differential pressure which indicates that the aircraft's speed is exceeding V_{mo} or M_{mo},[4/] depending on the aircraft's altitude. A redundant Mach airspeed warning system is incorporated in the FDR Pitot and static systems.

The Pitot head for the pilot-in-command's Pitot system is located on the left side of the aircraft's fuselage; the Pitot heads for the co-pilot's system and the FDR system are located on the right side of the fuselage. Each of these heads incorporates a heating element and a small drain hole, for exhausting moisture, aft of the total pressure sensing inlet. The three static systems each have a static port located on either side of the fuselage. The left static port is connected to the right static port to offset side-slip effects by balancing the pressures within the systems. Each of the ports is equipped with a heating element.

4/ Maximum operating limit speed or maximum operating limit Mach.

In addition to the above systems, two independent Pitot-static systems are connected to a mechanism in the aircraft's longitudinal control system. The force which the pilot must exert to move the elevator control surfaces varies as a function of the dynamic pressure measured by these systems. The two Pitot heads for these systems are mounted one on each side of the vertical stabilizer, and their design is similar to the other Pitot heads.

1.7 Meteorological information

Northwest Airlines' meteorology department supplied the weather information for Flight 6231. This information included a synopsis of surface conditions, terminal forecasts, a tropopause and wind forecast for the 300-millibar level, appropriate surface observations, and turbulence plots. For the period 1700 to 2300, Northwest meteorologists forecast moderate to heavy snow showers from Lake Michigan to the Appalachian Mountains and moderate to heavy rain showers and scattered thunderstorms east of the Appalachians.

Northwest's turbulence plot (TP) No. East 2 was in effect and available to the flight crew on the day of the accident. TP East 2 was a triangular area defined by lines connecting Pittsburgh, Pennsylvania, New York City, New York, and Richmond, Virginia. Thunderstorm cells with maximum tops to 28 000 ft were located in this area.

SIGMET[5/] Delta 2, issued at 1755 and valid 1755 to 2200, predicted frequent moderate icing in clouds, locally severe in precipitation above the freezing level, which was at the surface in southwestern New York and which sloped to 6 000 ft eastward to the Atlantic coast.

The surface weather observations at Newburgh, New York, about 17 miles north of the accident site, were:

1900 - Estimated ceiling 2 500 ft broken, 5 000 ft overcast, visibility 12 miles, temperature 34°F, dew point 22°F, wind 070° at 14 kt, gusts 24 kt, altimeter setting 29.98 in.

2000 - Similar conditions to those reported at 1900 except that very light ice pellets were falling.

Another Northwest flight was on a similar route behind Flight 6231. The pilot-in-command of that flight stated that he encountered icing and light turbulence in his climb. He was in instrument conditions from 1 500 ft to 23 000 ft, except for a few minutes between cloud layers at an intermediate altitude.

1.8 Aids to navigation

There were no problems with navigational aids.

1.9 Communications

There were no problems with air-to-ground communications.

1.10 Aerodrome and ground facilities

Not applicable.

5/ A SIGMET is an advisory of weather severe enough to be potentially hazardous to all aircraft. It is broadcast on navigational and voice frequencies and by flight service stations. It is also transmitted on Service-A weather teletype circuits.

1.11 Flight recorders

N-274US was equipped with a Fairchild Model 5424 flight data recorder (FDR), serial No. 5146, and a Fairchild A-100 cockpit voice recorder (CVR), serial No. 1640. Both recorders sustained superficial mechanical damage, but the recording tapes were intact and undamaged. All of the FDR traces and the CVR channels were clearly recorded.

The readout of the FDR traces invovled 11 minutes 54.6 seconds of flight, beginning 15 seconds before lift-off.

Pertinent portions of the CVR tape were transcribed, beginning with the flight crew's execution of the pre-take-off check list and ending with the sounds of impact. The following transcript was made on the flight crew's activities between 1906:36 and 1906:51:

Co-pilot: Zero, zero and thirty-one, fifteen, fifteen ... blue.

Second Officer: Bug.

Second Officer: Pitot heat.

Co-pilot: Off and on.

Pilot-in-command: One forty-two is the bug.

Co-pilot: Or ... do you want the engine heat on?

Co-pilot: Huh!

Sound of five clicks.

Air-to-ground communications, cockpit conversations, and other sounds recorded on the CVR were correlated to the FDR altitude, airspeed, heading, and vertical acceleration traces by matching the radio transmission time indications on both the CVR and FDR.

The FDR to CVR correlation showed that after take-off, the aircraft climbed to 13 500 ft and remained at that altitude for about 50 seconds, during which time the airspeed[6/] increased from 264 kt to 304 kt. During that 50 seconds, the airspeed trace showed two aberrations in a 27-second period; each aberration was characterized by a sudden reduction in airspeed. These reductions were 40 kt and 140 kt and lasted for 7 and 5 seconds, respectively.

The aircraft then began to climb 2 500 ft per minute while maintaining an airspeed of about 305 kt. As the altitude increased above 16 000 ft, the recorded airspeed began to increase. Subsequently, both the rate of climb and the rate of change in airspeed increased. About this same time, the co-pilot commented, "Do you realize we're going 340 kt and I'm climbing 5 000 ft a minute?"

The flight crew discussed the implications of the high airspeed and high rate of climb. The second officer commented, "That's because we're light", after which the pilot-in-command said, "It gives up real fast", and "I wish I had my shoulder harness on, it's going to give up pretty soon". The rate of climb eventually exceeded 6 500 ft per minute.

6/ All airspeeds are indicated airspeeds, unless otherwise noted.

The sound of an overspeed warning horn was recorded as the altitude reached 23 000 ft. At that time, the recorded airspeed was 405 kt and the following conversation took place:

Pilot-in-command: "Would you believe that #".

Co-pilot: "I believe it, I just can't do anything about it".

Pilot-in-command: "No, just pull her back, let her climb".

This last comment was followed by the sound of a second overspeed warning horn.

The sound of the stall warning stick shaker was recorded intermittently less than 10 seconds after the onset of the overspeed warning. Five seconds later, vertical acceleration reduced to 0.8 g, and the altitude levelled at 24 800 ft. The recorded airspeed was 420 kt.

The stall warning began again and continued while the co-pilot commented, "There's that Mach buffet,[7/] guess we'll have to pull it up", followed by the pilot-in-command's command, "Pull it up", and the sound of the landing gear warning horn. The FDR readout shows the following:

Two seconds later (about 13 seconds after the aircraft arrived at 24 800 ft), the vertical acceleration trace again declined to 0.8 g and the altitude trace began to descend at a rate of 15 000 ft per minute. The airspeed trace decreased simultaneously at a rate of 4 kt per second and the magnetic heading trace changed from 290° to 080° within 10 seconds, which indicated that the aircraft was turning rapidly to the right.

As the aircraft continued to descend, the vertical acceleration trace increased to 1.5 g. The aircraft's magnetic heading trace fluctuated, but moved basically to the right. About 10 seconds after the descent began, the "Mayday" was transmitted.

Thirty-three seconds later the crew reported, "We're descending through 12, we're in a stall". About 5 seconds after that transmission, the pilot-in-command commanded, "Flaps two ....", and a sound similar to movement of the flap handle was recorded. There was no apparent change in the rate of descent; however, the vertical acceleration trace increased immediately, with peaks to +3 g. The recorded airspeed decreased to zero, and the sound of the stall warning became intermittent.

Five seconds after the pilot-in-command's command for flaps, the co-pilot said, "Pull now ... pull, that's it". Ten seconds later, the peak values for vertical acceleration increased to +5 g. The rate of descent decreased slightly; however, the altitude continued to decrease to 1 090 ft, the elevation of the terrain at the accident site. The aircraft had descended from 24 800 ft in 83 seconds.

7/ A slight buffet that occurs when an aircraft exceeds its critical Mach number. The buffet is caused by the formation of a shock wave on the airfoil surfaces and a separation of airflow aft of the shock wave. The change from laminar flow to turbulent flow aft of the shock wave causes a high frequency vibration in the control surfaces which is described as "buffet" or "buzz".

1.12 Aircraft wreckage

The aircraft struck the ground in a slightly nose-down and right wing-down attitude in an area where the terrain sloped downward about 10°. The aircraft structure had disintegrated and ruptured and was distorted extensively. There was no evidence of a pre-existing malfunction in any of the aircraft's systems.

Except for both elevator tips, the left horizontal stabilizer, and three pieces of light structure from the left stabilizer, the entire aircraft was located within an area 180 ft long and 100 ft wide. The above components were located between 375 ft and 4 200 ft from the main wreckage.

The horizontal stabilizer trim setting was 1.2 units of trim aircraft nose-up. The landing gear and spoilers were retracted. The wing trailing edge flaps were extended to the 2° position, and the Nos. 2, 3, 6 and 7 leading edge slats were fully extended, which corresponded to a trailing edge flap selection of 2°.

The No. 1 and No. 3 engines were separated from their respective pylons. The No. 2 engine remained in its mounting in the empennage. The engines exhibited impact damage but little rotational damage. The speed servo cams in all three fuel control units were at or near their high speed detents.

The outboard section of the left horizontal stabilizer had separated between stations 50 and 60. The inboard section remained attached to the vertical stabilizer. The left elevator between stations 78 and 223 remained attached to the separated section. The right horizontal stabilizer was attached to the vertical stabilizer except for the tip section from station 188 outboard. The right elevator, from station 188 inboard, remained attached to the horizontal stabilizer.

The three altitude indicators were damaged on impact. The indicators showed similar attitude information 20° nose-down, with the wings almost level.

The two Pitot head heater switches were in the "off" position and the switches' toggle levers were bent aft. The damage to the switch levers and the debris desposited on them was that which would be expected if they had been in the "off" position at impact. A new switch with its toggle lever in the "off" position, when struck with a heavy object, exhibited internal damage similar to the damage found in the internal portions of the right Pitot heater switch.

Four of the five Pitot head heater circuit breakers were operable and were electrically closed. The auxiliary Pitot head heater circuit breaker was jammed into its mounting structure, and it was electrically open.

The left elevator Pitot head was lying on the frozen ground; when retrieved, at least eight drops of water dripped from the pressure inlet port. After exposure to sunlight, more water drained from the port. The pilot-in-command's Pitot head was retrieved and cleared of frozen mud. The pressure inlet port was filled with dry wood fibres. After exposure to sunlight, wet wood fibres were removed from the interior of the inlet port, and moisture was present on the inner surface of the port. The co-pilot's Pitot head and the auxiliary Pitot head were crushed and damaged severely; they could not be checked for water content. The right elevator Pitot head remained attached to the vertical stabilizer. The head was in good condition and contained no water or ice.

The engine anti-ice switches for the Nos. 1 and 2 engines were in the "open" position. The switch for the No. 3 engine was in the "closed" position and the switch handle was bent aft. Tests of the bulb filaments of the engine anti-ice indicator lights showed that all three lights were on at impact.

1.13 Medical and pathological information

The three crew members were killed in the crash. Toxicological tests disclosed no evidence of carbon monoxide, hydrogen cyanide, alcohol, or drugs in any of the crew members.

1.14 Fire

There was no fire, either during flight or after impact.

1.15 Survival aspects

The accident was not survivable.

1.16 Tests and research

Pitot head examination and icing tests

A metallurgical examination of the separated heater conductor wire in the Pitot head from the co-pilot's Pitot system showed that the circumference of the wire was reduced before the wire broke. The metal in the wire had not melted, and there were no signs of electrical current arcing or shorting.

A Pitot head of the same type that provided Pitot pressure to the co-pilot's airspeed/Mach indicator was exposed to icing conditions in a wind tunnel. With the Pitot heater inoperative, 1 to 2 inches of ice formed over the pressure inlet port. During the exposure, a thin film of water flowed into the pressure port, some of which flowed out of the drain hole.

Blockage of the drain hole by ice seemed to depend on the length of time required for ice to form and block the total pressure inlet port. The longer it took for ice to form and block the total pressure port, the more likely it became that the drain hole would be blocked by ice. Also, the greater the angle between the longitudinal axis of the Pitot head and the relative wind, the greater the likelihood that the drain hole would become blocked with ice.

Constant altitude pressure measurements showed that when the total pressure inlet port was blocked by ice and the drain hole remained open, pressure changes occurred that would cause a reduction of indicated airspeed. However, when both the total pressure port and drain hole were blocked, the total pressure remained constant, which would cause indicated airspeed to remain fixed. Also, abrupt and small pressure fluctuations occurred shortly before either the pressure port or drain hole became blocked by ice.

In an effort to reproduce the apparent inconsistencies between the airspeed and latitude values on the FDR traces, tests were conducted with an airspeed indicator and an altimeter connected to vacuum and pressure sources. By altering the vacuum to the altimeter and to the airspeed indicator, the altitude trace could be reproduced. However, following ascent above 16 000 ft, the FDR airspeed and altitude values could be simultaneously duplicated only when the total pressure to the airspeed indicator was fixed at its FDR value for an altimeter reading of about 15 675 ft and an indicated airspeed of about 302 kt.

Aircraft performance analysis

Following the accident, the Safety Board requested that the aircraft manufacturer analyse the data from the CVR and FDR to determine: 1) The consistency of these data, particularly the airspeed and altitude values, with the theoretical performance of the aircraft; 2) the significance and possible reason for a simultaneous activation of the overspeed and stall warning systems; and 3) the body attitude of the aircraft during its final ascent and descent. The following are some results of the manufacturer's performance analysis:

The airspeed and altitude values which were recorded were consistent with the aircraft's predicted climb performance until the aircraft reached 16 000 ft. The simultaneous increases in both airspeed and rate of ascent which were recorded thereafter exceeded the theoretical performance capability of a B-727-200 series aircraft of the same weight as N-274US. Consequently, the recorded airspeed values were suspected to be erroneous, and it appeared that they varied directly with the change in recorded altitude. The recorded airspeeds correlated within 5 per cent with the theoretical airspeeds which would be expected if the pressure measured in the Pitot system had remained constant after the aircraft's climb through 16 000 ft.

The indicated airspeed of the aircraft when the stick shaker was first activated was calculated to be 165 kt as compared to the 412 kt recorded by the FDR. The decrease in airspeed from 305 kt to 165 kt as the aircraft climbed from 16 000 ft to 24 000 ft (within 116 seconds) is within the aircraft's theoretical climb power performance. The aircraft's pitch attitude would have been about 30^{o} nose-up as stick shaker speed was approached. The stall warning stick shaker is activated by angle of attack instrumentation which is completely independent of, and therefore not affected by errors in, the aircraft's airspeed measuring systems.

Vertical acceleration reduced slightly as the aircraft levelled at 24 800 ft probably because the pilot relaxed the back pressure being applied to the control column. The stick shaker ceased momentarily; however, the aircraft continued to decelerate because of the drag induced by the high body attitude, and the stick shaker reactivated. Boeing personnel interpreted the sound of the landing gear warning horn on the CVR to indicate that the thrust levers had been retarded to idle. The second reduction in vertical acceleration to 0.8 g which was coincident with a sudden descent and a rapid magnetic heading change was probably caused by an aerodynamic stall with a probable loss of lateral control.

Theoretical relationships of angle of attack, velocity, and drag were compared to the recorded rate of descent and load factor to determine the attitude of the aircraft after the stall. The comparison showed that the aircraft attained an angle of attack of 22^{o}, or greater, during the descent. Transient nose-down attitudes of more than 60^{o} would have been required to achieve the measured descent rate with an angle of attack of 22^{o}. The variations in load factors, which averaged about +1.5 g, were attributed to variations in the aircraft's angle of bank.

The aircraft was probably exceeding 230 kt, with a nose-down attitude of about 50^{o} as it descended below 11 000 ft, when the flaps were extended to 2^{o}. The momentary cessation of the stick shaker indicated that the angle of attack had been reduced to less than 13^{o}. The increase in vertical acceleration to 2.5 g was attributed to the aircraft's being in a tight nose-down spiral with a bank angle between 70^{o} and 80^{o}.

With a normally operating elevator feel system, and a stabilizer trim setting of 1.2 units aircraft nose-up, the pilot would have to expert a pull force of between 45 and 50 lb to achieve a 2.5 g load factor at 5 000 ft and 250 kt. If, however, the elevator Pitot system was blocked so that the system sensed a zero indicated airspeed, a pull force of less than 30 lb would have produced the same load factor. After the aircraft had descended through 5 000 ft, the load factor reached peak values of +5 g.

The manufacturer's engineers stated that the aircraft's structural limits would have been exceeded at high angles of side-slip and load factors approaching +5 g. They stated that a consequent failure of the elevator assemblies could have produced an aerodynamic flutter which could have, in turn, caused the elevator spar to fail and the left horizontal stabilizer to separate. With the aircraft at a stall angle of attack when the horizontal stabilizer separated, an uncontrollable nose-up pitching moment would have been produced, which could have resulted in an angle of attack of 40^{o} or more.

1.17 Other information

Pre-take-off checklist

Northwest Airlines' operational procedures require that the flight crew make a pre-take-off check of certain items. The second officer is required to read the checklist items, and the co-pilot must check the items and respond to the second officer's challenge. Included on the checklist are:

Second Officer	Co-Pilot
Flaps	15, 15 (25, 25) Blue
Marked Bug _______K	(C, FO) Numbers Set
Ice Protection	OFF (ON)
Pitot Heat	ON
Pressurization	(C, FO) Zero, _______o, Normal Flags

Company pilots stated that the checklist is used only to check that the required action has already been performed; it is not used as a list of items to be accomplished. With regard to the activation of Pitot head heaters, it was the co-pilot's duty to turn the two switches to the "on" position shortly after the engines had been started and to check the ammeter readings on the various heaters to confirm their proper operation. After checking these items, he was supposed to leave the Pitot heater switches on and to check that they were on during the pre-take-off check.

Airspeed measuring system

When an aircraft moves through an air mass, pressure is created ahead of the aircraft, which adds to the existing static pressure within the air mass. The added pressure, dynamic pressure, is directly proportional to the velocity of the aircraft. When a symmetrically shaped object, such as a Pitot head, is placed into the moving airstream, the flow of air will separate around the nose of the object so that the local velocity at the nose is zero. At the zero velocity point, the airstream dynamic pressure is converted into an increase in the local static pressure. Thus, the pressure measured at the nose of the object is called total pressure, and it is equal to the sum of the dynamic pressure and the ambient static pressure.

In an aircraft airspeed measuring system, the total pressure is measured by the Pitot head and is transmitted through the Pitot system plumbing to one side of a differential pressure measuring instrument (airspeed indicator). The ambient static pressure is measured at static ports which are mounted in an area that is not significantly influenced by the moving airstream. The static pressure measured at these ports is transmitted to the opposite side of the differential pressure measuring instrument. In effect, the differential pressure instrument (whether it be an airspeed indicator gauge, a flight data recorder pressure transmitter, or a component within an air data computer) subtracts the ambient static pressure measured by the static system from the total pressure measured by the Pitot system. The resultant dynamic pressure is a direct measurement of indicated airspeed.

Since the ambient static pressure is a component part of total pressure, any change in static pressure would normally result in an equal change in both the Pitot and static pressure systems. Therefore, a change in ambient static pressure, such as that encountered during a change in altitude, would normally have no effect on airspeed measurement. Only a change in dynamic pressure produced by a change in the aircraft's velocity would cause a change in the indicated airspeed. If, however, only one side of the airspeed indicator sensed a change in the ambient static pressure, an erroneous change in indicated airspeed would result, even though the actual dynamic pressure remained unchanged. Such a condition would occur if either the Pitot or static system was blocked or was otherwise rendered insensitive to external pressure changes.

In the event of a blocked Pitot or static system, the direction of the indicated airspeed error would depend on which of the systems was blocked and the direction of change in the ambient static pressure. Under conditions where the pressure in the static system increases with respect to the pressure in the Pitot system, the indicated airspeed will read low erroneously. For the opposite condition, where the pressure in the static system decreases with respect to the pressure in the Pitot system, the indicated airspeed will read high erroneously. The latter would exist if the Pitot head was blocked so that a constant pressure was trapped in the Pitot system while the aircraft was ascending. This is because the static system pressure would decrease and the resultant differential pressure would appear as an increase in dynamic pressure.

Indicated airspeed error may also occur when the Pitot system becomes insensitive to changes in total pressure in such a manner that the system vents to an ambient static pressure source. The pressure measured by the Pitot system will equalize with the pressure in the static system, and the dynamic pressure (indicated airspeed) will decrease to zero. The vent source in a Pitot head which can produce this kind of error is the moisture drain hole which is located downstream from a blocked total pressure sensing inlet.

B-727 stall characteristics

During its type certification process, the B-727-200 series aircraft demonstrated stall characteristics which met the requirements of the Civil Air Regulations, parts 4b. 160-162. The significant requirements defined therein are: 1) That, at an angle of attack measurably greater than that of maximum lift, the inherent flight characteristics give a clear indication to the pilot that the aircraft is stalled - typical indications are a nose-down pitch or a roll which cannot be readily arrested; 2) that recovery from the stall can be effected by normal recovery techniques starting as soon as the aircraft is stalled; 3) that there is no abnormal nose-up pitching and that the longitudinal control force be positive, up to and including the stall; 4) that a safe recovery from a stall can be effected with the critical engine inoperative; and 5) that a clear and distinctive stall warning be apparent to the pilot at an airspeed at least 7 per cent above the stalling airspeed.

The certification stall tests, conducted with the aircraft in all operating configurations and with the most adverse weight and centre of gravity conditions, demonstrated that as the aircraft was slowed and its wing angle of attack was increased, the buffet produced by airflow separation from the wing provided a natural warning of impending stall. With the landing flaps extended, however, the airspeed margin provided by the buffet warning was considered to be insufficient. Consequently, a stick shaker system was installed to provide an artificial warning for all configurations.

In the clean configuration,[8/] the stick shaker activated when the angle of attack reached 13°. When the aircraft was slowed further, natural buffeting occurred at an angle of attack between 16° and 18°. The buffet was described as "quite heavy" when the speed was reduced to within 2 to 3 kt of the speed associated with maximum lift. When the angle of attack for maximum lift (about 22°) was reached, there was a tendency for the nose to drop if the pilot relaxed pressure on the control column. Also, lateral stability was reduced noticeably, which increased the pilot's workload in maintaining wings-level flight.

During certification flight tests, the angle of attack was increased to 25°, after which recovery was effected by relaxing the pull force on the control column. With the use of engine thrust during recovery, the altitude lost was restricted to about 2 000 ft.

Up to the onset of stall buffet, the longitudinal control forces needed to effect stall entry increased as the angle of attack increased. At higher angles of attack, up to and beyond the angle for maximum lift, the pull force required to maintain a nose-up pitching moment decreased. The forces did not reverse, however, and, with normal trim, a reduction in pull force resulted in a decreased angle of attack.

The B-727 longitudinal control system is capable of developing the nose-up pitching moments needed to obtain angles of attack much higher than those associated with stall. For an aircraft having the same weight, centre of gravity location, and stabilizer trim setting as N-274US, the manufacturer's analysis showed that an angle of attack of approximately 37° could be attained if a continuous pull force was exerted to hold the control column aft.

Like other aircraft which have horizontal stabilizers located near or on top of their vertical stabilizers, the B-727 does pass through a range of high angles of attack where longitudinal instability occurs. This instability causes the aircraft, when no control force is applied, to pitch to even higher angles of attack. Longitudinal instability is caused by degraded horizontal stabilizer effectiveness when the aircraft's attitude is such that the horizontal stabilizer is enveloped by the low-energy turbulent air in the wake from the wings. When these high angles of attack are reached, a push force on the control column is required to reduce the angle of attack. For a B-727 with an aft centre of gravity location and stabilizer trim in the cruise range, wind tunnel data show that a nose-down pitching moment will decrease the angle of attack and stall recovery can be attained by applying push forces to the control column.

A stick pusher is a device which will apply a force to move the control column forward when the angle of attack for maximum lift is exceeded. The usefulness of a stick pusher is controversial since it can affect primary control of the aircraft. However, a stick pusher is required on B-727 and other aircraft registered by the United Kingdom. That stick pusher is designed so that its action can be overpowered by a pull force of about 80 lb on the pilot's control column.

8/ Without landing gear, flaps, or spoilers extended.

2.- Analysis and Conclusions

2.1 Analysis

The aircraft was certificated, equipped, and maintained in accordance with regulations and approved procedures. The aircraft weighed substantially less than its authorized maximum weight for take-off.

Although the speed servo cams in all three engine fuel controllers were positioned for high engine revolutions per minute, the engines were producing very little thrust at impact as evidenced by the absence of significant rotational damage to the engines. Probably, the throttles had been advanced shortly before impact, but there was either insufficient time for the engines to accelerate, or acceleration was limited because airflow into the engine inlets had been distorted by the extreme angle of attack and probable side-slip.

The flight crew was properly certificated and each crew member had received the training and off-duty time prescribed by regulations. There was no evidence of medical or physiological problems that might have affected their performance.

The conversations recorded on the CVR revealed that, following ascent above 13 500 ft, the flight crew became concerned and puzzled by the apparent performance of the aircraft because of the indicated airspeed and the indicated rate of ascent. The FDR airspeed and altitude traces provided investigators an insight into these conversations. The airspeed trace increased rapidly after the aircraft ascended above 16 000 ft while the rate of climb continued to increase and eventually reached a peak value of 6 500 ft per minute. The Boeing Company's analysis of the airspeed and rates of climb values that registered above 16 000 ft showed that these values were incompatible with the aircraft's performance capabilities.

Analysis showed that there was a direct relationship between the airspeed and altitude values. This relationship was based on the assumptions that 1) the total pressure measured by the FDR Pitot system remained constant after the aircraft ascended above 16 000 ft, and 2) the pressure measured by the FDR static system varied according to the recorded altitude values. These assumptions were substantiated by the tests which determined that the FDR airspeed and altitude traces could be reproduced only if the total pressure to the airspeed indicator was held constant during ascent above 16 000 ft.

Although the Pitot systems for pilot-in-command's and co-pilot's airspeed Mach indicators and the FDR airspeed instrumentation are three separate and completely independent systems, it is reasonable to conclude that all three systems were sensing nearly identical and erroneous total pressures. This can be concluded because the flight crew made no reference to any difference between the airspeed readings on the pilot-in-command's and co-pilot's indicators, and the co-pilot's reference to "... going 340 kt ..." corresponded closely to the airspeed value recorded on the FDR at that time. Additionally, the near simultaneous activation of the overspeed warning systems tends to prove that the co-pilot's airspeed was close to the value recorded on the FDR when the aircraft neared its peak altitude.

The erroneously high airspeed indications were caused by a complete and nearly simultaneous blockage of all three Pitot pressure systems. Moreover, since the only common elements among the systems were the design features of the Pitot heads and the environment to which they were exposed, the Safety Board concludes that the Pitot heads were blocked by ice which formed around the heads and closed the drain holes and the pressure inlet ports. The conclusion is supported by the airspeed aberrations that were recorded while the aircraft was flying level at 13 500 ft and by the moisture which was found in the Pitot heads when they were recovered and examined. Additionally, it is known that icing conditions existed in the area through which Flight 6231 was flying, and it is unlikely that any other type of blockage or malfunction would simultaneously affect the three independent systems.

The formation of ice on the Pitot heads should have been prevented by electrical heating elements which are activated by the Pitot heater switches located in the cockpit. The Safety Board concludes that the heating elements were never activated because the Pitot heater switches were not in the "on" position during the flight. This conclusion is substantiated by the position and condition of the switches in the wreckage, the internal damage to the right switch, and the lack of evidence that electrical current was present in the heater circuit to the Pitot head in the co-pilot's Pitot system at the time of impact.

The Safety Board was unable to determine why the Pitot head heater switches were not placed in the "on" position before departure. It is clear that the flight crew performed the pre-take-off checks required by Northwest's operational procedures. However, the proper check-list sequence was not followed, and it is possible that the co-pilot positioned the switches improperly because of an omission in the sequence and his inexperience as a B-727 co-pilot.

While reading the check-list, the second officer called "bug" and, before receiving a response from either the pilot-in-command or co-pilot, he omitted the "ice protection" call and called "Pitot heat". The co-pilot apparently responded to both the omitted call and the "Pitot heat" call by saying, "off and on", but following the pilot-in-command's response to the "bug" call, the co-pilot asked whether the engine heat was needed. The pilot-in-command may or may not have responded with a nod or hand signal, but the sound of five clicks was recorded and the co-pilot returned to the task of setting his airspeed bug.

The five clicks may have been the movement of the Pitot heater switches to the "off" position and the movement of the engine anti-ice switches to the "on" position a reversal of their normal positions. This assumption is supported by the position of the engine anti-ice and Pitot heater switches in the wreckage, the condition of the lights associated with the engine anti-ice switches, and the lack of any reference during the flight to the need for engine anti-ice.

Because of the flight crew's comments concerning aircraft performance and the absence of comments about possible instrument error or airspeed system icing, the Safety Board concludes that the flight crew attributed the high airspeed and the high rate of climb to the aircraft's relatively low gross weight and to an encounter with unusual weather, which included strong updraughts. The flight crew's analysis of the situation must have been strongly influenced by these factors and by the fact that both airspeed instruments were indicating essentially the same values. However, the aircraft's attitude as it neared the top of its ascent should have warned them that the aircraft's performance was abnormal because its nearly 30° nose-up attitude was about 25° higher than the normal climb attitude, and at such a high nose-up attitude it would have been impossible for the airspeed to continue to increase even if influenced by extreme updraughts. Because the use of attitude references is a fundamental of instrument flying, which is stressed in Northwest's flight crew training programme, the Safety Board concludes that the flight crew improperly relied on airspeed indications as a means of determining aircraft performance.

Although the activation of the overspeed warning systems probably reinforced the flight crew's belief that they were taking appropriate action, the operation of the stall warning stick shaker should have alerted them that the aircraft actually was approaching a stall. The co-pilot apparently misinterpreted the control column vibration produced by the stick shaker as Mach buffet because when the stick shaker began, he commented, "... there's that Mach buffet". The pilot-in-command apparently agreed with this interpretation because be then commanded, "Pull it up". The almost simultaneous activation of the stall and the overspeed warning systems undoubtedly created some confusion; however, the differences between stall buffet and Mach buffet are substantial and the former should have been easily recognized. Again, though, it appears that the flight crew relied almost exclusively on the airspeed indicators and their related warning systems to assess the aircraft's performance.

Even after the stall, as manifested by the rapid heading change (banked attitude) and the sudden descent, the flight crew failed to recognize the problem for a number of seconds. They continued to exert back pressure on the control column which kept the aircraft at a high angle of attack. They probably were having difficulty with lateral control, and the aircraft entered into a spiralling descent to the right, during which the actual airspeed of the aircraft began to increase rapidly.

The erroneous airspeed indications, the steep nose-down attitude, and the proprioceptive sensations associated with the positive vertical acceleration forces undoubtedly contributed to confusion which prevented the flight crew from recognizing the true condition of the aircraft. Additionally, it is probable that the nose-down and banked attitudes of the aircraft were so steep that the horizon references in the attitude instruments were nearly hidden. This would have made the lateral attitude of the aircraft difficult to determine. However, had the pilots concentrated more on the attitude indicators, and particularly the position of the "sky pointers,"[9/] they probably could have returned the aircraft to level flight had they taken appropriate corrective action within 30 to 40 seconds after the stall.

Probably because of the low airspeed indications, the pilot-in-command decided that the aircraft was in a stall. He transmitted: "We're descending through 12, we're in a stall", and he called for the flaps to be extended to 2^{o} - a proper step in the stall recovery procedure. However, the actual indicated airspeed at that time was probably in excess of 230 kt and increasing rapidly; consequently, although the stick shaker ceased operation momentarily, the extension of the flaps had little favourable effect.

Even after the pilots decided that the aircraft was stalled, the Safety Board believes that they continued to react primarily to the high rate of descent indications and proprioceptive sensations because they continued to exert a pull force on the control column. This is substantiated by the increasing vertical acceleration forces as the descent continued. However, because the wings were not levelled first, the aircraft continued to descend rapidly in a spiralling, accelerated stall.

Since the Pitot heads for the elevator feel system were probably blocked by ice, the force required of the pilots to move the elevators would have been increased while the aircraft was above 16 000 ft. However, when the aircraft descended below that altitude, the force required would have been diminished. As the descent continued below 5 000 ft, the actual indicated airspeed probably exceeded 350 kt while the airspeed sensed by the elevator feel system was probably near zero. Consequently, conditions were created in which high vertical acceleration forces could be produced with relative ease. As evidenced by the FDR acceleration trace, high vertical acceleration forces were produced below 5 400 ft.

9/ A triangular index which is positioned above the movable horizon and which moves in the opposite direction from the aircraft's banked attitude to indicate the number of degrees of bank.

As the aircraft continued its descent through 3 500 ft, the high vertical acceleration forces induced were sufficient to cause the failure of the left horizontal stabilizer. Thereafter, the aircraft probably rolled to a near wings-level attitude, pitched up to an extremely high angle of attack, and continued to descend in an uncontrollable stall to the ground.

During the Safety Board's investigation, incidents involving possible Pitot-static system icing were reviewed. Although none of these incidents resulted in a catastrophic accident, it became clear that Pitot or static system icing during flight can and does occur. Also, the resultant effects on pressure-operated flight instruments can produce at least momentary confusion among the crew members.

While all of the flight crews involved in these incidents reverted to attitude flying until the cause of the icing would be eliminated or instrument flight could be terminated, it was apparent from these incidents that some pilots who understood the basic principles of airspeed measurement failed to analyse the possible results of a blockage of the Pitot or static systems. The pilots often failed to determine the proper reasons for an increasing airspeed indication; they attributed such indications to unusual weather phenomena.

Although unusual weather phenomena such as mountain waves, extreme turbulence, and vertical wind shear can produce significant airspeed deviations, these phenomena usually are of short duration and cause erratic or abruptly changing airspeed indications rather steadily increasing, steadily decreasing, or fixed airspeed indications. Also, the aircraft's attitude during encounters with these phenomena is important in determining airspeed trends and possible sources of error. Consequently, the Safety Board believes that potential Pitot-static system problems and attitude flying as a temporary remedy for these problems should be re-emphasized in instrument flying training programmes, and the Safety Board has made a recommendation to this effect to the Administrator, Federal Aviation Administration.

2.2 Conclusions

a) Findings

1. All members of the flight crew were properly certificated and were qualified for their respective duties.

2. The aircraft had been properly maintained and was airworthy for the flight; its gross weight and centre of gravity were within the prescribed limits.

3. There was no evidence of a system malfunction or failure or of a structural defect in the aircraft.

4. The flight crew had adequate weather information for the flight.

5. The FDR vertical acceleration trace indicates that only light turbulence was encountered.

6. The weather conditions encountered during the flight were conducive to the formation of moderate airframe ice.

7. The aircraft accumulated sufficient ice during its flight to block completely the drain holes and total pressure inlet ports of the Pitot heads; the static ports were not affected by the ice.

8. The Pitot heads became blocked at an altitude of about 16 000 ft.

9. The ice formed on the Pitot heads because the Pitot head heater switches had not been turned on before Flight 6231 departed JFK.

10. The complete blockage of the Pitot heads caused the cockpit airspeed indicators to read erroneously high as the aircraft climbed above 16 000 ft and the static pressure decreased.

11. The flight crew reacted to the high airspeed indications by increasing the nose-up attitude of the aircraft which increased the rate of climb. While this caused the indicated airspeed to increase more rapidly because the static pressure decreased more rapidly with the increased rate of climb, the actual airspeed was decreasing.

12. The airspeed overspeed warning and stall warning stick shaker operated simultaneously because of the blocked Pitot heads and the high nose-up attitude of the aircraft.

13. The flight crew misconstrued the operation of the stall warning stick shaker as Mach buffet.

14. The flight crew continued to increase the nose-up attitude of the aircraft following the operation of the stall warning stick shaker.

15. The aircraft stalled at an altitude of 24 800 ft while in a nose-up attitude of about 30°.

16. Following the stall, the aircraft entered into a right spiralling dive at a high rate of descent. Throughout the descent, the flight crew reacted primarily to airspeed and rate of descent indications instead of attitude indications, and thus failed to initiate proper recovery techniques and procedures.

17. In an effort to recover the aircraft from a high rate of descent, the flight crew exerted excessive pull forces on the control columns which induced high vertical acceleration forces and caused the left horizontal stabilizer to fail.

b) Cause or
Probable cause(s)

The National Transportation Safety Board determines that the probable cause of this accident was the loss of control of the aircraft because the flight crew failed to recognize and correct the aircraft's high-angle-of-attack, low-speed stall and its descending spiral. The stall was precipated by the flight crew's improper reaction to erroneous airspeed and Mach indications which had resulted from a blockage of the Pitot heads by atmospheric icing. Contrary to standard operational procedures, the flight crew had not activated the Pitot head heaters.

3.- Recommendations

As a result of this accident, three recommendations were made to the Administrator, Federal Aviation Administration. (See Appendix D.)

ICAO Note: Appendices A to D not reproduced. The specific recommendations were:

The National Transportation Safety Board believes that corrective action is necessary and recommends that the Federal Aviation Administration:

1. Issue an Operations Bulletin to all air carrier and general aviation inspectors to stress the need for pilots to use attitude information when questionable information is presented on instruments that are dependent on the air data system. The information in this Bulletin should be disseminated to all operators for incorporation into their operations procedures and training programmes. (Class 1)

2. Issue an Airworthiness Directive to require that a warning system be installed on transport category aircraft which will indicate, by way of a warning light, when the flight instrument Pitot heating system is not operating. The warning light should operate directly from the heater electrical current. (Class 2)

3. Amend the applicable Federal Air Regulations to require the Pitot heating system to be on any time electrical power is applied to an aircraft. This should also be incorporated in the operator's Operations Manual. (Class 2)

ICAO Ref.: AIG/436/74

No. 21

Martinair, DC-8-55F, PH-MBH, accident on "Anjimalai" mountain, Maskeliya, Sri Lanka, on 4 December 1974. Report dated 16 June 1975 released by the Department of Civil Aviation, Sri Lanka.

1.- Introduction

1.1 Accident details

Location

On the 5th mountain of the range of hills popularly known as "Anjimalai" at Theberton Estate, Maskeliya, Sri Lanka, at a latitude of 6°- 53'- 32.22"N and longitude 80°- 29'- 25.30"E at a height of 4 355 ft above Mean Sea Level and at a distance of approximately 40 NM from Bandaranaike International Airport, Colombo, located in Katunayake.

Date and time of accident

On 4 December 1974 at approximately 1641 GMT.*

Name of Owner, Operator and Hirer

Owner : Martinair Holland N.V.

Operator: Martinair Holland N.V.

Hirer : Garuda Indonesian Airways.

Aircraft type and registration

Type : McDonnell Douglas DC-8 55F.

Registration: PH-MBH.

Extent of damage

Aircraft destroyed.

* All times in this report are GMT. To convert to local time add 7 hours for Indonesia and 5 hours 30 minutes for Sri Lanka.

Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	9	182	-
Non-fatal	-	-	-
None	-	-	

Type of operation

Non-scheduled transport service.

Phase of operation

En-route descent to Primary Approach Facility.

Type of accident

Collision with rising terrain.

1.2 Summary

Brief summary of events leading to the accident

The aircraft PH-MBH took off from Surabaya Airport, Indonesia, at approximately 1200 hours on 4 December 1974, to proceed to Jeddah, Saudi Arabia, with a programmed technical stop at Bandaranaike International Airport, Katunayake, Sri Lanka. Aircraft contacted Bandaranaike International Airport Approach Control at 1616:45 hours indicating that they were 130 miles out at 35 000 ft, in reply to which Bandaranaike International Airport Approach Control passed on the weather and requested the aircraft to change over to Colombo Area Control on 119.1 MHz for descent clearance. This message was acknowledged by the aircraft and contact made with Area Control accordingly. The aircraft was descended from 35 000 ft by Area Control and handed over to Approach Control, at 1634:14 hours and the aircraft contacted Approach Control at 1638:10 hours, informing Approach Control that they were out of 7 000 for 6 000 at a distance of ONE FOUR (14) miles out. Approach Control acknowledging this message cleared the aircraft to 2 000 ft with instructions to report "Kilo Alpha Tango" (Katunayake Non-Directional Beacon) or "airfield in sight". This message was acknowledged by the aircraft. There was no further communication with the aircraft. Eyewitnesses state that the aircraft was sighted flying at an altitude lower than normal over Castlereigh, Bogawanthalawa and Agrapatana, and to all appearances the engines sounded normal and there was no evidence of any fire on board during flight. The sound of the aircraft exploding on impact was heard clearly by residents close to the site of crash and subsequently it was discovered that the aircraft had crashed into the 5th mountain on the range of hills called "Anjimalai" at Maskeliya, with fatal injuries to all on board. The aircraft was completely destroyed consequent to the impact.

Repeated attempts by Approach Control to establish contact with the aircraft met with no success, and in consultation with Area Control Colombo the distress phase was initiated, search and rescue operations being organized subsequently.

Notification of accident

A telephone message was received in the Approach Control Tower at Bandaranaike International Airport from the night telephone operator, Post Office, Hatton to the effect that an aircraft had crashed at Maskeliya. This was the first intimation of the accident.

ICAO Note: Paragraph 1.2.3 and Part II of the report not reproduced (the Foreword refers).

2.- Discussion of evidence

Flight data recorder

After an intensive search launched by the Sri Lanka Army and volunteers from Theberton Estate, approximately 130 ft of foil were recovered in small fragments off the Flight Data Recorder. The foil recovered was despatched to the National Transportation Safety Board of the United States of America for read-out and analysis, but this proved futile as all the foil recovered was from the supply spool, the recordings on it being not relevant to the flight in question. The only other part recovered of the Flight Data Recorder was a portion of its outer cover in a badly damaged condition.

Examination of wreckage at site

Having regard to the substance of the communication between the aircraft and Approach Control Bandaranaike International Airport, a major failure of the aircraft or its systems prior to impact is highly improbable.

The initial graze of the port wing on the fourth mountain and the statements of eyewitnesses along the flight path indicate that the aircraft was in a descending attitude immediately prior to impact. The initial graze resulted in dislodging approximately one-third of the port wing which was found at the foot of the mountain.

Just before final impact on the 5th mountain the aircraft appears to have banked 30° to port, in a yaw of 15° to port and in a nose up pitch of approximately 25°. This was deduced from the damage to foliage at the site of final impact. This bank and yaw were induced by the initial graze. On final impact the starboard wing had separated from the fuselage and had been thrown a distance of approximately 200 ft to the right. The ensuing fuel spillage had initiated a fire which consumed wreckage blown in that area. The initial graze and fuel spillage on the 4th mountain had brought about a fire on the 4th mountain. There was no indication of fire in the area of fuselage impact and it could be reasonably assumed that there was no fire on board the aircraft prior to impact.

This impact was the final phase in the accident, the real causes of which have to be traced to the factors which led the aircraft to arrive at this place.

Under the circumstances this investigation has been directed towards the examination of the following points in detail.

Route

The route selected by Martinair was the former ATS route GREEN 62 Surabaya/Djakarta/Colombo.

During the first few flights of this series conducted by Martinair, it was observed that crew reported at 92°E, 85°E, and "Over the Coast". In view of the fact that there were other routes crossing this route, and the reporting points on these being 88°E and 84°E, the Air Traffic Control Units of Djakarta and Surabaya were requested to brief operating crew of Martinair to report at 88°E and 84°E. This request was complied with. Consequently, certain crews reported as requested while others continued to report 92°E and 85°E. When conflicting traffic was anticipated, crews which reported 92°E and 85°E were requested to provide estimated times for 88°E and 84°E. These requests were complied with.

In respect of this flight, although the information on the reporting points requested was available at Surabaya, the crew reported at 92°E and 85°E and although they failed to comply with the requested reporting points (88°E and 84°E) there was no request from Air Traffic Control of Sri Lanka for the additional reporting points as there was no conflicting traffic. However, this investigation is of the view that the said deviation has no bearing on the cause of the accident.

This flight of the PH-MBH was the 56th operated by Martinair on this route and was the 19th flight of PH-MBH. Martinair continued to fly on this route after the accident. There were many flights before and after this accident on this route.

Approach control

On a perusal of the "Extract of Radio Telephony Recording of Pilot to Controller Communications on VHF", it is observed that Approach Control cleared the aircraft to 2 000 ft on the aircraft's statement that "We are out of 7 000 for 6 000 and we are One Four Miles out". The procedure is to clear an aircraft to 3 500 ft over the beacon or report visual. In this instance the aircraft was cleared to 2 000 ft or report "Airfield in Sight", which is a deviation from the laid-down procedure. However, this investigation is of the view that the said deviation had no bearing on the cause of the accident.

Public representations

In response to the notification in the Government Gazette and the newspapers. several representations were received, most of which were not relevant to the investigation.

This investigation has to consider the hypothesis adduced by certain members of the public that the aircrew mistook the lights of Adam's Peak or of the Hydro-electric Scheme at Norton Bridge for the runway lights at the Bandaranaike International Airport. This has to be discounted since in the last conversation of the co-pilot with Approach Control he did not state that he had the airfield in sight. Further, confirmation was received from the Ceylon Electricity Board that the lights on Adam's Peak were not switched on till the end of December 1974, it being the practice to light the path to the Peak during the pilgrim season which goes on from the end of December till May the following year.

Reconstruction of flight path

The aircraft had departed Surabaya at 1203 hours and had passed over Semarang Non-Directional Beacon (NDB) at 1227 hours at flight level (FL) 260 and estimated arrival over Jerabon NDB at 1241 hours. The aircraft reported over Jerabon NDB at 1241 hours and estimated over Halim beacon at 1254 hours. At 1251 hours before arrival over Halim beacon the aircraft had reported leaving FL 260 for FL 350. The aircraft was over Halim beacon at the estimated time, (average ground speed - 465 kt) estimating over Tanjungkarang NDB at 1309 hours. The average ground speed on this sector was 442 kt. This reduction in ground speed was probably due to the climb from FL 260 to FL 350 within this sector. At 1305 hours the aircraft had reported reaching FL 350. At 1309 hours it had passed over Tanjungkarang and gave an estimate for Bengkulen NDB as 1334 hours. The aircraft passed over Bengkulen as estimated. Bengkulen was the last navigational fix the aircraft passed over on this flight. The average ground speed of the aircraft from Tanjungkarang to Bengkulen was 460 kt.

After passing over Bengkulen the next reporting point was the entry point to Colombo Flight Information Region (FIR) at 01°10'N 92°E which is 692 NM from Bengkulen.

The aircraft reported over Bengkulen at 1334 hours at FL 350, gave the estimate for Colombo FIR boundary 92°E as 1503 hours. This works out to a ground speed of 466 kt.

The aircraft, however, reported over the boundary at 1457 hours in 1 hour 23 minutes, six minutes earlier then estimated. This works out to an average ground speed of 500 kt for this sector. This is 34 kt faster than that estimated. The position report, however, is probably a deduced position and being over the sea, could have been in error.

The next position was at 85°E also over the sea and 467 NM from the 92°E position. The aircraft reported over 85°E at 1557 hours, one hour after the 92°E position. This works out to a ground speed of 467 kt.

From this position the aircraft gave an estimate for the coast at 1627 hours expecting to cover the distance of 233 NM in 30 minutes i.e. at a ground speed of 466 kt.

From these reports it appears that the aircraft had averaged a ground speed of around 465 to 470 kt for most of the route, while for the stretch from Bengkulen to 92°E (Colombo FIR boundary) its time over the reporting points suggests a ground speed of 500 kt.

After reporting over 85°E at 1557 hours air/ground high frequency radio telephony (HFRT) Operator's log indicates that the aircraft was changing over the VHF communication with Colombo Control. This call on HFRT was at 1605 hours.

The first call by the aricraft on VHF to Colombo was on 119.7 MHz to Colombo Approach, instead of on 119.1 MHz to Colombo Control. At 1622 hours the aircraft contacted on Approach Control Frequency and the pilot reported that he was 130 NM out at 35 000 ft. Colombo Approach after passing the weather to the aircraft directed it to contact Colombo Control on 119.1 MHz for descent.

FROM THIS STAGE THE RECONSTRUCTION OF THE FLIGHT PATH IS BASED ON THE ASSUMPTION THAT THE AIRCRAFT DESCENDED ON A STANDARD DESCENT SCHEDULE. THE STANDARD RATE OF DESCENT ABOVE 10 000 FT IS 2 500 FT PER MINUTE AND BELOW 10 000 FT is 2 000 FT PER MINUTE.

The aircraft descended from 35 000 ft to 4 355 ft, the elevation of the scene of the final impact. At no stage during the descent had there been any restriction imposed on the descent and it can be assumed that it would have been a continuous descent.

Assuming an average descent speed of 370 kt True Air Speed (TAS) down to 10 000 ft and an average speed of 280 kt TAS below 10 000 ft it would have covered a distance of 94 NM at an average ground speed of 5.84 NM per minute. The crash site is 40 NM away from the terminal airport on a true bearing of 116° (the bearing gives an indication that the aircraft was within reasonable tolerance of the required track). The distance covered during the descent added to the distance of the crash site from the airport, gives a distance of 134 NM as the actual distance at which the aircraft would probably have commenced its descent. The pre-crash position report was made from an altitude around 7 000/6 750 ft and the aircraft would have taken 1 minute 12 seconds approximately to reach 4 355 ft the elevation of the crash site.

According to the timings on the tape recording this last communication commenced at 1639:48 hours. The crash would thus have occurred at approximately 1641 hours. This would take the time of commencement of the descent to approximately 1628 hours.

Crew familiarization

According to the documentation made available this flight was the first made by the Pilot-in-command and his co-pilot on the route Surabaya/Colombo.

The Pilot-in-command's most recent flight into Colombo had been on 16 January 1972 from Bangkok and on 17 January 1972 he flew the sector Colombo/Djakarta.

His most recent flight in the Far Eastern Region was in April 1974, when he flew as co-pilot on the route Amsterdam-Abadan, Abadan-Kuala Lumpur, Bangkok-Dubai, Dubai-Istanbul, Istanbul-Amsterdam.

It is the practice of Martinair to detail captains in command of new operations after adequate pre-flight briefing in respect of the route and facilities. In this instance, another Captain (B) had orally briefed the Pilot-in-command on 1 December 1974. The Pilot-in-command also inquired from a third Captain (C) a couple of hours before departure about the route, flight preparation, ground services, hotels, etc.

Captain (B) stated that such inquiries are usual and are not indicative of lack of familiarity with the route. It was further stated by Captain (B) that this type of briefing is a normal practice amongst airline pilots.

In view of the fact that the Pilot-in-command sought further information from Captain (C) this investigation is unable to arrive at a definite conclusion as to whether he had sufficient familiarity with the route.

The co-pilot whose normal position is in the right hand seat was observed in the right hand seat prior to departure. As such he would have carried out radio-communications and navigation under the supervision of the Pilot-in-command.

As for the co-pilot, this was his first flight on this route and in this region and he had only a very limited number of hours of experience on the type. It is relevant to note that of his total of 2 240 flying hours as co-pilot, 47 hours were on the DC-8, and the 47 hours on the DC-8, 24 hours 05 minutes had been flown by him in the capacity of supernumerary crew. His co-pilot endorsement on the DC-8 had a restriction for crosswind landing which is the normal procedure adopted in granting a new type rating in the Kingdom of the Netherlands. His lack of familiarity with the route is supported by the fact that he failed to comply with the requested reporting points. On this flight the crew reported at 92°E/85°E/Over the Coast, whereas the requested reporting points since 20 November 1974 were 92°E/88°E/84°E/Over the Coast.

It is relevant to note here that the failure on the part of the Pilot-in-command to correct the co-pilot as regards the reporting points, leads to the conclusion that the Pilot-in-command was unaware of the correct reporting points. The Colombo HFRT Control requested the aircraft to call Area Control on VHF giving the correct frequency (119.1 MHz). This message was received by the aircraft and the co-pilot contacted Approach Control on a different frequency (119.7 MHz) whereon Approach Control having passed on the weather, requested the aircraft to contact Area Control for descent clearance on the frequency 119.1 MHz. By way of confirmation the co-pilot repeated the wrong frequency (119.7 MHz) and once again Colombo Approach Control had to repeat the correct frequency.

Crew fatigue

During the 24 hours preceding the accident the crew had flown approximately five hours. Crew fatigue has no bearing on the cause of the accident.

Operational requirements

It is customary to conduct route checks on flight crew who are due to fly on routes new to them prior to their being detailed as crew as per Annex 6 to the Convention on International Civil Aviation. It is observed that procedures set out in Annex 6, Part I, to the Convention had not been strictly adhered to. Martinair adopted procedures of employing freelance captains who have world-wide experience by ascertaining their proficiency on the simulator and by flying captains as co-pilots on regular flights. However, it is worthy of note that even in these instances no written records have been maintained by Martinair "when no problems or deficiencies were apparent". It is also of interest to note that subsequent to this accident a new system has been adopted wherein route reports and route checks are carried out and records maintained by Martinair.

Operation and maintenance at Surabaya

Maintenance

Maintenance at Surabaya was carried out by Garuda ground engineers holding KLM licences. The statement of an official of the Operations Division of the Netherlands Civil Aviation dated 21 January 1975 states inter alia that "The technical servicing at Surabaya did not lead to complaints from the side of most pilots and flight engineers, although some critical remarks have been made". The view was expressed that the words "technical servicing" were the subject matter of the critical remarks made, and that this could be interpreted as a reference to the delay in the supply of spare parts to rectify defects which would not make it essential to ground the aircraft. Some of the Technical Log slips were examined which indicated that certain defects had not been put right prior to subsequent flights due to lack of spare parts. These defects according to the Aircraft Operations Manual (AOM) are items which could be allowed to remain unrectified after consultation between crew and ground engineer. Statements made by two Captains and a Flight Engineer indicate that they have no remarks to make in respect of technical servicing at Surabaya.

Operations

A few points worthy of record are the lapses regarding flight preparation documentation and maintenance documentation. The Golden Copy of the Technical Log and all copies of the Loadsheet and Navigational Flight Plan were destroyed with the aircraft due to the failure to retain copies as required at the base at Surabaya.

The fact that no maintenance records after 1 December 1974 and no navigational documentation relevant to this flight are available as the officers concerned failed to carry out this part of their duties, points in the direction of negligence on the part of officers responsible for the organization at Surabaya prior to this flight.

Peculiarities of PH-MBH

Doppler system

Martinair took delivery of PH-MBH and in keeping with their maintenance practice the aircraft was handed over to KLM for maintenance and standardization in conformity with the KLM fleet. On the information made available to this investigation the following facts could be established. PH-MBH on delivery to Martinair was equipped with a Bendix Doppler System which was off-standard to the KLM DC-8 fleet.

To meet the operational requirements a KLM Standard Marconi Doppler Computer Indicator had to be built in. This had been accomplished. An Aeronautical Inspector of the Department of Civil Aviation of the Netherlands investigated the Doppler System on PH-MBH. As per extract of translation of his report, reproduced below, the system functions as follows:

> "During cockpit standardization of PH-MBH, the Doppler control panels - Doppler computer control panels and the ground speed and drift indicators are relocated by means of modification order No. 34-153B, to standardize the PH-MBH cockpit to the KLM configuration. The Doppler system, originally installed in the PH-MBH has been manufactured by the Bendix Corporation, while the KLM aircraft are equipped with Doppler systems of Canadian Marconi. Because of the different presentation between the two systems, operational difficulties arise.
>
> An operational requirement was the installation of a Doppler computer indicator. To meet this requirement, a KLM standard Canadian Marconi Doppler computer indicator has been built in. This indicator, connected into a Bendix Doppler computer system, does not give a correct indication on the "distance to go" counter as a result of technical differences between the Canadian Marconi and Bendix systems. Now the "distance to go" counter of the Canadian Marconi indicator counts in steps of 100 NM instead of the normal steps of 1 NM.
>
> In the aircraft Operations Manual, it is noted that the "distance to go" counter of the Doppler computer indicator is not active.
>
> It can be been also that the "distance to go" must be read on the computer controller panel, on the counter labelled "Miles to go".
>
> To avoid misunderstanding, miles stated for nautical miles."

In this connexion a translation of a letter from the Chief, Electrical and Electronic Systems Group of KLM Central Engineering Department, is also reproduced below:

> "With reference to your letter of 5th April 1974, I inform you that a Doppler Computer Indicator has been installed in the PH-MBH. Because the D.C.I. is from another make, it does not function fully in the Bendix Doppler system. As a result of this the "Distance to Go" presentation on the indicator cannot function properly.

> The three-disks-counter of the indicator is directed by the 100-miles counterdisk of the computer. Therefore only the 100-miles indication is correct; the positions of the ten and one mile indicator disks are more or less arbitrary.
>
> The choice between disconnexion of this counter and the present incomplete indication has been determined by the consideration that with the configuration chosen now the chance of misinterpretation is the smallest.
>
> The deviation from the normal indicator presentation has been reported on the aircraft's "list of special items", and the crews have been informed by means of the AOM (Aircraft Operations Manual)."

According to the above statement by the Chief, Electrical and Electronic Systems Group the chance of misinterpretation is the smallest. The corrective action in respect of this anomaly has been the inclusion of item 7 in the Cockpit Briefing Card, which document is not available. Special instructions in this regard pertaining to PH-MBH had also been incorporated in Volume I of the Aircraft Operations Manual in the form of yellow pages IA and 2A in part 1.15.5. On page IA under the illustration of the Doppler Computer Indicator the following remark is made "Distance-to-go not active".

The extracts of the Tech Log Slips made available to this investigation show that on two occasions the flight crew observed that the "distance-to-go" counter on the Doppler Computer Indicator was faulty. The subsequent corrective action the engineers took was to refer them back to the Briefing Card. This leads us to the conclusion that these flight crews were ignorant of the deviation in the Doppler System.

It is observed that 42 Tech. Log slips within the period 1 August 1974 to 1 December 1974 are missing. It is possible that in these extracts there may have been references to deficiencies in the Doppler System.

In view of the foregoing it is the opinion of this investigation that it would have been more appropriate to have the "Distance-to-go Digital Indicator", on the Doppler Computer System on PH-MBH masked out so that the chances of flight crew misinterpretation would have been completely eliminated. In the flight in question, the confirmation of the co-pilot of his distance in no uncertain terms as "One Three Zero" and "One Four" points in the direction of his having relied for the greater part on the "distance-to-go" digital counter.

Having regard to the above facts this investigation rejects the opinion of the Chief, Electrical and Electronic Group that "the chance of misinterpretation is the smallest" and concludes that the "distance-to-go" presentation on the Doppler Computer Indicator was confusing and consequently the chances of misinterpretation were the greatest.

Weather radar

The flight crew had the alternative of checking their distance by the use of the Weather Radar on board the aircraft. This would mean that the indication they obtained would have been more or less confined within a limit depending on the range selected on the Weather Radar.

It would have been possible for the flight crew to have cross-checked their Doppler "Miles-to-go" Indicator by use of the Weather Radar to interpret the coastline. Here, too, the possibility of misinterpretation of an overlapping cloud giving an advanced simulation of the coastline cannot be discounted.

The report of the Aeronautical Inspector of the Department of Civil Aviation of the Netherlands, which sets out the peculiarities of the Weather Radar System on the PH-MBH is reproduced below:

"During the cockpit standardization programme of the PH-MBH to the KLM standard configuration, the weather radar system has been modified so that the existing PPI indicator has been relocated from the forward pedestal to the left hand gusset panel, the control panel from the forward pedestal to the aft pedestal and an additional PPI indicator has been installed on the right hand gusset panel. This modification is described in modification order M.O. 34-151B.rev.1.

The modified system now consists of the following units:

One transceiver type RDR-1E Bendix PN 2067 157-0101

One control panel Cable PN G 2424

Two PPI indicators type IGT Bendix PN 2085268-0108

One antenna type 1P-B Bendix PN 2087181-0501

This type of transceiver includes synchronizer and power supply which can be a separate unit in other systems.

Despite standardization, there are still some operational differences between the standard KLM DC-8-50 series installations and the PH-MBH, which mainly lie in the application of the PPI indicator type IGT, because there are more controls on the PPI type IGT and also the range markers are different.

The Aircraft Operations Manual describes exactly how the system can be switched on.

No remarks are given in the AOM with respect to differences in range markings. The KLM DC-8-50 series is normally equipped with PPI indicators type ID. The differences between the two types of indicators with respect to range markings are summarized in the following table.

KLM standard DC-8-50 Series PPI - ID			PH-MBH PPI - IGT		
Range nautical miles	Number of range marks	Nautical miles per range mark	Range nautical miles	Number of range marks	Nautical miles per range mark
20	4	5	30	3	10
50	5	10	80	4	20
150	6	25	180	6	30

With the value of the selected range and associated range mark increments in mind (both are indicated on the range selector switch) no difficulties can be expected with respect to distance interpretation of a displayed object. When, as a result of a lot of experience with the KLM standard system operation, selections are made on the basis of the number of range marks displayed, the supposed distance can be in error by a factor 4 of the selected value in the case of selection of a 4 range mark display.

With respect to weather radar complaints only four aircraft maintenance logs are written from the date of installation till 22 October 1974. The nature of the technical troubles as well as the number of these troubles do not enable us to discover a specific trend of the malfunctions.

Conclusions

No difficulties can be expected in the operation of this off-standard system when the crew is familiar with the instructions given in the AOM. Additional remarks in the AOM with respect to differences, in range marks and range selection is recommended.

Captain (B) made the following statement on the operational details of the Weather Radar System on PH-MBH. "The Bendix Radar on this aircraft was fitted out with a Plan Position Indicator (PPI) of the daylight type which gives a much clearer picture than the Marconi PPI. The mapping feature of this radar set is very effective and in this connexion prominent terrain features such as lakes, rivers, mountains and coastlines may also be monitored as navigational aids".

The possibility of the pilot-in-command having cross-checked the reading on the "Miles-to-go" indicated in the Doppler System with the presentation on the Weather Radar Screen was considered. In view of the fact that:

a) the Weather Radar System was off-standard,

b) no instructions had been laid down in the Aircraft Operations Manual with respect to differences in the range markings from the standard,

this investigation concludes that such a cross-check, if done, would have been misleading. In the event of his having been aware of the deviation from the standard, there is the possibility that the Pilot-in-command and the co-pilot misinterpreted the range markings on the Weather Radar Screen.

This investigation assumes that the Weather Radar System was fully serviceable at the commencement of this flight since in the opinion of Captain (B) serviceable radar is essential on this route.

Possibilities of position determination

On this flight there were in theory two possibilities available to the crew to determine their position in relation to the Bandaranaike International Airport, after the initiation of the descent. One was taking ADF bearings on two Radio Beacons, and the other was a reading from the Doppler system combined with an interpretation of the presentation on the Weather Radar Screen.

With regard to the first possibility, the pilot could have taken an ADF bearing from the Katunayake and China Bay Non-Directional Beacons. If the crew relied on these beacons, in spite of the beacons being serviceable, the bearings thus obtained would not prove accurate on account of the prevailing meteorological conditions and terrain. Moreover at this stage of the flight it is not the practice nor is it practicable to do so.

Therefore this investigation concludes that the crew would have relied for the greater part on the second possibility.

3.- Conclusions

This investigation concludes that:

1) the Pilot-in-command held a valid licence with a valid type rating. He had considerable experience on the type in general and sufficient experience on the PH-MBH in particular.

2) the Pilot-in-command had no recent experience on this route.

3) the Pilot-in-command had been briefed on this route prior to departure.

4) no proper route check had been carried out prior to permitting the Pilot-in-command to fly on this route; certain provisions of Chapter 9, 9.4 of Annex 6, Part I, to the Convention on International Civil Aviation had not been strictly complied with.

5) the co-pilot held a valid licence with a valid type rating subject to a restriction for crosswind landing which is usual in the Netherlands.

6) the co-pilot had little experience on the type in general and no experience on PH-MBH in particular.

7) the co-pilot had no previous experience on the route.

8) the Doppler Computer System was off-standard to the Martinair DC-8 fleet and left room for misinterpretation of the "distance-to-go" presentation by the crew.

9) the Weather Radar System was off-standard to the Martinair DC-8 fleet and no instructions had been included regarding this in the Aircraft Operations Manual, thus leaving room for misinterpretation of the range-markings on the screen by the crew.

10) there are indications that the crew relied for the greater part on the Doppler System to determine their "distance-to-go".

11) there were shortcomings on the part of Martinair in the maintenance of Technical Records pertaining to aircraft, and to cockpit personnel in respect of route qualification.

12) the officers responsible for the organization at Surabaya pertaining to this flight displayed a certain degree of negligence in that they failed to retain copies of maintenance records and navigational documentation relevant to this flight.

13) the Pilot-in-command and co-pilot were unaware of the correct reporting points in the Colombo Flight Information Region.

14) there are no indications of a major pre-crash failure of the aircraft or of its systems, nor of any pre-crash fire.

3.1 Cause or Probable cause(s)

This accident occurred following collision with rising terrain as the crew descended the aircraft below safe altitude owing to incorrect identification of their position vis-à-vis the Airport. This investigation is of the opinion that this was the result of dependence on Doppler and Weather Radar Systems on board PH-MBH which left room for misinterpretation.

4.- Recommendations

This investigation recommends that:

i) indicators which are not fully accurate be masked;

ii) cockpit crew be briefed in detail about all off-standard instrumentation;

iii) regardless of experience of cockpit crew, charter operators ensure that route checks are carried out prior to detailing cockpit crew on sustained operations on a new route;

iv) charter operators ensure that operating cockpit crew demonstrate an adequate knowledge of the route to be flown and aerodromes which are to be used in terms of Chapter 9, 9.4.3.2 of Annex 6, Part I, to the Convention;

v) ground operations personnel of operators be adequately briefed regarding their responsibilities.

COMMENTS OF THE STATE OF REGISTRY

The Netherlands Aircraft Accident Investigation Board heard the case in a public session on 16 March 1977. In paragraph 6 "Analysis and Conclusions" of its findings the Board came to conclusions which on some points differ from those in the Sri Lanka report:

"6. Analysis and Conclusions

The Board notes with deep regret that so many people lost their lives in this aircraft accident.

The Board wishes to express its appreciation and thanks for the co-operation given by the Sri Lankan aviation authorities in the preliminary investigation.

On the basis of the facts established in the preliminary investigation the Board is of the opinion that the aircraft was in an airworthy condition until the accident took place, and that the engines were functioning normally. There is no evidence that the weather conditions were a contributory factor to the accident.

There are not sufficient grounds to assume that the pilot-in-command or the co-pilot were under stress or fatigued, or that they were unacquainted with important information.

All the evidence assembled in the investigation indicates that the necessary conditions for a good safe flight were met. From the evidence on the flight and the radio communications between the crew and Sri Lanka Air Traffic Control the Council concludes that an error occurred during navigation as a result of which the crew was convinced that the aircraft was 30 to 35 NM closer to Bandaranaike Airport than it actually was. It reported "14 miles out", although the actual distance then must have been almost 50 NM. This position report shows the crew had the erroneous idea that the mountainous area had been passed and that the descent below the appropriate minimum altitude for that region could be started safely.

The Board is unable to establish what caused this navigational error. After passing Bengkulen NDB on Sumatra there were no beacons or other devices available to establish positions during the crossing of the Indian Ocean other then the "distance to go" counters of the Doppler computer controllers. There is no doubt that upon approaching the Sri Lankan coast the crew would have re-established their position by means of the weather radar on board.

On the radar screen the distance to the coast line could be measured by means of the distance markings. The maximum range of the weather radar aboard the aircraft was 180 NM; when this range was set the distance between the markings represented 30 NM.

These values differ from those on the radar screens installed in the other DC-8 55 aircraft operated by Martinair; their maximum range was 150 NM and the distances between the markings, when set to this range, represented 25 NM.

These characteristics of this type of weather radar, although not mentioned in the Aircraft Operations Manual, were brought to the attention of the flight crews - as stated during the investigation; moreover, the instrument itself displayed both the range and the value of the distance markings. The extent to which these were visible, however, depended on the setting of the light intensity.

Nevertheless, the possibility cannot be excluded that the pilots did not realize these differences, and as a result of this misinterpreted the indications on the radar screen. From the preliminary investigation it was learned that when the aircraft was at distances of 160 and 80 NM from the airport, misinterpretation could have led to the incorrect assumption that the distances were 130 and 50 NM respectively; these were precisely the two positions that were reported.

It can be assumed that the pilots adjusted the "distance to go" counters to agree with their interpretation of the readings on the radar screen where the two readings were different.

A continuous error of about 30 NM affected the remainder of the flight. The accuracy of the position report "14 miles out" shows that the crew relied upon the indications of the "distance to go" counters.

Despite this navigational error, it is certain that this accident could have been avoided. No beacon was available for the flight over Sri Lanka except the Bandaranaike NDB.

In view of this limitation in ground facilities, the safe course of action would have been to pass the airport overhead at a safe altitude and after passing the beacon to continue the descent over the sea.

However, it is evident that the crew fully relied upon the navigation equipment on board.

Summarizing, the Board concludes that the accident was the result of a navigational error. The Board considers it possible that the error was encouraged by the non-standard weather radar equipment of the aircraft. Moreover, the accident could have been avoided by flying over the airport NDB at a safe altitude and then descending over the sea.

The Board notes with satisfaction that this approach procedure has now been laid down in the operating regulations of Martinair for similar flights.

Since September 1976 the installation of a Ground Proximity Warning System has been obligatory in certain types of transport aircraft registered in the Netherlands, and this may help to avoid air disasters like this in the future."

ICAO Ref.: AIG/435/74

No. 22

Eastern Air Lines, Boeing 727-225, N-8845E, accident at New York/J.F. Kennedy, U.S.A., on 24 June 1975. Report No. NTSB-AAR-76-8, dated 12 March 1976, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

On 24 June 1975, Eastern Air Lines Flight 66, a Boeing 727-225, N-8845E, operated as a scheduled passenger flight from New Orleans, Louisiana, to New York, New York. The flight departed New Orleans about 1319 EDT[1/] with 116 passengers and 8 crew members aboard. It proceeded to the John F. Kennedy International Airport, Jamaica, New York, on an instrument flight rules (IFR) flight plan.

Eastern 66 arrived in the New York City terminal area without reported difficulty, and, beginning at 1535:11, Kennedy approach control (Southgate arrival controller) provided radar vectors to sequence the flight with other traffic and to position it for an instrument landing system (ILS) approach to Runway 22L at the Kennedy Airport. The flight had received a broadcast on the automatic terminal information service (ATIS), which gave in part the 1251 Kennedy weather observation and other data as follows: "Kennedy weather, VFR, sky partially obscured, estimated ceiling 4 000 broken, 5 miles with haze... wind 210° at 10, altimeter 30.15. Expect vectors to an ILS Runway 22L, landing Runway 22L, departures are off 22R..."

At 1551:54, the Southgate arrival controller broadcast to all aircraft on his frequency, "... we're VFR with a 5-mile, light, very light rain shower with haze, altimeter check 30.13 ... It's ILS 22L, also". At 1552:43, the controller transmitted, "All aircraft this frequency, we just went IFR with 2 miles very light rain showers and haze. The runway visual range is --- not available, and Eastern 66 descend and maintain four thousand, Kennedy radar one three two four". Eastern 66 acknowledged the transmission.

Eastern 66 was one of a number of aircraft that were being vectored to intercept the ILS localizer course for Runway 22L. At 1553:22, the flight contacted the Kennedy final vector controller who continued to provide radar vectors around thunderstorms in the area, to sequence the flight with other traffic, and to position the flight on the localizer course. About 1557:21, the flight crew discussed the problems associated with carrying minimum fuel loads when confronted with delays in terminal areas. One of the crew members stated that he was going to check the weather at the alternate airport, which was LaGuardia Airport, Flushing, New York. Less than a minute later, one of the crew members remarked, "... one more hour and we'd come down whether we wanted to or not". At 1559:19, the final vector controller transmitted a message to all aircraft on his frequency that "a severe wind shift" had been reported on the final approach and that he would report more information shortly.

1/ All times herein are eastern daylight based on a 24-hour clock.

Eastern Air Lines Flight 902, a Lockheed 1011, had abandoned its approach to Runway 22L at 1557:30. At 1559:40, Eastern 902 re-established radio communications with the Kennedy final vector controller, and the flight crew reported, "... we had ... a pretty good shear pulling us to the right and ... down and visibility was nil, nil out over the marker ... correction ... at 200 ft it was ... nothing". The final vector controller responded, "Okay, the shear you say pulled you right and down?" Eastern 902 replied, "Yeah, we were on course and down to about 250 ft. The airspeed dropped to about 10 kt below the bug and our rate of descent was up to 1 500 ft a minute, so we put take-off power on and we went around at a hundred feet".

Eastern 902's wind shear report to the final vector controller was recorded on Eastern 66's cockpit voice recorder (CVR). While Eastern 902 was making this report, the pilot-in-command of Eastern 66, at 1600:33, said, "You know this is asinine". An unidentified crew member responded, "I wonder if they're covering for themselves".

The final vector controller asked Eastern 66 if they had heard Eastern 902's report. Eastern 66 replied, "... affirmative". The controller then established the flight's position as being 5 miles from the outer marker (OM) and cleared the flight for an ILS approach to Runway 22L. Eastern 66 acknowledged the clearance at 1600:54.5, "Okay, we'll let you know about the conditions". At 1601:49.5, the co-pilot, who was flying the aircraft, called for completion of the final check-list. While the final check-list items were being completed, the pilot-in-command stated that the radar was, "Up and off... stand-by". At 1602:20, the pilot-in-command said, "... I have the radar on stand-by in case I need it, I can get it off later".

At 1602:42, the final vector controller asked Eastern 902, "... would you classify that as severe wind shift, correction, shear?" The flight responded, "Affirmative".

At 1602:50.5, the co-pilot of Eastern 66 said, "Gonna keep a pretty healthy margin on this one". An unidentified crew member said, "I ... would suggest that you do"; the co-pilot responded, "In case he's right".

At 1602:58.7, Eastern 66 reported over the OM, and the final vector controller cleared the flight to contact the Kennedy tower. At 1603:12.4, the flight established communications with Kennedy tower local controller and reported that they were, "outer marker, inbound". At 1603:44, the Kennedy tower local controller cleared Eastern 66 to land. The pilot-in-command acknowledged the clearance and asked, "Got any reports on braking action ...?" The local controller did not respond until the query was repeated. At 1604:14.1, the local controller replied, "No, none, approach end of runway is wet ... but I'd say about the first half is wet -- we've had no adverse reports.

At 1604:45.8, National Air Lines Flight 1004 reported to Kennedy tower, "By the outer marker" and asked the local controller, "... everyone else ... having a good ride through?" At 1604:58.0, the local controller responded, "Eastern 66 and National 1004, the only adverse reports we've had about the approach is a wind shear on short final ..." National 1004 acknowledged that transmission - Eastern 66 did not.

Both flight attendants who were seated in the aft portion of the passenger cabin, described Eastern 66's approach as normal - there was little or no turbulence. According to one of the attendants, the aircraft rolled to the left, and she heard engine power increase significantly. The aircraft then rolled upright and rocked back and forth. She was thrown forward and then upright; several seconds later she saw the cabin emergency lights come on and oxygen masks drop from their retainers. Her next recollection was her escape from the wreckage.

Witnesses near the middle marker (MM) for Runway 22L saw the aircraft at a low altitude and in heavy rain. It first struck an approach light tower which was located about 1 200 ft southwest of the MM; it then struck several more towers, caught fire, and came to rest on Rockaway Boulevard. Initial impact was recorded on the CVR at 1605:11.4. The accident occurred during daylight hours at 40° 39' N latitude and 73° 45' W longitude.

Five witnesses located along the localizer course, from about 1.6 miles from the threshold of Runway 22L to near the MM, described the weather conditions when Eastern 66 passed overhead as follows: heavy rain was falling and there was lightning and thunder; the wind was blowing hard from directions ranging from north through east.

Persons driving on Rockaway Boulevard stated that a driving rainstorm was in progress when they saw the aircraft hit the approach light towers and skid to a stop on the Boulevard. Persons located about 0.6 miles south of the accident site stated that no rain was falling at their location when they saw the crash. They stated that the visibility to the northeast was good, but that visibility to the north was reduced. Persons who were in the north and northwest areas of the airport between 1555 and 1600 stated that heavy rain was falling; one stated that a violent wind was blowing from the northwest.

Flying Tiger Line Flight 161, a DC-8, had preceded Eastern 902 on the approach and had landed on Runway 22L about 1556:15. After clearing the runway, at 1557:30, the pilot-in-command reported to the local controller: "I just highly recommend that you change the runways and ... land northwest, you have such a tremendous wind shear down near ... the ground on final". The local controller responded, "Okay, we're indicating wind right down the Runway at 15 kt when you landed". At 1557:50, the pilot-in-command of Flight 161 said, "I don't care what you're indicating; I'm just telling you that there's such a wind shear on the final on that runway you should change it to the northwest". The local controller did not respond. At 1557:55, he transmitted missed approach directions to Eastern 902 and asked "... was wind a problem?" Eastern 902 answered, "Affirmative".

The pilot-in-command of Flying Tiger 161 stated that during his approach to Runway 22L he entered precipitation at about 1 000 ft2/, and he experienced severe changes of wind direction, turbulence, and downdraughts between the OM and the airport. He observed airspeed fluctuations of 15 to 30 kt and at 300 ft he had to apply almost maximum thrust to arrest his descent and to strive to maintain 140 kt on his inertial navigation system ground speed indicator. The aircraft began to drift rapidly to the left, and he eventually had to apply 25° to 30° of heading correction to overcome the drift. He believed that the conditions were so severe that he would not have been able to abandon the approach after he had applied near maximum thrust, and therefore he landed.

The pilot-in-command of Eastern 902 states that on his approach to Runway 22L he flew into heavy rain near 400 ft. The indicated airspeed dropped from about 150 kt to 120 kt in seconds and his rate of descent increased significantly. The aircraft moved to the right of the localizer course, and he abandoned the approach. He was unable to arrest the aircraft's descent until he had established a high nose-up attitude and had applied near maximum thrust. He thought the aircraft had descended to about 100 ft before it began to climb.

2/ All altitudes herein are mean sea level.

Two aircraft, Finnair Flight 105, a DC-8, and N-240V, a Beechcraft Baron, followed Eastern 902 on the approach. Their pilots stated that they also experienced significant airspeed losses and increased rates of descent. However, they were able to cope with the problem because they had been warned of the wind shear condition and had increased their airspeeds substantially to account for the condition. Neither pilot reported the wind shear conditions; one pilot stated that he did not report the wind shear because it had already been reported and he believed that the controllers were aware of the situation.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	6	106	-
Non-fatal	2	10[3/]	-
None	-	-	

1.3 Damage to aircraft

The aircraft was destroyed.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

The aircraft was certificated, equipped, and maintained in accordance with regulations and approved procedures. There was no evidence of a malfunction or failure of the aircraft or its components that would have affected its performance.

All three engines were operating normally until impact. The presence of debris within the eighth-stage compressor bleed air systems and the absence of debris within the thirteenth-stage bleed air systems indicates that the Nos. 2 and 3 engines were operating at engine pressure ratios of about 1.20 or more at the time the debris was ingested into the engines. The damage to the fan blades and compressor section on the No. 1 engine was consistent with a high-power setting at impact.

The flight crew was certificated properly and each crew member had received the training and off-duty time prescribed by regulations. There was no evidence of medical or physiological problems that might have affected their performances.

It is clear from surface weather reports, weather radar data, and witness and pilot statements that a large area of very strong thunderstorms accompanied by strong, variable, and gusty surface winds was moving rapidly along the northern perimeter of Kennedy Airport between 1540 and 1620. The storm area was moving east-southeasterly, and about 1550 it began to seriously affect safe approach operations to Runway 22L. Although

3/ One of the passengers who is listed as having non-fatal injuries died 9 days after the accident. Since 49 CFR 830.2 defines "fatal injury" as one that results in death within 7 days of the accident, this passenger's injuries are listed as non-fatal.

the weather along the final approach course to that runway deteriorated rapidly from about 1550 to the time of the accident, the approach paths to the northwest runways remained relatively unaffected by the storms. Significant clues (both visual and radar) were available to air traffic controllers and flight crews alike to indicate the existence of these conditions on and near Kennedy Airport.

Given the above circumstances, two causal aspects of this accident require discussion and analysis: 1) The weather hazards that existed along the approach path to Runway 22L and how they affected Eastern 66, and 2) the reason or reasons why approach operations to Runway 22L were continued even though the thunderstorms along the final approach course were evident and hazardous wind conditions had been reported.

How thunderstorms affected Eastern 66

Air flow is disturbed significantly within a mature thunderstorm cell and in the air mass surrounding the cell. These disturbances are dominated generally by vertical draughts, both up and down, which are created when the relatively cold and more dense air formed at higher altitudes displaces the warmer and less dense air near the surface. The downdraughts, which are frequently accompanied by heavy rain, can reach vertical speeds exceeding 30 fps. The interaction between the descending air and the earth's surface causes the flow to change from the vertical direction to the horizontal direction and creates a horizontal outflow of air in all directions beneath the cell and near the surface. The speeds of the vertical draughts and horizontal outflows depend on the severity of the storm. An aircraft passing through, below, or near a thunderstorm cell at low altitude may encounter these rapidly changing vertical and horizontal winds.

To analyse the effects of these rapidly changing winds on the flight path of an aeroplane, forces which act on the aeroplane must be considered. These forces are lift, drag, weight, and thrust. In a dynamic situation, changes in the lift and drag are most significant because they depend at any instant on the aeroplane's relative wind vector; that is, the direction and speed of the impinging air stream relative to the aeroplane's control axes. The aeroplane's weight can be considered a constant since it varies only as fuel is consumed. Thrust is related primarily to throttle position and only to a small extent to the properties of the engine inlet air.

The analysis is simplified by resolving the components of these forces along the aircraft's vertical and longitudinal axes. As long as the components of the forces are balanced, the aeroplane will remain in unaccelerated flight. However, if the forces are unbalanced, by the pilot's manipulation of the throttles or flight controls or by a change in the environment surrounding the aeroplane, the aeroplane will accelerate or decelerate until a new flight path is established and the forces are again balanced.

When the aeroplane flies into a vertical wind, the transient change in the direction of the total wind vector, relative to the aeroplane's entry path, causes a change in both lift and drag. If the vertical wind's direction is downward, the lift and drag will decrease and the aeroplane will accelerate downward. The basic stability of the aeroplane will cause it to pitch nose-up initially; however, the ultimate effect on the aeroplane's flight path will be an increase in the descent rate relative to the ground. If the flight controls remain fixed, the aircraft will restabilize and descend with the descending air mass. Thus, the change in the aeroplane's rate of descent relative to the ground will equal the vertical speed of the wind and, if longitudinal wind does not change, the airspeed will remain approximately constant. The pilot can compensate for this condition by increasing the aeroplane's pitch attitude and by adding thrust to establish a climb relative to the descending air mass. He will thereby maintain the desired flight path.

When an aeroplane flies into an area where the direction of the horizontal wind changes abruptly, the indicated airspeed will change. The change is equivalent to the abrupt change in the relative wind. Both lift and drag will also change abruptly and thus produce an imbalance in the forces acting along the aeroplane's longitudinal and vertical axes.

If the aeroplane flies into an increasing head wind or a decreasing tail wind, the speed of the relative wind will increase. The indicated airspeed, lift, and drag will increase; the nose of the aeroplane will pitch up; and the vertical speed will change in the positive direction. If the wind speed continues to change, the aeroplane will appear to have a positive increase in its performance. When the wind speed stabilizes, if thrust has not been changed, the longitudinal forces will be unbalanced because of the increased drag. The aeroplane will decelerate and eventually will return to equilibrium at its original airspeed. The pilot might react to the initial airspeed increase by reducing thrust. If he does, the thrust must be reset to prevent the aeroplane for decelerating to an airspeed lower than the original airspeed. When equilibrium is regained, however, the aeroplane's speed relative to the ground will have been changed by the amount of the change in the longitudinal wind component.

If the aeroplane flies into a decreasing head wind or an increasing tail wind, the effect will be opposite. The indicated airspeed will decrease, lift will decrease, the aeroplane's nose will pitch down, and the vertical speed will change in the negative direction.

An aeroplane that is approaching to land is generally operated in a high-drag configuration but at an airspeed near that at which minimum drag for that configuration is produced. Therefere, an abrupt decrease in airspeed may not cause a significant reduction in drag, and drag may even increase. Under such conditions, the only imbalance in the longitudinal forces which will cause the aeroplane to return to equilibrium is that change in the longitudinal component of weight produced by the change in the aeroplane's pitch attitude. Consequently, the increased descent rate which is developed will continue until the aeroplane responds to positive actions from the pilot.

The pilot must exert back pressure on the control column to bring the nose of the aeroplane up, and he must increase thrust. These actions will increase lift to decrease the descent rate and simultaneously produce the longitudinal force needed to accelerate the aeroplane to a safe flying speed.

The severity of the effects produced by an encounter with a decreasing head wind will depend on the magnitude of the change in wind speed and the abruptness with which the change occurs. Obviously, the higher the speed change and the shorter the time interval involved, the greater the effect on the aeroplane's flight path.

Other significant factors include the aeroplane's entry airspeed, its configuration, and its flight characteristics under such conditions. For example, a jet transport which encounters the wind change at an indicated airspeed of 155 kt will experience less loss of lift and will develop a lower initial descent rate than the same aeroplane which encounters the condition at 140 kt. Also, a smaller aircraft, with a lower wing loading, and operating with a higher relative airspeed margin between approach and stall speeds, will likely be less affected than the large transport. Therefore, the pilot of a jet transport who flies at a higher-than-normal approach speed and the pilot of a small aeroplane who flies at a normal approach speed may be able to stop the rate of descent imposed on their aircraft quicker, with lower control forces, and with less thrust addition than the pilot of a jet transport who flies at normal approach speed.

As illustrated above, passage through either a downdraught or a decreasing head wind can be singularly hazardous; however, when combined, the two conditions produce an even more critical situation. A mature thunderstorm cell contains both. As the aeroplane approaches the storm, it encounters the influence of the horizontal outflow in the opposite direction of flight as an increasing head wind; as the flight continues, it passes below the storm and through the peak downdraught. Almost immediately, the change in direction of the horizontal outflow will affect the aircraft as an abrupt decrease or loss of head wind. The sequence of the wind change can be particularly dangerous since the pilot might reduce power when he senses the positive performance effect caused by the initially increasing head wind. Therefore, the aeroplane may already be power deficient when it encounters the downdraught and loss of head wind; thus, their negative effect on the aeroplane's performance is compounded.

The Safety Board concludes from the evidence that Eastern 66 and at least four of the flights which preceeded it encountered abrupt changes in the vertical and horizontal winds on the approach path to Runway 22L.

When Eastern 66 was tracking the glide slope near the OM, the aeroplane was affected by a slight head wind and little or no vertical winds. While the aeroplane descended and approached the strongest cells of the thunderstorm, it was influenced by the vertical winds and the horizontal outflow. The increase in head wind of about 15 kt and possibly an updraft produced a reduction in the rate of descent and the aeroplane moved slightly above the glide path as it descended between 600 ft and 500 ft. When the flight descended through 500 ft, about 8 000 ft from the runway threshold, the aeroplane was passing into the most severe part of the storm. The vertical draft changed to a downdraught of about 16 fps and the head wind diminished about 5 kt. As the aeroplane descended through 400 ft, the downdraught velocity increased to about 21 fps and the aeroplane began to descend rapidly below the glide slope. Almost simultaneously, the change in the direction of the horizontal outflow produced a 15 kt decrease in the aeroplane's head wind component, which caused the aeroplane to lose more lift and to pitch nose-down. Consequently, the descent rate increased.

The wind conditions encountered by Flying Tiger 161, Eastern 902, Finnair 105, and N-240V were similar but possibly less severe than those encountered by Eastern 66. All of these flights managed to negotiate the conditions without mishap, but not without difficulty. The pilot-in-command of Flying Tiger 161 stated that after he recognized the shear he needed near maximum thrust to keep his aircraft from losing altitude. At that point, he was not sure of his aircraft's missed-approach capability and he had to continue to a landing.

The pilot of Eastern 902 had no forward visibility when he penetrated the area of the most severe wind changes. Therefore, he was flying his aircraft solely by reference to flight instruments. It is obvious from the DFDR traces that he immediately recognized the downward acceleration of his aircraft and responded with the addition of thrust and nose-up pitch changes. Nevertheless, the aircraft descended about 120 ft below the glide slope and within about 70 ft of the elevation of the approach lights.

The pilot of Finnair 105 anticipated the adverse wind conditions and added 20 to 25 kt to his normal approach reference airspeed. Although he too experienced an increase in the rate of descent as a result of the downdraught and horizontal wind changes, the total effect and control corrections required to decrease the rate of descent were probably lessened by the higher airspeed. The pilot apparently detected the effect of the wind and responded rapidly to maintain flight path control.

Likewise, the pilot of N-240V, a Beechcraft Baron, was able to limit the altitude loss caused by the wind conditions with less difficulty because of the different flight characteristics of his smaller aircraft and because he was flying it at a higher-than-normal approach speed.

The flight crew of Eastern 66 was made aware of the adverse wind conditions by Eastern 902's report on wind shear, and they, too, added 10 to 15 kt to their normal approach reference speed. Both theory and simulator test results indicate that increasing final approach airspeed is advantageous when an aircraft is flying through dynamic wind conditions. However, too much airspeed can lead to a potentially hazardous situation for landing, particularly when the runway is wet. Since the pilot-in-command of Eastern 66 inquired about the braking conditions, he was concerned about stopping the aircraft after landing. Therefore, after considering all of the approach conditions, the Safety Board believes that the addition of a 10- to 15-kt airspeed margin was reasonable. Simulator tests showed that even with this airspeed margin, the pilot must recognize immediately the aircraft's descent below the glide slope. He then must make rapid and pronounced pitch attitude and thrust changes to stop the aircraft's descent and prevent impact short of the runway.

There were no voice comments or sounds, until shortly before impact, which indicated that the flight crew was either aware of or concerned about the increased rate of descent. Throughout the time period, the pilot-in-command probably was looking outside, because about 6 seconds before the rate of descent began to increase he called "I have approach lights" and about 7 seconds after the rate began to increase he called "runway in sight". At the time of the latter call, the aeroplane was descending rapidly through 150 ft and was about 80 ft below the glide slope -- twice the distance that would have produced a fullscale "fly up" indication on the related flight instruments if the glide slope signal was reliable. The Safety Board believes that the co-pilot's immediate response, "I got it", to the pilot-in-command's identification of the runway indicates that the co-pilot also had probably been looking outside or was alternating his scan between the flight instruments and the approach lights. Although the aircraft was in heavy rain, the absence of significant turbulence might have caused him to underestimate the severity of the winds' effects.

Even though the pilot-in-command might have detected some of the glide slope, airspeed, and rate of descent excursions, simulator tests suggested that he probably reacted with insufficient thrust and pitch corrections to alter the excursions before he switched to visual references. These tests showed that large pitch and thrust changes were needed to stop the descent, and that the pilots often applied less sufficient changes than were needed because of the control forces involved and their reluctance to alter their instrument scan to verify the thrust settings.

Because of the low visibility, the flight crew probably realized too late how rapidly they were descending and the magnitude of the corrections which were needed to stop the descent. By the time the co-pilot called for take-off thrust, impact was inevitable.

The Safety Board recognizes the tendency of the pilot who is flying the aircraft to transfer at the earliest opportunity from instruments to visual references. In fact, this tendency is probably greater on approaches to runways like Runway 22L at the Kennedy Airport because the ILS glide slope is designated as unusable below 200 ft. However, the Safety Board continues to believe that the visual references available to a pilot under conditions of rain and reduced visibility are often inadequate to provide timely recognition of flight path deviations, such as those which can occur when traversing adverse wind conditions. This accident and others like it emphasize the need for air carriers to educate their flight crews on the effect of a wind shear encounter, and to review instrument approach procedures which are related to flight crew duties. The Safety Board believes that these procedures should stress that at least one pilot must scan the instruments until sufficient exterior references are visible to provide vertical guidance. Also, the Safety Board believes that research must be continued to develop a better method to transition from instrument flight to visual flight. High intensity VASI's on all runways served by instrument approaches, the "heads-up" displays, and the monitoring of flight instruments until touchdown as practiced by some air carriers are three concepts that appear promising.

Even with these landing aids, an approach which places an aeroplane in or near a thunderstorm at low altitude is hazardous. The wind conditions which might exist can place the aeroplane in a position from which recovery is impossible - even if both the pilot and the aeroplane perform perfectly. The number of recent approach and landing accidents which have been caused by the aeroplane's passage through or near localized thunderstorm cells indicates that many pilots and air traffic controllers do not have the proper appreciation for the hazards involved.

Approach operations to Runway 22L

Since the thunderstorm astride the localizer course to Runway 22L was obvious and since there was a relatively clear approach path to at least one of the northwest runways (31L), the Safety Board sought to determine why approach operations to Runway 22L were continued, particularly after both pilots and controllers had been warned that severe wind shear conditions existed along the final approach to the runway.

According to the Kennedy tower local controller, he did not consider a runway change, either before or after he received the recommendation from Flying Tiger 161, because the surface winds were most nearly aligned with Runway 22L. He further stated that he was too busy to pass the recommendation to the assistant tower chief who was responsible for initiating runway changes. Although the runway-use programme did not require that runway selection be based on alignment with the wind, the criteria did require that, if conditions permitted, another set of runways be used for noise abatement because Runways 31L/R had been in use for more than 6 hours. Therefore, because noise abatement favoured the use of Runways 22L/R, which were most nearly aligned with the wind, the control tower personnel apparently believed that they were operating with the best runway configuration.

However, the Safety Board concludes that had the thunderstorm activity been evaluated properly, it should have been apparent that the approach to Runway 22L was unsafe and that approaches to that runway should have been discontinued. The Safety Board believes that ATC did not consider a runway change either before or after the Flying Tiger pilot-in-command's recommendation because a change of runways would have further increased traffic delays and would have increased the already heavy workload.

When operating at capacity, the air traffic system in a high density terminal area tends to resist changes that disrupt or further delay the orderly flow of traffic. Delays have a compounding effect unless they can be absorbed at departure terminals or within the en-route system. Consequently, controllers and pilots tend to keep the traffic moving, particularly the arrival traffic because delays involve the consumption of fuel and tardy or missed connexions with other flights, which could lead to further complications. As weather conditions worsen, the system becomes even less flexible.

Although ATC has major responsibilities in the safe conduct of air operations, under current regulations and procedures, the pilot-in-command is the final authority on whether he will pursue a certain course of action, including whether he will conduct an instrument approach through a thunderstorm or other adverse conditions.

In view of the above, the Safety Board sought to determine why the pilot-in-command of Eastern 66 continued his approach to Runway 22L. The pilot-in-command had received only one report of adverse conditions - the report from Eastern 902. This report apparently disturbed the pilot-in-command ("... this is asinine"), but it also apparently was quickly rationalized to some degree("I wonder if they're covering for themselves"). Had the pilot-in-command known that two flights had reported adverse conditions, rationalization probably would have been more difficult. However, had he decided to make his approach to a different runway, he probably would have been delayed up to an additional 30 minutes because simultaneous instrument approach operations could not be conducted to two different runways. A 30-minute delay would have reduced substantially his fuel reserve of about 1 hour. Considering the thunderstorm activity affecting the New York City area, including his alternate airport, LaGuardia, his fuel reserve would have been minimal.

It is uncertain when the pilot-in-command of Eastern 66 made his final decision to continue the approach. He apparently had not made a final determination when the flight was 5 miles from the OM and was cleared for the approach because he told the final vector controller, "... we'll let you know about conditions". Also, about a minute later, he explained to the co-pilot, "I have the radar on stand by in case I need it ...", which suggests he was thinking about the possibility of either not making the approach or having to abandon it. However, because pilots commonly rely on the degree of successes achieved by pilots of preceding flights when they are confronted with common hazards, it is likely that he continued the approach pending receipt of information on the progress of the two flights which were immediately ahead of him. By the time the second of these two flights had landed without reported difficulty, the pilot-in-command of Eastern 66 was apparently committed to the approach, which discloses the hazards of a reliance on the success of pilots of preceding flights when dynamic and severe weather conditions exist. Within minutes, flight conditions can change drastically in or near mature thunderstorms. Moreover, pilot and controller workloads, and communication frequency congestion, can lead to omissions and assumptions, and confusion about who is aware of what.

In summary, the accident involving Eastern 66 and the near-accidents involving Flying Tiger 161 and Eastern 902 were the results of an underestimation of the significance of relatively severe and dynamic weather conditions in a high density terminal area by all parties involved in the movement of air traffic in the airspace system. The Safety Board, therefore, believes that no useful purpose would be served by dwelling critically on individual actions or judgements within the system, but that the actions and judgements required to correct and improve the system should be reviewed. All parts of the system must recognize the serious hazards that are associated with thunderstorms in terminal areas. A better means of providing pilots with more timely weather information must be designed.

Air traffic controllers and their supervisors must closely follow the development and movement of severe weather conditions by gathering, assimilating, and disseminating information from all sources - radar, visual, pilot reports, and weather reports - so that appropriate action can be planned before air safety is threatened. ATC must recognize that thunderstorms and other dynamic weather conditions which develop within, or move into, terminal areas may seriously disrupt the safe flow of traffic. When these conditions appear likely, ATC must be capable of adjusting the flow of traffic into terminal areas so that timely actions and rational judgements in the interest of air safety are primary to moving the traffic.

Pilots must exercise more independent judgements when they are confronted with severe weather conditions in the terminal areas. They must recognize that the conditions within, under, or near rapidly developing and maturing thunderstorms are dynamic and can change significantly within a short distance or within a short time, or both. In particular, they must recognize and avoid low-altitude hazards associated with thunderstorms along or near the approach path.

Air carrier and National Weather Service (NWS) forecasters must emphasize the accurate and timely forecasting and reporting of severe weather conditions. The NWS must emphasize the determination of thunderstorm severity and must accurately project thunderstorm development and movement, particularly in or near high-density terminal areas. The NWS must provide this information and other weather radar information to the air traffic control system in a timely manner. As a corollary, the improved location of weather radar equipment is needed, particularly in high-density terminal areas.

The Safety Board stresses the continuing need for air carrier operations managers and dispatchers, in conjunction with pilots-in-command of flights destined for high density terminal areas, to plan their operations to take into account the extensive delays that might become necessary when severe weather conditions exist or are forecast in the areas. These delays must be predicted conservatively and procedures developed to cope with them, particularly if it is likely that the pilot-in-command might have to choose a non-routine course of action to avoid penetration of thunderstorms.

Finally, reliable wind shear detection equipment is needed at commercial airports. However, several years of research may be needed before a reliable system can be developed and made operational. In the meantime, flight crews must be trained to recognize meteorological conditions conducive to wind shear and flight techniques to overcome wind shear should be emphasized. Similarly, ATC supervisors and controllers must learn that low-altitude wind shear is a serious hazard to all aircraft particularly to large jet transports, and that air traffic operations should be conducted to avoid the phenomenon whenever possible.

During the past seven years, the Safety Board has made a number of recommendations in the preceding areas.[4/] Although the development of wind shear detection equipment has been emphasized, limited operational progress has been made. Additionally, little progress has been made in the areas of: 1) The dissemination or radar-detected severe weather information to the air traffic control system, 2) the formal training of flight crews in the recognition of wind shear and the techniques for coping with wind shear, and 3) timely and accurate forecasts of wind shear.

2.2 Conclusions

a) Findings

1. There was no evidence of a malfunction or failure of the aircraft's structure, flight instruments, flight controls, or powerplants before impact with the approach light towers.

4/ Report Nos. NTSB-AAR-74-5, Ozark Air Lines, Inc., Fairchild Hiller FH-227B, N-4215, near the Lambert-St. Louis International Airport, St. Louis, Mo., 23 July 1973; and NTSB-AAR-74-14, Iberia Líneas Aéreas de España, (Iberian Airlines) McDonnell Douglas DC-10-30, EC CBN, Logan International Airport, Boston, Mass., 13 December 1973.

2. Eastern 66 was conducting an ILS approach to Runway 22L at the Kennedy Airport; the co-pilot was flying the aircraft.

3. When Eastern 66 approached the airport, a very strong thunderstorm was located along the localizer course near the MM.

4. The pilots of Flying Tiger 161 and Eastern 902 reported that hazardous wind shear conditions existed on the final approach to Runway 22L.

5. Eastern 66 received Eastern 902's report on the wind shear but did not receive Flying Tiger 161's report.

6. While penetrating the thunderstorm between 600 and 500 ft, Eastern 66 encountered an increased head wind of about 15 kt; about 500 ft, it encountered a downdraught of about 16 fps. Between 500 ft and 400 ft, the head wind diminished about 5 kt; at 400 ft, the downdraught increased to about 21 fps, and the head wind decreased about 15 kt within 4 seconds.

7. At 400 ft the aircraft began to descend rapidly below the glide slope because of the downdraught and decreased head wind.

8. About 400 ft, the pilot-in-command stated that he had the approach lights in sight, and he directed the co-pilot to remain on instrument references.

9. In response to the pilot-in-command's direction, the co-pilot replied that he was remaining on instruments; however, he probably began transitioning to the visual references he would need to complete the approach.

10. Although the co-pilot might have applied pitch and thrust changes to correct for the aircraft's deviation below the glide slope, any changes made were insufficient to alter significantly the aircraft's high rate of descent and reduced airspeed.

11. The flight crew probably did not recognize the deviation below the normal approach path until a high descent rate had developed because of their reliance on visual references which were obscured by heavy rain and low visibility.

12. By the time the flight crew recognized the aircraft's dangerously low altitude, impact with the approach light towers was inevitable because of the aircraft's high rate of descent.

13. Simulator tests showed that approximately 9^{o} of nose-up pitch change was needed to stop the aircraft's high rate of descent; also, tests showed that pilots applied less pitch change than was needed and were hesitant to divert their instrument scan to verify that sufficient thrust had been added to compensate for the airspeed loss.

14. The simulator tests were inconclusive as to whether the flight crew could have avoided the accident had they relied on and responded rapidly to the flight path deviations which were probably evident on their flight instruments.

15. The flight crew of Eastern 66 and the air traffic controllers were aware of the thunderstorm activity on the localizer course to Runway 22L.

16. The terminal air traffic system at Kennedy Airport was operating at capacity for at least 30 minutes before the accident, and the air traffic controllers were very busy.

17. After 1551, only one runway could be used for landing because IFR weather conditions prevailed.

18. At least one of the northwest runways (31L) was relatively unexposed to the influences of the thunderstorms.

19. Even though thunderstorm hazards were visible on the approach path, neither the pilots of inbound flights nor air traffic control took action to discontinue the initiation of approaches to Runway 22L or to change the landing runway.

20. The accident was not survivable because the fuselage almost completely disintegrated and the occupant restraint systems failed. The unrestrained occupants collided with numerous objects and received multiple extreme impact injuries.

21. The fire departments's rapid response and application of fire extinguishing agents prevented fatal burns to nine of the passengers who ultimately survived.

22. The non-frangible approach light towers caused extensive damage to the aircraft.

b) Cause or Probable Cause(s)

The National Transportation Safety Board determines that the probable cause of this accident was the aircraft's encounter with adverse winds associated with a very strong thunderstorm located astride the ILS localizer course, which resulted in a high descent rate into the non-frangible approach light towers. The flight crew's delayed recognition and correction of the high descent rate were probably associated with their reliance upon visual cues rather that on flight instrument references. However, the adverse winds might have been too severe for a successful approach and landing even had they relied upon and responded rapidly to the indications of the flight instruments.

Contributing to the accident was the continued use of Runway 22L when it should have become evident to both air traffic control personnel and the flight crew that a severe weather hazard existed along the approach path.

3.- Recommendations

As a result of its investigation of this accident, the National Transportation Safety Board had issued the following recommendations to the Administrator, Federal Aviation Administration:

"1. Conduct a research programme to define and classify the level of flight hazard of thunderstorms using specific criteria for the severity of a thunderstorm and the magnitude of change of the wind speed components measured as a function of distance along an aeroplane's departure or approach flight track and establish operational limitations based upon these criteria.

"2. Expedite the programme to develop and install equipment which would facilitate the detection and classification, by severity, of thunderstorms within 5 NM of the departure of threshold ends of active runways at airports having precision instrument approaches.

"3. Install equipment capable of detecting variations in the speed of the longitudinal, lateral, and vertical components of the winds as they exist along the projected take-off and approach flight paths within 1 NM of the ends of active runways which serve air carrier aircraft.

"4. Require inclusion of the wind shear penetration capability of an aeroplane as an operational limitation in the aeroplane's operations manual, and require that pilots apply this limitation as a criterion for the initiation of a take-off from, or an approach to, an airport where equipment is available to measure the severity of a thunderstorm or the magnitude of change in wind velocity.

"5. As an interim action, install equipment capable of measuring and transmitting to tower operators the speed and direction of the surface wind in the immediate vicinity of all runway ends and install lighted wind socks near to the side of the runway, approximately 1 000 ft from the ends, at airports serving air carrier operations.

"6. Develop and institute procedures whereby approach controllers, tower controllers, and pilots are provided timely information regarding the existence of thunderstorm activity near to departure or approach flight paths.

"7. Revise appropriate air traffic control procedures to specify that the location and severity of thunderstorms be considered in the criteria for selecting active runways.

"8. Modify or expand air traffic controller training programmes to include information concerning the effect that winds produced by thunderstorms can have on an aeroplane's flight path control.

"9. Modify initial and recurrent pilot training programmes and tests to require that pilots demonstrate their knowledge of the low-level wind conditions associated with mature thunderstorms and of the potential effects these winds might have on an aeroplane's performance.

"10. Expedite the programme to develop, in co-operation with appropriate Government agencies and industry, typical models of environmental winds associated with mature thunderstorms which can be used for demonstration purposes in pilot training simulators.

"11. Place greater emphasis on the hazards of low-level flight through thunderstorms and on the effects of wind shear encounter in the Accident Prevention Programme for the benefit of general aviation pilots.

"12. Expedite the research to develop equipment and procedures which would permit a pilot to transition from instrument to visual references without degradation of vertical guidance during the final segment of an instrument approach.

"13. Expedite the research to develop an airborne detection device which will alert a pilot to the need for rapid corrective measures as an aeroplane encounters a wind shear condition.

"14. Expedite the development of a programme leading to the production of accurate and timely forecasts of wind shear in the terminal area".

ICAO Ref.: AIG/193/75

No. 23

Continental Air Lines, Boeing 727-224, N-88777 accident at Denver/Stapleton, U.S.A., on 7 August 1975. Report No. NTSB-AAR-76-14, dated 5 May 1976, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

1.1 History of the flight

On 7 August 1975, Continental Air Lines Flight 426, a Boeing 727-224, operated as a scheduled passenger flight from Portland, Oregon, to Houston, Texas, with intermediate stops at Denver, Colorado, Wichita, Kansas, and Tulsa, Oklahoma. The flight departed the passenger terminal at Stapleton International Airport, Denver, Colorado, with 127 passengers and 7 crew members aboard.

Before they began to taxi the aircraft to the departure runway, the flight crew received a broadcast on the automatic terminal information service (ATIS) which gave the 1537[1/] Stapleton weather in part as follows: "Temperature - 84°F, wind - 070° at 15 kt, and altimeter setting - 30.03 in". At 1606:37, when the Denver tower local controller cleared the flight to taxi to Runway 35L he reported that the winds were 300° at 14 kt.

Two flights preceded Continental 426 on the take-off from Runway 35L. About 1605, the local controller cleared Braniff International Flight 67, a Boeing 727-100, for take-off; he reported that the winds were 250° at 15 kt with gusts to 22 kt. At 1606:33, Braniff 67 reported, "OK, you got some pretty good up and downdraughts out here from two, three hundred feet". The local controller acknowledged Braniff 67's report. Continental 426 did not receive Braniff 67's report, because the flights were on different radio frequencies.

About 1607, the local controller cleared Frontier Airlines Flight 509, a Convair 580, to take-off on Runway 35L. The controller informed Frontier 509 that the winds were 280° at 13 kt with gusts to 22 kt and that Braniff 67 had reported updraughts and downdraughts at 200 to 300 ft. Frontier 509 acknowledged the information. Continental 426 also did not receive this information, because it was operating on the ground control frequency.

At 1608:58, Continental 426 informed the local controller that it was ready for take-off. The local controller cleared the flight to hold in the take-off position.

At 1609:15, Frontier 509 reported, "... there's a pretty good shear line there about halfway down 35". The local controller responded, "... you got an altitude on it". Frontier 509 replied, "Oh about just like that other aeroplane called it, about 200 ft". At 1609:31, Continental 426 transmitted, "426 copied".

At 1610:11, the local controller cleared Continental 426 for take-off. He informed the flight that the winds were 230° at 12 kt and, "there have been reports of pretty stout up and downdraughts and that shear out there at 200 to 300 ft". The flight acknowledged the clearance and the information.

1/ All times herein are mountain daylight based on the 24-hour clock.

The flight crew of Continental 426 used maximum take-off thrust and they stated that all instrument readings were normal when a check was made at 80 kt indicated airspeed (KIAS). At 1610:58, the pilot-in-command called, "V_1, rotate."[2/], and the co-pilot, who was flying the aircraft, rotated the aircraft to a pitch attitude of between 13° and 15°. The second officer said that the rotation manoeuvre was normal and that he saw 14° of pitch on the attitude indicator.

According to the co-pilot, the aircraft left the runway just after it had passed over the interstate highway, which is located about 4 670 ft from the threshold of Runway 35L. He saw a positive rate of climb and at 1611:05 he called, "gear up." The pilot-in-command said that the aircraft entered heavy rain about the time the co-pilot executed the rotation manoeuvre. The pilot-in-command turned on the windshield wipers and, in response to the co-pilot's command, then moved the gear handle to the "up" position.

According to the flight crew, the aircraft climbed normally to 150 ft to 200 ft above the runway and accelerated to an indicated airspeed of about V_2+5 kt.[3/] The airspeed fluctuated and then decreased to V_2-5 kt, and the co-pilot relaxed back-pressure on the control column. The pilot-in-command felt the aircraft sink and saw the airspeed at V_2-20 kt. He took control of the aircraft, advanced the power levers to maximum thrust, and lowered the nose to a pitch attitude of about 10°. The aircraft continued to descend, and the pilot-in-command attempted to increase the pitch attitude. Just before the aircraft struck the ground, the stall warning system activated.

The aircraft first struck the ground on the right shoulder of Runway 35L, just south of the departure end of the runway. It slid about 1 995 ft and came to rest on an airport road. Initial impact was recorded on the cockpit voice recorder (CVR) at 1611:18. The accident occurred during daylight hours at 39° 47' 42" N latitude and 104° 53' 18" W longitude, and at an elevation of about 5 290 ft MSL.

The pilot-in-command of Braniff 67 stated that when he landed at Stapleton (about 50 minutes before his departure) he had encountered moderate to severe turbulence on the approach to Runway 26L. While he was taxiing the aircraft to Runway 35L for take-off, he noticed a large dust cloud along the northern portion of Runway 35L. By the time he started the take-off, the dust cloud had moved west of the runway.

Although the take-off gross weight of his aircraft was only 130 000 lb (about 10 000 lb less than the maximum authorized weight) the pilot-in-command of Braniff 67 used maximum take-off thrust and decided to climb at V_2+20 kt (10 kt higher than normal) because of the variable surface winds and his experience with turbulence on arrival at Stapleton. He noticed moderate to severe turbulence almost immediately after take-off; when the aircraft was between 100 and 300 ft above the runway, the indicated airspeed fluctuated considerably and then decreased rapidly about 10 to 15 kt. He levelled the aircraft momentarily by decreasing the pitch attitude from about 12° to 5°, regained the airspeed, and continued the climb-out.

The pilot-in-command of Frontier 509 stated that when he aligned his aircraft for take-off on Runway 35L, he noticed some virga[4/] about 1 000 to 1 500 ft above the centre of the runway. He saw a dust cloud move eastward across the runway and the northern half of the runway appeared to be wet.

2/ V_1 is critical engine failure speed. V_R is rotation speed. In this instance, both speeds were identical - 132 kt.

3/ V_2 is take-off safety speed; in this instance it was 143 kt.

4/ Precipitation which evaporates before it reaches the ground.

The pilot-in-command of Frontier 509 described the take-off as normal for the near maximum load aboard until his aircraft reached an altitude about 300 ft above the runway, where it suddenly encountered moderate turbulence and rain. The indicated airspeed was about 130 kt, and he began to retract the wing flaps from their 15° position. The airspeed decreased rapidly to about 120 kt, so he stopped the flap retraction at 10°. He decreased the aircraft's pitch attitude, and the aircraft descended about 100 ft before it regained the airspeed. The turbulence and rain stopped, and he resumed the climb. Two or three minutes later, as his aircraft flew towards the southwest, he saw a large dust cloud on the ground - the cloud moved rapidly north along what appeared to be Runway 35R, which was under construction.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	-	-	-
Non-fatal	5	10	-
None	2	117	

1.3 Damage to aircraft

The aircraft was substantially damaged.

ICAO Note: Paragraphs 1.4 to 1.17 not reproduced (the Foreword refers).

2.- Analysis and Conclusions

2.1 Analysis

The aircraft was certificated, equipped, and maintained in accordance with regulations and approved procedures. There was no evidence of a malfunction or failure of the aircraft, its components, or its powerplants that would have affected its performance.

The flight crew was certificated properly and each crew member had received the training and off-duty time prescribed by regulations. There was no evidence of pre-existing medical or physiological problems that might have affected their performance. Therefore, the Safety Board directed its attention to the meteorological and operational factors that could have caused the aircraft to descend rapidly and crash.

The National Weather Service (NWS) radar returns and witness reports indicate that a thunderstorm developed a short distance west of Stapleton Airport, moved over the northern portion of the airport, dissipated, and moved east-northeast of the airport in a short period of time between 1600 and 1620. The thunderstorm's development and existence were not readily visible either to air traffic controllers or to flight crews because its base was high above the ground and it was surrounded by other cumulus clouds and thunderstorms with high bases.

As it began to dissipate, the thunderstorm generated numerous downdraughts. The downdraughts were not accompanied by the usual heavy rainshafts because the low relative humidity caused much of the rain to evaporate before it reached the ground. The resultant virga also made the thunderstorm less apparent. However, because the evaporation further cooled the descending air, causing it to descend even more rapidly, the downdraughts associated with the thunderstorm probably were severe near ground level.

The thunderstorm over the northern portion of the airport produced a situation conducive to wind shear. The problems associated with wind shear have been explored in depth in several recent Safety Board accident investigation reports.5/ Although these accidents involved aircraft conducting precision instrument approaches, the effects of an encounter with wind shear are substantially similar whether encountered on take-off or landing. Both situations are hazardous at low altitudes and at normal take-off and landing speeds.

Based on the evidence, the Safety Board concludes that Continental 426, Braniff 67, and Frontier 509 encountered wind shears at critically low altitudes and during critical phases of their departures. The meteorological conditions, the analysis of surface wind conditions, the analysis of Continental 426's performance, the FDR information from Braniff 67 and Frontier 509, and the observations of witnesses support this conclusion. In view of this conclusion, the Safety Board sought to determine the reason for Continental 426's failure to negotiate the wind shears, particularly in view of the fact that Braniff 67 and Frontier 509 successfully negotiated the wind shears.

From the surface wind analysis, it was determined that the surface winds in the vicinity of Runway 35L between 1600 and 1620 were significantly affected by the thunderstorm over the northern portion of the airport which probably contained more than one centre of divergence.

About 1600, the most influential centre of divergence was probably located west of the centre of Runway 35L; and it was moving east-northeast at about 9 kt. As the thunderstorm expanded and moved east-northeastward, this centre of divergence began to strongly affect the wind conditions on Stapleton Airport because of its strong horizontal outflow.

About the time that Braniff 67 was on take-off, the streamline pattern indicates that a line6/ of convergence probably was located across Runway 35L about 4 000 ft from the threshold. The northern portion of the runway probably was under the influence of relatively weak centres of divergence located on both sides of the runway and the strong centre of divergence which then was about 1.3 miles west of the centre of the runway.

Braniff 67 probably passed through the area of convergence when the aircraft became airborne, which would account for the moderate to severe turbulence the pilot-in-command experienced. However, the tail wind which Braniff 67 encountered shortly after lift-off was probably produced by the relatively weak centre of divergence and probably was comparatively slight. Braniff 67 lost 23 kt of airspeed in 15.6 seconds, or an average of 1.47 kt per second.

When Frontier 509 began its take-off, the streamline pattern had changed because the storm was moving east. The northern portion of Runway 35L probably was influenced more strongly by the main centre of divergence which then was about 1 mile west

5/ NTSB-AAR-74-14, Iberia Líneas Aéreas de España, DC-10-30 Logan International Airport, Boston, Massachusetts, 13 December 1973, and NTSB-AAR-76-8, Eastern Airlines, Inc., B-727, John F. Kennedy International Airport, Jamaica, New York, 24 June 1975.

6/ Although indicated as a line on the streamline patterns, it is actually an area in which turbulent wind conditions exist because of the collision of winds from essentially opposite directions. It can also indicate the area of convergence between two or more thunderstorm gust fronts.

of the runway. Also, the two weaker centres of divergence had moved east so that one of them was almost directly over the runway. This centre probably produced the virga, rain, and turbulence that Frontier 509 encountered. The tail wind encountered by Frontier 509 over the northern portion of the runway probably was greater than that encountered by Braniff 67 because of the increased influence of the main centre of divergence as it approached the runway. Frontier 509 lost 36 kt of airspeed in 10.8 seconds - an average of 3.33 kt per second.

When Continental 426 began its take-off, the streamline pattern shows that the main centre of divergence had moved farther eastward and was dominating the surface wind flow on the northern portion of the runway. The line of convergence had moved farther south which would have provided considerable variations in wind during the take-off roll and would have provided a head wind during the latter part of Continental 426's take-off. Shortly after lift-off, the aircraft would have encountered a situation wherein the wind changed rapidly from a head wind to a tail wind of substantial magnitude. The airspeed loss of 41 kt in 5.0 seconds - an average loss of 8.2 kt per second - reflects the severity of the change.

Notwithstanding the existence of the thunderstorm over the northern portion of the airport, the Safety Board concludes that the weather information available to Continental 426 was adequate except for the wind information. Although the official winds reported by the air traffic controllers reflected considerable variation in both direction and speed, the information was available from only one source, the anemometer located about 1 800 ft southeast of the threshold of Runway 35L. Consequently, the surface winds over the northern portion of the airport were unknown. Moreover, no other wind information was available except that reported by Braniff 67 and Frontier 509. Neither of their reports contained quantitative information that could be related, except in a general manner, to an adverse effect on aircraft performance.

The Safety Board believes that had the means existed to measure and report the wind shear that existed along and above Runway 35L and to relate the quantitative wind shear measurements to aircraft performance, the flight crew of Continental 426 would have been better prepared for the conditions encountered or would have been able to make an intelligent decision on whether or not to take-off. Under the circumstances, with limited wind information, good visibility, and high cloud bases, the pilot-in-command's decision to take-off on Runway 35L cannot be faulted.

In view of the probable severity of the wind conditions that Continental 426 encountered, the Safety Board sought to determine whether the conditions were severe enough to have prevented the flight crew from countering the shear effectively and, consequently, avoiding the accident.

Based on the aircraft performance analysis, the Safety Board concludes that the accident was unavoidable after the aircraft encountered the wind shear because, at the altitude and airspeed at which the encounter occurred, the aircraft was performing near its maximum capability, and the flight crew, after applying full thrust, could have done nothing to overcome the aircraft's descent relative to the ground which was induced by the wind shear.

At the altitude and airspeed at which the aircraft encountered the wind shear, it had a given amount of potential energy because of its altitude above the runway and a given amount of kinetic energy because of its mass and speed. Under such circumstances, the only effective additive to the aircraft's total energy is thrust. Consequently, if the engines were producing maximum thrust, the flight crew had no way of increasing the total energy available to the aircraft within the short period of time that was available.

Whether different take-off procedures would have enabled the flight crew of Continental 426 to negotiate the severe wind shear is not known. Although any procedure that will increase the aircraft's total energy rapidly will make the aircraft less vulnerable to force changes from air mass motion, such procedures have limitations when other operational factors such as obstacle clearance and engine failure are considered. Consequently, any alteration of take-off procedures would have to be considered carefully to preclude the reduction in potential of one hazard at the expense of increasing the potential of other hazards.

Although it is uncertain what precise effect formal wind shear training might have had on the performance of the flight crew involved in this accident, the Safety Board believes that the FAA's action in response to the Safety Board's recommendations on wind shear training programmes for air carrier pilots was not timely. Formal requirements were not issued until Air Carrier's Operations Bulletin 75-8 was issued in August 1975 even though the FAA had informed the Safety Board in November 1974 that each air carrier's training programme was being evaluated. With regard to Continental's training programme, little had been accomplished until shortly before the accident. It is believed that the FAA's wind shear training requirements could have and should have been issued in a more timely and positive manner.

Additionally, in view of the widespread publicity in the air carrier industry about wind shear problems, the Safety Board believes that Continental Air Lines could have and should have taken more positive action to provide their flight crews with information and training on wind shear. It is believed that such training would have at least alerted the flight crew in this instance that a serious hazard to safe flight had been reported to exist along the departure path from Runway 35L, and the training might have provided them with a means for contending with the hazard.

Survivability aspects

The accident was survivable because the impact forces did not exceed human tolerances, the passenger restraint systems remained intact, the occupiable space was not appreciably disrupted, and there was no fire.

Of the nine emergency exits in the cabin of the aircraft, only five were usable for evacuation - the four overwing window exits and the right forward galley exit. The three aft exits, including the ventral stairway, were unusable because the engines continued to run at high power settings and because of the damage to the empennage. The engines could not be shut down because the normal and emergency control cables were rendered inoperative by fuselage structural failures. The main entry door was blocked by the dislodged coat closet.

Although, under the circumstances, the lack of four exits did not affect the success of the evacuation, the situation could have been different had there been a fire. Under such circumstances, the loss of almost half of the emergency exits could have significantly prolonged the evacuation of the fully occupied aircraft. Therefore, the major factor that probably accounted for the success of the evacuation was the absence of fire. All fuel tanks and fuel lines remained intact; consequently, although ignition sources were present, there were no combustible fluids to ignite.

The passengers initiated and completed the evacuation largely unaided. The evacuation was completed in 3 to 4 minutes. Of the seven crew members, only two flight attendants directed the evacuation from inside the aircraft.

The forward flight attendants were not able to assist in the evacuation, because during the crash sequence they were incapacitated and then trapped in their seats by the forward coat closet. They were knocked unconscious probably because the protective padding behind their seats did not extend above the level of their shoulders and, therefore, provided no protection to their heads.7/

The aft flight attendants had difficulty with their restraint systems. They tightened their shoulder harnesses shortly after the aircraft left the ground, which probably pulled their seat belts above the pelvic area. Consequently, when they were thrown forward by the impact forces, they slid from beneath their seat belts and were trapped between the webbing of their restraint systems and their seat. They were able to free themselves, however, and were able to assist in the evacuation.

Since there was no evidence that the cockpit door was jammed or otherwise inoperable, the Safety Board believes that the flight crew made little effort to proceed to their evacuation duty stations in the passenger cabin. Instead, the evidence indicates that the flight crew abandoned the cockpit through the sliding windows as rapidly as possible. The Safety Board concludes that the flight crew's performance in this respect did not conform to the standards of professional crew members.

Although the pilot-in-command re-entered the aircraft and helped the forward flight attendants escape, and the other members of the flight crew performed well from outside the aircraft in assisting the passengers, their presence at their duty stations inside the aircraft would have been essential had there actually been a fire. In such a situation, experience has shown that well-trained and able-bodied crew members, including flight crews, are needed inside the aircraft to achieve the best results possible in the short period of time that usually is available to complete an evacuation.

An individual crew member's response to an emergency situation depends largely on his training. Crew members must understand that they lead the evacuation and that they must act swiftly and aggressively to assist the passengers and to prevent panic. Each crew member must have an understanding of his duties and of the duties of the other crew members so that his efforts will complement theirs. Also, in the event of disabling injuries, each crew member must be able to assume command of the evacuation or to accomplish the duties of another crew member.

For proper indoctrination on their professional duties and responsibilities during an emergency evacuation, the crew members evacuation training should be conducted in an environment approximating that of an actual aircraft evacuation. Environmental factors such as darkness, smoke, and confusion should be introduced into the evacuation training. Training should be conducted in facilities which simulate an aircraft as closely as possible and should be conducted on a crew basis rather than on an individual basis so that each crew member can become familiar with the duties and responsibilities of the others.

Although Continental Air Lines' evacuation training met FAA requirements, the Safety Board believes that the flight crew's performance during this evacuation might have been more effective if their training: 1) had been conducted jointly with that of the flight attendants, 2) had been conducted under realistically simulated emergency conditions and 3) had been as comprehensive as that given to the flight attendants.

7/ The FAA issued a notice of proposed rulemaking on 11 July 1975, to revise 14 CFR 25.785 and 14 CFR 121.311, which will require that flight attendant seats be provided with protective padding in this area.

2.2 Conclusions

a) Findings

1. There was no evidence of a malfunction or failure of the aircraft's structure, flight instruments, flight controls, or powerplants before impact with the ground.

2. There was a thunderstorm with associated rain showers over the northern portion of Stapleton Airport when Continental 426 began its take-off from Runway 35L. The bases of the clouds were relatively high, the prevailing visibility was excellent, and the surface winds were variable, strong, and gusty.

3. When Continental 426 began its take-off, the main centre of divergence of the thunderstorm probably was located just west of the centre of Runway 35L. This centre dominated the wind flow pattern over the northern portion of the airport, but the wind flow was not officially recorded because the sole, official, recording anemometer was located about 1 800 ft southeast of the threshold of Runway 35L. It was recording a southwesterly wind flow.

4. During the first half of its take-off roll, Continental 426 encountered gusty tail winds. During the second half of the take-off roll, the aircraft probably encountered variable tail winds and head winds of about 10 kt, which increased to a head wind of about 20 kt after the aircraft was rotated. Shortly after lift-off, the aircraft probably encountered updraughts, downdraughts, and a rapid change in the horizontal wind from a head wind to a tail wind; the latter probably was in excess of 60 kt at or near the point of impact.

5. At an altitude of about 100 ft above the runway, the aircraft lost about 41 kt of indicated airspeed in 5.0 seconds. The aircraft struck the ground 11.6 seconds after the airspeed began to decrease.

6. The accident was unavoidable because the aircraft was performing near its maximum capability when it encountered the wind shear.

7. Neither the FAA nor Continental Air Lines acted in a positive and timely manner in providing wind shear training for Continental's flight crews.

8. The accident was survivable.

9. The evacuation was successful because there was no fire.

10. The flight crew's performance during the evacuation did not conform to the standards of professional crew members because they failed to perform their assigned evacuation duties.

b) Cause or
Probable Cause(s)

The National Transportation Safety Board determines that the probable cause of this accident was the aircraft's encounter, immediately following take-off, with severe wind shear at an altitude and airspeed which precluded recovery to level flight; the wind shear caused the aircraft to descend at a rate which could not be overcome even though the aircraft was flown at or near its maximum lift capability throughout the encounter. The wind shear was generated by the outflow from a thunderstorm which was over the aircraft's departure path.

3.- Recommendations

As a result of its investigation of this accident, the National Transportation Safety Board has issued the following recommendations to the Federal Aviation Administration:

"Require modification of Continental Air Lines' flight crew emergency evacuation training programme to ensure that adequate emphasis is placed on the aspects of crew co-ordination, team effort, and awareness of individual crew member's responsibilities as leaders of an evacuation. (Class II - Priority Follow-up.) (A-76-73.)

"Issue an Air Carrier Operations Bulletin to require that Principal Operations Inspectors review the emergency evacuation training programmes of their assigned air carriers to ensure that adequate emphasis is placed on the aspects of crew co-ordination, team effort, and awareness of individuals' responsibilities as leaders of an evacuation. (Class II - Priority Follow-up.) (A-76-74.)

"Require that the flight crew manuals and the flight attendant manuals of all air carriers include the evacuation duty assignments of the entire crew. (Class II - Priority Follow-up.) (A-76-75.)

"Issue an Airworthiness Directive to require that the seat belt tiedown rings on all Boeing 727 forward jumpseats be relocated so that the seat belt will be positioned across the occupant's pelvic girdle at the recommended angle with the seatpan of 45° to 55°. (Class II - Priority follow-up.) (A-76-80.)

"Inspect the flight attendant jumpseats on all other air carrier aircraft to ensure that the seat belt tiedowns are positioned properly; where improper installations are found, take immediate action to require that the tiedowns be relocated. (Class II - Priority follow-up.) (A-76-81.)"

... in conjunction with the National Aeronautics and Space Administration. The Air Line Pilots' Association, Aerospace Industries Association, and the Air Transport Association:

"Evaluate all air carrier take-off and climb procedures to determine whether different procedures can be developed and used that will better enable flight crews to cope with known or suspected low-altitude wind shears. If different procedures are developed, they should be incorporated into the air carriers' flight manuals. (Class II - Priority follow-up.) (A-76-76.)

As a result of the aforementioned accidents involving an Iberia Líneas Aéreas de España DC-10-30 and an Eastern Air Lines B-727, the Safety Board has made a number of recommendations on the detection and measurement of thunderstorms and wind shear, on the training of air carrier flight crews in the recognition of hazards associated with wind shear, and on the conduct of air traffic operations to avoid thunderstorms and wind shear.

During the formulation of recommendations related to the Eastern Air Lines accident, the Safety Board considered the similar factors which were involved in this accident. Consequently, the Safety Board believes that the recommendations previously issued, if implemented, should prevent the recurrence of accidents similar to this accident. However, the recommendation on revision of take-off procedures has been added to strengthen these recommendations. Safety Recommendations A76-31 to 44, issued on 1 April 1976, are repeated below to emphasize the scope of the corrective action that the Safety Board believes is needed to prevent this type of accident:

> "... the National Transportation Safety Board recommends that the Federal Aviation Administration, in co-ordination with the National Oceanic and Atmospheric Administration, where appropriate:
>
> "Conduct a research programme to define and classify the level of flight hazard of thunderstorms using specific criteria for the severity of a thunderstorm and the magnitude of change of the wind speed components measured as a function of distance along an aeroplane's departure or approach flight track and establish operational limitations based upon these criteria. (A-76-31.)
>
> "Expedite the programme to develop and install equipment which would facilitate the detection and classification, by severity, of thunderstorms within 5 NM of the departure or threshold ends of active runways at airports having precision instrument approaches. (A-76-32.)
>
> "Install equipment capable of detecting variations in the speed of the longitudinal, lateral, and vertical components of the winds as they exist along the projected take-off and approach flight paths within 1 NM of the ends of active runways which serve air carrier aircraft. (A-76-33.)
>
> "Require inclusion of the wind shear penetration capability of an aeroplane as an operational limitation in the aeroplane's operations manual, and require that pilots apply this limitation as a criterion for the initiation of a take-off from, or an approach to, an airport where equipment is available to measure the severity of a thunderstorm or the magnitude of change in wind velocity. (A-76-34.)
>
> "As an interim action, install equipment capable of measuring and transmitting to tower operators the speed and direction of the surface wind in the immediate vicinity of all runway ends and install lighted wind socks near to the side of the runway, approximately 1 000 ft from the ends, at airports serving air carrier operations. (A-76-35.)
>
> "Develop and institute procedures whereby approach controllers, tower controllers, and pilots are provided timely information regarding the existence of thunderstorm activity near to departure or approach flight paths. (A-76-36.)

"Revise appropriate air traffic control procedures to specify that the location and severity of thunderstorms be considered in the criteria for selecting active runways. (A-76-37.)

"Modify or expand air traffic controller training programmes to include information concerning the effect that winds produced by thunderstorms can have on an aeroplane's flight path control. (A-76-38.)

"Modify initial and recurrent pilot training programmes and tests to require that pilots demonstrate their knowledge of the low-level wind conditions associated with mature thunderstorms and of the potential with mature thunderstorms and of the potential effects these winds might have on an aeroplane's performance. (A-76-39.)

"Expedite the programme to develop, in co-operation with appropriate Government agencies and industry, typical models of environmental winds associated with mature thunderstorms which can be used for demonstration purposes in pilot training simulators. (A-76-40.)

"Place greater emphasis on the hazards of low-level flight through thunderstorms and on the effects of wind shear encounter in the Accident Prevention Programme for the benefit of general aviation pilots. (A-76-41.)

"Expedite the research to develop equipment and procedures which would permit a pilot to transition from instrument to visual references without degradation of vertical guidance during the final segment of an instrument approach. (A-76-42.)

"Expedite the research to develop an airborne detection device which will alert a pilot to the need for rapid corrective measures as an aeroplane encounters a wind shear condition. (A-76-43.)

"Expedite the development of a programme leading to the production of accurate and timely forecasts of wind shear in the terminal area. (A-76-44.)"

ICAO Ref.: AIG/272/75

No. 24

American Airlines, DC-10, N-124 and Trans World Airlines, L-1011, N-11002, near collision near Carleton, U.S.A., on 26 November 1975. Report No. NTSB-AAR-76-A, dated 28 January 1976, released by the National Transportation Safety Board, U.S.A.

1.- Investigation

History of the flights

American Airlines Flight 182

American Airlines, Inc., Flight 182 (American 182), a Douglas DC-10-10, N-124, was a regularly scheduled passenger flight between San Francisco, California, and Newark, New Jersey, with a scheduled stop at O'Hare International Airport, Chicago, Illinois. American 182 departed Chicago at 1839 EST[1/] with 13 crew members and 179 passengers aboard. The flight received progressive climb clearances from Chicago departure control.

At the times indicated, the following communications were exchanged between American 182 and Chicago Air Route Traffic Control Center (Chicago Center):

1915:50 (Chicago Center) - American 182, maintain flight level 370[2/]
1915:55 (American 182) - One eighty two is out of 279 for 370
1916:00 (Chicago Center) - One eighty two heavy Roger direct Carleton[3/] on course contact Cleveland Center 127.05
1916:05 (American 182) - Twenty seven oh five and that's direct Carleton on course so long

After American 182 changed to the Cleveland Center frequency, the following communications took place:

1916:24 (American 182) - Cleveland Center, American Flight 182 heavy with you out of 280 for 370
1916:31 (Cleveland Center) - American 182, Roger squawk 3202 and ident.

There were no further communications between American 182 and Cleveland Center for the next 6 minutes. The circumstances under which communications were resumed began at 1922:05, when United Air Lines Flight 680, which was climbing to flight level 330, asked Cleveland Center: "Any idea of the tops?" This question prompted the controller to make the following communications:

1922:08 (Cleveland Center) - Well, they were at 35 earlier, just a minute, let me check.
1922:13 (Cleveland Center) - TWA 37, Cleveland, what are the tops?

1/ All times herein are eastern standard time, based on the 24-hour clock.

2/ Flight levels are stated in 3 digits that represent hundreds of feet: FL 370 = 37 000 ft.

3/ Carleton is a navigation aid (VORTAC) located about 70 NM east of the boundary between Chicago Center and Cleveland Center.

1922:17 (TWA 37) - They are higher than we are; it's hard to say. You can see through it; I'd say it must be at least 37.
1922:25 (Cleveland Center) - Okay, TWA 37, thank you.
1922:29 (Cleveland Center) - Six eighty, did you copy?
1922:31 (United 680) - Yes, thank you.
At 1922:38 another flight, American Airlines 26, reported: "American 26 is just skimming the tops".
1922:42 (Cleveland Center) - Okay, American 26, thank you and United 680, that aircraft is 370.
1922:52 (Cleveland Center) - American 182, Cleveland, what is your altitude?
1922:55 (American 182) - American 182, passing through 347 at this time, and we can see the stars above us but we're still in the area of the clouds.
1923:03 (Cleveland Center) - American 182, descend immediately to 330.
1923:06 (American 182) - Descending to 330 at this time.
1923:11 (Cleveland Center) - TWA 37, traffic twelve o'clock and a mile descending out of 345.
1923:40 (American 182) - American 182 is at 330.
1923:46 (Cleveland Center) - American 182, thank you.
1923:52 (American 182) - What altitude was that other aircraft at?
1923:57 (Cleveland Center) - He was at 35, sir.
1924:02 (American 182) - I'd check on that.
1924:07 (Cleveland Center) - Yes sir, will do.

According to the pilot-in-command of American 182, the flight was climbing eastbound on jet route 584 (J-584) and approaching or going through FL 350, when they were advised to descend immediately to FL 330. He started an immediate descent with the autopilot vertical speed control. Simultaneously, he and the other crew members sighted the lights of another aircraft in the 12 o'clock position. He then applied forward pressure on the control wheel to avoid the aircraft. He estimated that the vertical distance between the aircraft when they passed was 100 ft, and that 3 to 4 seconds elapsed from the moment he sighted the aircraft until it passed them. At the time of the near-collision, American 182 was operating in instrument meteorological conditions (IMC), in and out of the cloud tops.

According to cockpit voice recorder (CVR) information, about 16 seconds after the Cleveland Center controller advised "United 680, that aircraft is at 370", the pilot-in-command of American 182 made the intracockpit remark: "There he is". One second later, the controller cleared American 182 to descend immediately. The pilot-in-command cannot remember the exact sequence of his observations and actions during the short time span in which the traffic conflict materialized and was avoided.

About 30 seconds after the flight was levelled at FL 330, cabin personnel informed the pilot-in-command that some persons in the cabin had been injured. The pilot-in-command requested and obtained an immediate reroute clearance to the nearest suitable airport - Wayne Metropolitan Airport, in Detroit, Michigan. He arranged for medical assistance upon arrival in Detroit.

The flight landed in Detroit at 1950. All injured persons were transported immediately to Wayne County General Hospital in Detroit for examination and treatment.

Trans World Airlines Flight 37

Trans World Airlines, Inc., Flight 37 (TWA 37) a Lockheed 1011, N-11002, was a regularly scheduled passenger flight between Philadelphia, Pennsylvania, and Los Angeles, California. TWA 37 departed Philadelphia at 1815 with 11 crew members and 103 passengers aboard.

About 1919, the flight passed over the Carleton VORTAC at its assigned flight level of 350 and was proceeding westbound on J-584. The flight was under the control of Cleveland Center and operating in IMC. At 1922:13, the Cleveland Center controller queried the flight about the cloud tops.

About 1923, the flight engineer saw what appeared to be position lights pass under the right side of the aircraft and made an exclamation to that effect. The pilot-in-command and co-pilot did not see any lights or another aircraft. In the cockpit discussion that followed, it was explained how reduced visibility could affect the appearance of another aircraft and its proximity. When TWA 37 arrived in Los Angeles, the crew was informed of the near-collision.

ATC handling of the flight

At the time of the accident, American 182 and TWA 37 were operating in positive control airspace which was under the jurisdiction of the Wayne sector of the Cleveland Center. The Wayne sector was responsible for aircraft operating at or above FL 350.

The aircraft radar beacon signals from American 182 and TWA 37 were being received by the national airspace system (NAS) Stage A Digitized (Narrow-band) Radar System and processed by the radar data processing equipment at the Cleveland Center. The equipment generated the data displayed on the radar controller's plan view display (PVD). The display for each aircraft consisted of a symbol for the aircraft's position and an alpha-numeric data block. The alpha-numeric data included the aircraft's identification or flight number and its assigned altitude. In the case of American 182, which was climbing, the alpha-numeric data also included reported actual altitude. The display on the PVD for each target was updated every 12 seconds.

The circumstances which led to the near-collision developed while the Wayne sector was being manned by two controllers: a radar controller and a manual controller. A third controller, who was assigned to the hand-off position, was at lunch. Consequently, the radar and hand-off positions were combined and manned by the radar controller.

The radar controller is responsible primarily for radar control of traffic within his sector. He can display targets within the sector on the PVD while inhibiting the targets for traffic outside of this airspace. He communicates with the data processing computer through various devices at his position to manage his PVD and to insert certain traffic control functions into the computer. He can initiate and accept a target's track as it moves into his sector; he can transfer a target's track to another sector, or point-out a target to another sector by forcing that target to be displayed on the other sector's PVD. The radar controller also can enter or change flight data stored in the computer such as a flight's assigned altitude or routing.

The manual controller functions as a non-radar controller. He maintains current flight data on the flight progress strips, issues departure clearances, and co-ordinates as necessary with adjacent sectors and air traffic facilities. Although the manual controller also can make computer inputs at the manual console, the same inputs can sometimes be made more expeditiously at the radar console.

The hand-off controller, positioned next to the radar controller, assists the radar controller with his duties and co-ordinates with adjacent sectors and air traffic facilities.

The radar data processing equipment stores data in the computer in both received and processed forms. A radar log which contains these data was obtained from Cleveland Center for the time period during which this accident occurred.

These data showed that the target for TWA 37 was first processed for display on the Wayne sector PVD at 1903:44.5. The display showed the target at its assigned flight level of 350 and tracking approximately 290° true at a ground speed of 408 kt. The target was about 105 NM southeast of Carleton VORTAC on J-34. The Wayne radar controller accepted the hand-off of the target track from the adjoining sector at 1903:53.0. A full data block showed the progress of TWA 37 as it proceeded to Carleton VORTAC and then turned westbound onto J-584. At 1918:50, the Wayne radar controller entered the appropriate code through an alpha-numeric keyboard to initiate the transfer of TWA 37's track to the Chicago Center. At that time the target was about 6 NM east of Carleton and tracking 282° at 400 kt. A track accept message was received from Chicago at 1918:54. The target position symbol and data block continued to be generated for display on the Wayne sector PVD until 1928:54.

The target representing American 182 was initially processed for the Wayne sector PVD at 1914:24. The data showed the aircraft to be about 100 NM west of Carleton, climbing through FL 262 to assigned FL 370. The aircraft was tracking approximately 092° at 465 kt. The Wayne radar controller accepted the target track from Chicago at 1914:40.5. The target position symbol and a full data block were then generated for the Wayne sector. The periodic change in reported altitude showed that American 182 was climbing about 1 000 ft per minute as it proceeded eastbound on J-584.

At 1921:19.5, American 182 was about 40 NM west of TWA 37 and reporting at FL 330. The two aircraft were on reciprocal courses and were closing at a speed of about 850 kt.

The radar controller stated that when he accepted the hand-off of American 182, he realized that there might be a traffic conflict between that flight and TWA 37. However, his previous experience that day had shown that several flights climbing eastbound out of Chicago to FL 370 had been levelling off a considerable distance west of where the incident later occurred. He thought that by keeping an eye on the situation he would be able to turn the aircraft in case the required separation criteria would not be met.

When asked if there were any operational factors that might have distracted him, he said that at about the time American 182 reported at FL 280, Chicago Center called with a manual point-out and hand-off of a Learjet. He accepted the hand-off and for about 5 minutes thereafter he attempted to insert a change in the routing of the Learjet into the computer. According to the radar controller, the flight-planned route of the Learjet was not identical to its actual route, and Chicago Center failed to update the computer prior to handing it off to him.

The radar log showed that the Learjet had taken off from Chicago on an IFR flight plan to London, Canada. At 1917:55.5, the Wayne radar controller attempted to enter a change in the routing of the Learjet into the computer. The computer rejected the routing change because the requested route involved a point to point, or direct, routing into airspace under the control of Toronto, Canada.

The radar controller said that, normally, the manual controller would have handled the computer inputs of the Learjet but he felt that the manual controller was busy.

The radar controller considered his workload to be moderate at the time. According to the radar log, during the 10 minutes preceding the near-collision, there were 11 targets, including those for TWA 37 and American 182, being processed for display in the Wayne sector. The controller indicated that, although TWA had been handed off to Chicago at 1918, the flight was under his control since it was still in his area of jurisdiction. He also stated that an aircraft is not turned over to another sector until it has been separated from known traffic.

The radar controller recalled that he last saw TWA 37 southeast of Carleton, when he handed the aircraft off to Chicago. He did not remember when he last saw American 182.

According to ATC records, about 1922 the radar controller was relieved by the third controller who had returned from lunch. Hereafter, the relieving controller will be referred as radar controller No. 2.

Both controllers stated that during the briefing associated with the transfer of duties TWA 37, the Learjet, and several other aircraft were mentioned but American 182 was not. Federal Aviation Administration (FAA) Handbook 7210.3C, Facility Management, stipulates that the relieving controller accept responsibility for the position only after assuring, to the extent possible, that the briefing is complete and that no unresolved questions concerning the operation of the position remain. The controller being relieved is responsible for the completeness and accuracy of the briefing.

Radar controller No. 2 made his first transmission at 1921:59; he did not communicate with the Learjet and made no computer inputs for that aircraft. He considered his workload to be light to moderate.

At 1922:52, radar controller No. 2 queried American 182 about its altitude. The flight reported its altitude (FL 347) and its weather observations. As soon as this 7-second transmission was completed, radar controller No. 2 cleared American 182 to descend immediately.

When asked what drew his attention to the traffic conflict the controller said that he was just scanning the radar and noticed that American 182's data block showed the aircraft to be at FL 345, and climbing to FL 370. TWA 37's data block showed that the flight was maintaining FL 350. The aircraft were at 12 o'clock to each other and about 3 to 4 miles apart.

When asked why he questioned the pilot of American 182 about his altitude before he issued a descent clearance, the controller stated that his first reaction was one of disbelief. In addition, he stated that since there might be a lag in the readout on his data block compared to the aircraft's actual altitude, he considered the possibility that the flight might have been higher than shown on his data block. He used the term "immediate" because he did not think that a normal descent would be adequate to resolve the traffic conflict. When he issued the clearance, the aircraft were about a mile apart; he then saw the targets merge and then separate.

The manual controller stated that during the period involved he was posting flight progress strips and entering flight plans into the computer. The flight progress strips of American 182 and TWA 37 were posted in the proper bays. He considered his workload to be light to moderate.

When the radar controller received a hand-off on the Learjet, he asked the manual controller if there was a flight strip for this aircraft in the Wayne sector. When it was discovered that there was none, the radar controller sent the manual controller to the sector through which the original flight plan would have taken the Learjet. The manual controller found the strip there and took it to the Wayne sector.

According to the manual controller, he was not aware of the radar controller's problems with entering the Learjet's revised flight plan into the computer. He became aware of the near-collision when he heard the clearance for an immediate descent.

Flight track information

Both aircraft were equipped with digital flight data recorders (DFDR).

One second after American 182 acknowledged the advisory to descent immediately, the aircraft's pitch attitude decreased from $+2.4^{o}$ to $+1.8^{o}$. Five seconds later, it had decreased to -10.9^{o} - the lowest value it reached.

The push-over manoeuvre resulted in vertical G forces below the normal force of gravity (1G) which lasted about 6 seconds and which reached a minimum of -.86G. This was followed within about 2 seconds by positive G forces with a maximum of +2.07 G's.

Thirty seconds after the evasive manoeuvre was started, the aircraft had reached FL 330. A maximum pressure altitude of 34 953 ft was reached 4 seconds after the downward pitch movement began. At this time (1923:11) TWA 37's pressure altitude was 34 965 ft (see Appendix A).

The NAS Stage A radar positions for the two targets were interpolated to 1/2-second intervals for the 20 seconds from 1923:00 to 1923:20. The interpolation showed that at 1923:16.5 the targets of TWA 37 and American 182 converged to within 0.108 NM. This figure is within the range of the resolution of the radar equipment which is specified to be accurate to 1/8 NM in range and about $1/10^{o}$ in azimuth. TWA 37 was reporting a constant flight level of 350 and American 182 reported FL 349 at 1923:08.0. At 1923:20.0 American 182's beacon reported FL 345.

The aircraft came closest at geographical co-ordinates $42^{o}02'32''$ N and $083^{o}58'00''$ W. This position is about 23 NM west of Carleton, Michigan, on J-584.

Injuries and damage

The seat belt sign had been on throughout the 45-minute flight of American 182. Meals and beverages were being served when the pilot-in-command began the push-over manoeuvre. During this manoeuvre, the flight attendants and service carts were thrown against the cabin ceiling by negative G forces. There passengers who did not have their seat belts fastened and one passenger who was adjusting her seat belt also were thrown against the overhead.

During the transition from negative to positive G conditions, all unrestrained persons, service carts, and other objects which had been momentarily pinned to the overhead, came down heavily and hit the floor, the other passengers, the cabin furnishings, and other equipment. The contents of the service carts were scattered throughout the cabin.

The 10 flight attendants received minor injuries; 14 passengers were injured, 3 of them seriously. The injuries to the flight attendants consisted of miscellaneous abrasions, contusions, lacerations, and sprains. Two of the three serious injuries consisted of fractured bones (compression fracture of a vertebra and a fractured humerus); the third was classified as serious because of the length of time the patient was hospitalized for a knee laceration. There were no injuries in the cockpit. The more serious injuries and the more extensive damage to the aircraft interior occurred in the centre and aft section of the cabin. Shattered plastic cups caused several lacerations.

After American 182 arrived in Detroit, American Airlines maintenance personnel inspected the aircraft to determine if any structural damage had resulted. No evidence of damage to primary structures or controls was found. The aircraft was then ferried to a maintenance facility for repair of the cabin interior. Damaged cabin furnishings included overhead panels, light fixtures, seats, seat tray tables, and oxygen panel covers. Seat belts did not fail. The mounting and support structures of all seats retained their integrity.

Other information

Both aircraft were certificated and maintained according to regulations. Both were equipped with high intensity discharge lights. The lights on TWA 37 were on and operating; those on American 182 were off since the aircraft was climbing through clouds.

No problems with the navigational aids or air-to-ground communications were reported.

The NAS Stage A automated system was functioning as programmed while American 182 and TWA 37 were operating in Cleveland Center airspace. There were three computer malfunctions on the day of the accident, two of which required the transfer to the older, standby equipment (broad-band radar). The Cleveland Center log of facility operations showed that the malfunctions occurred at 0935, at 1835, and at 1955; the last two involved the transfer to broad-band radar and lasted 9 and 5 minutes, respectively. The log did not contain an explanation of the malfunctions. The assistant chief in charge during the shift that the accident occurred stated that computer problems require the transfer to broad-band radar about once a shift.

No developmental controller training was being conducted at the Wayne sector during the duty shift involved.

The minimum required separation for aircraft operating above FL 290 is 2 000 ft vertically, or 5 miles, when using narrow-band radar. These criteria are specified in FAA Handbook 7110.9D, En-Route Air Traffic Control.

Two days after the accident, the Chief of Cleveland Center sent a letter to all Center personnel, on the subject of "Control Technique, Converging Transitional Traffic". The letter stressed the need to maintain vertical separation between converging aircraft when there is no positive assurance that the required vertical or lateral separation will exist when they pass each other. The letter also stated that the Cleveland Center had 20 system errors in 1975 and that 10 of the errors pertained to inadequate separation between en-route aircraft.

According to FAA, an ATC system error is defined as a human, equipment, or procedural failure that results in less than the required separation between aircraft. Preliminary data obtained from the FAA summarize the system errors as follows:

Year	Total System Errors	Near Midair Collisions
1972	313	19
1973	288	39
1974	340	26
1975 (Jan. Nov.)	278	21

The FAA supplied the following breakdown of system errors by causal factors:

HUMAN:	Percentage
Judgements	55
Communications	22
Attention	19
Procedures	0.6
Operations Management	0.6
	97.2
MACHINE:	2.7
	99.9

On 16 December 1975, the Chief of the FAA's ATC Operations and Procedures Division distributed a general notice (GENOT) to all ATC facility chiefs, stressing the human failure aspects of system errors and outlining methods for more positive control techniques.

On 8 December 1975, the Administrator, FAA, ordered all ARTCC's to programme the NAS Stage A computers with the conflict alert system as rapidly as possible. This system employs the computer to project the radar position of any controlled aircraft on a possible collision course with another controlled aircraft. In that case, visual indications of the two aircraft will flash to alert the controller that action may be needed. This system is now operational in all centres.

2.- Analysis and Conclusions

2.1 Analysis

A potential traffic conflict between American 182 and TWA 37 was evident when American 182 was handed off to Wayne sector of the Cleveland Center. Although the radar controller was aware of a potential conflict, he assumed that American 182 would have climbed to FL 370 before passing TWA 37, which was cruising at FL 350. In addition, he assumed that, by keeping an eye on the situation, he would be able to take timely steps if the anticipated separation did not materialize.

Both of these assumptions were not compatible with safe and positive traffic control practices and procedures. By the time the radar controller's first assumption was invalidated, his second assumption, intended as a safeguard, did not work as planned because other activities distracted him. The fact that he consented to be relieved from his position about 2 minutes before the near-collision proves that he had become preoccupied with secondary duties to the extent that he had failed to see the impending conflict that was clearly displayed on his radarscope by that time. The Safety Board believes that the principle lesson in this near disaster is that intent to separate traffic can never be a substitute for positive action at the first opportunity to ensure separation.

During the briefing associated with the transfer of duties to radar controller No. 2, the first controller did not mention American 182, undoubtedly because he was no longer thinking about the flight as an unresolved problem. Since radar controller No. 2 had no reason to expect that the responsibility he accepted included an acute problem, it is fortunate that he noticed the problem within 50 seconds after taking over the position. However, this timely discovery does not exonerate both controllers from their failure to notice the conflict during the transfer of duties. The Safety Board concludes that the briefing was incomplete because neither controller reviewed the actual situation as depicted on the PVD.

The general discussion about the cloud tops and other traffic that took place on the Wayne sector frequency probably prompted the pilot-in-command of American 182 to look outside and observe the weather. His remark, "There he is", 1 second before the controller issued the descent clearance, was undoubtedly prompted by aircraft lights he saw. Although the pilot-in-command's recollection is vague, his remark probably referred to the presumed sighting of the aircraft that, according to a prior statement by the controller, was flying at FL 370. Considering the darkness, the climbing attitude of his aircraft, the restricted visibility conditions, the high altitude, and the closing speed, it would have been difficult for the pilot-in-command to determine if a traffic conflict existed and, if so, what corrective action to take when he first sighted the lights. However, the sighting alerted him so that, when the controller issued the clearance, he was ready to execute the evasive manoeuvre with the necessary urgency.

The circumstances of this accident indicate that automation technology can lead to complacency when it takes the controller "out of the loop" by reducing the need for his interaction with a flight crew and de-emphasizing the co-operative aspects of the air traffic system. Had the radar controller been working with the broad-band radar, he would have been forced to take positive steps to ensure separation as soon as American 182 was handed off to him. Of the several steps he could have taken, we mention only two: 1) He could have stopped American 182's climb at FL 330, or 2) he could have asked the flight to report at FL 310 or 330. However, the automatic altitude read-outs on the flight's alpha-numeric block induced him to rely solely on his own observation of the PVD data. He did not consider the possibility that he might become distracted or that the computer might fail, and thereby deprive him of his direct read-out capability.

The Safety Board is concerned that despite the advantages of narrow-band radar, the ATC system failed to provide the intended safeguards and endangered the lives of 306 persons. Advances in technology do not necessarily ensure greater reliability and safety. The new conflict-alert system can serve its intended purpose only when it is not treated as a substitute for timely, positive separation measures which continue to protect air traffic even when the computer fails.

Based on the high percentage of human failures in the ATC system, the Safety Board believes that, as long as the human element is part of the total system, an individual's level of competence, the quality of his performance, and his understanding of his primary responsibilities must be given as much managerial attention as the equipment he operates.

The serious injuries sustained by the passengers were the result of their not having their seat belts fastened, or properly fastened, although the seat belt sign was on. Therefore, this accident is another reminder to encourage passengers to keep their seat belts fastened, not only when the seat belt sign is on but also when it is off and flight conditions are smooth.

2.2 Conclusions

a) Findings

1. American 182 and TWA 37 were operating under control of the Wayne sector of the Cleveland Center.

2. Both flights were on the same jet route and approaching each other head-on; TWA 37 was maintaining FL 350, American 182 was cleared to climb through FL 350 to FL 370.

3. The radar controller was aware that a potential traffic conflict existed between the two flights but assumed that the required separation would exist when the two aircraft passed each other.

4. The radar controller intended to provide separation if the anticipated separation between the two flights did not materialize.

5. The radar controller became preoccupied with secondary duties and failed to see the impending traffic conflict displayed on his radarscope.

6. About 1 minute before the near collision, the radar controller was relieved and he failed to brief the relieving controller adequately. Both controllers failed to notice the unresolved conflict during the transfer of duties.

7. About 50 seconds after taking over the position, the second controller detected the conflict and cleared American 182 to descend immediately to FL 330.

8. The two aircraft came within 100 ft of each other.

9. As a result of the abrupt evasive manoeuvre, 24 occupants of the aircraft were injured, 3 of them seriously; the latter injuries were associated with failure to make proper use of the seat belt.

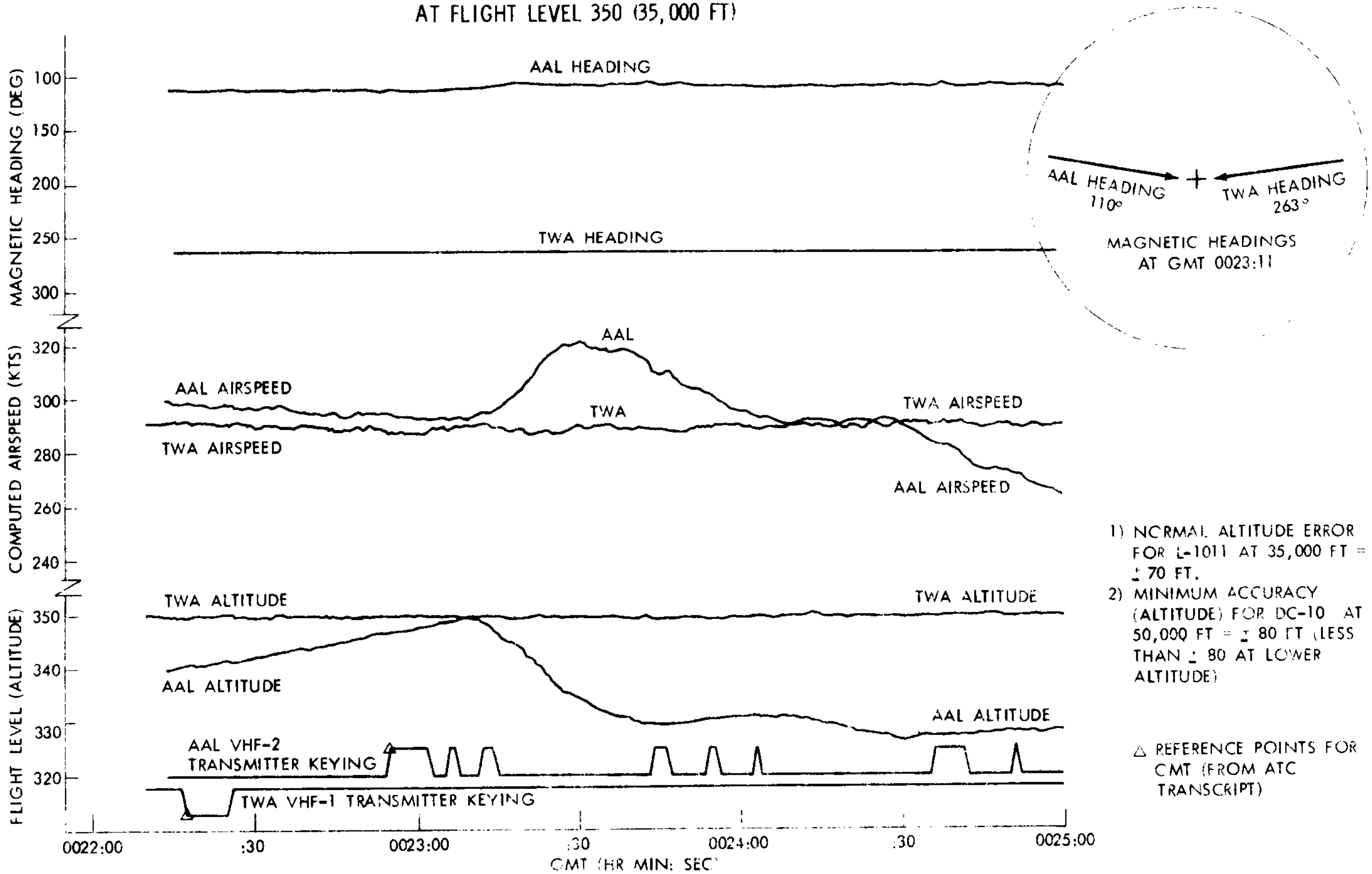
b) Cause or Probable Cause(s)

The National Transportation Safety Board determines that the probable cause of this near-collision was the failure of the radar controller to apply prescribed separation criteria when he first became aware of a potential traffic conflict, which necessitated an abrupt collision avoidance manoeuvre. He also allowed secondary duties to interfere with the timely detection of the impending traffic conflict when it was displayed clearly on his radarscope. Contributing to the accident was an incomplete sector briefing during the change of controller personnel - about 1 minute before the accident.

ICAO Ref.: AIG/429/75

APPENDIX A

AMERICAN AIRLINES DC-10, N124, FLIGHT 182
TRANS WORLD AIRLINES L-1011, N11002, FLIGHT 37
NOVEMBER 26, 1975 NEAR COLLISION
23 NMI W OF CARLETON VORTAC, MICHIGAN
AT FLIGHT LEVEL 350 (35,000 FT)



- END -

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

International Standards and Recommended Practices are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications contained in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

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The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

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Air Navigation Plans detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

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