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FOREWORD

Accident investigation is recognized today as one of the fundamental elements of improved safety and accident prevention. Nearly every accident contains evidence which, if correctly identified and assessed, will allow the cause to be ascertained so that corrective action can be undertaken to prevent further accidents from similar causes. Thus, the ultimate object of accident investigation and reporting, which is to permit the comparison of many accident reports and to observe what cause factors tend to recur, can be accomplished. These factors can then be clearly identified and brought to the attention of the responsible authorities.

The Accident Investigation Division of the Air Navigation Committee of PICAO* at its first session in 1946 recommended that States forward copies of reports of aircraft accident investigations and inquiries, and aeronautical publications and documents relating to research and development work in the field of aircraft accident investigation, to PICAO in order that the Secretariat might appraise the information gained and disseminate the knowledge to Contracting States.

The world-wide collection by ICAO of accident reports and aeronautical publications and documents relating to research and development work in the field of aircraft accident investigation, and publication of the material in condensed form, assists States and aeronautical organizations in research work in this field. By stimulating and maintaining continuity of interest in this problem the dissemination to individuals actively engaged in aviation of information on the actual circumstances leading up to the accidents and of recommendations for accident prevention also contributes to the reduction of accidents.

The first summary of accident reports and safety material received from States was issued in October 1946 (List No. 1 Doc 2177, AIG/56) under the title of "Consolidated List of publications and documents relating to Aircraft Accident Investigation Reports and Procedures, Practices, Research and Development Work in the field of Aircraft Accident Investigation received by the PICAO Secretariat from Contracting States". This was followed by further summaries at regular intervals, the last report being issued on 31 July 1950 (List No. 12, Doc 7026, AIG/513). These summary reports were found to be of considerable technical interest to States, and in view of the large number of requests for copies, it was decided, early in 1951, to revise the method of publication and to produce the material in the future in the form of an information circular entitled "Aircraft Accident Digest".

The first Digest was issued in 1951 under the present title and with the new method of presentation. Since then, the usefulness of the series has continued to elicit favourable comment from the aeronautical world.

However, late in 1964, the Secretariat carried out a study of the problems associated with the publication of the Digest and considered various methods which, it was thought, would lead to a more rapid dissemination of accident reports forwarned to ICAO for release in summarized form in the Digest. These studies also consider amending the presentation of the summaries with a view to producing them in a more

*Provisional International Civil Aviation Organization.

standardized manner. Accordingly, the Secretariat prepared a uniform plan using fixed subject headings, in an agreed order and with standard paragraph numbering, to enable readers to extract pertinent information more readily, according to their particular interests. This plan was submitted to the Third Session of the Accident Investigation Division - Montreal, 19 January - 11 February 1965 - for its consideration and development. The meeting accepted the concept of a uniform plan but modified the details. Commencing with this issue, Digests are being prepared in accordance with the final version of the uniform plan, as approved by the Council. This plan for the "Summary of Accident Report" appears in Appendix 3 of Annex 13 - Aircraft Accident Inquiry - (Second Edition).

It is hoped that States will co-operate to the fullest extent permitted by their national laws in submitting material for the Digests in accordance with the provisions of paragraphs 6.3 and 6.4 of Annex 13. It is recognized that investigations take a diversity of forms under the variety of constitutional and juridical systems that exist throughout the Contracting States of ICAO and that, for this reason, accident investigation presents one of the most difficult problems of standardization in international civil aviation. At the same time it is a most fruitful source of material for the attainment of the objectives of the Chicago Convention.

The usefulness of such a publication as this is directly proportional to the thoroughness with which accidents are investigated, the frankness and impartiality of the findings, and the readiness with which they are disclosed and authorized to be published. It is in this way only that this most fertile field for international co-operation can be effectively exploited. The measure of interest that this publication has aroused, and the vital information it imparts amply demonstrate the possibilities of ultimate achievement when every accident is investigated with the greatest thoroughness and the findings disclosed with complete frankness.

Restriction upon reproduction in the Digest seriously impairs, of course, the usefulness of any reports, as it is only by comparison between the circumstances that occasioned the accident and the circumstances of other operations that potentially hazardous circumstances can be foreseen and avoided. Names of persons involved may, however, be omitted without detracting from the value of the report.

Follow-up action and other supplementary information or comments on an accident report by the State of Registry or State of Occurrence provide useful material for inclusion in the Digest.

Whenever possible, photos and diagrams have been obtained for illustration purposes in order to give a clearer overall picture of the crash area, an idea of the probable flight paths of aircraft, the location of witnesses to the crash, and in general to make the reports more interesting to the reader.

Part II of this Digest dealing with Aircraft Accident Statistics is based on material derived from the Air Transport Reporting Forms G submitted by States and other sources. (For further review of material included refer to the Introduction, page 208).

Part III contains accident prevention articles and bulletins, and includes material pertaining to the following subjects: survival, approach speed control and stopping under adverse conditions.

Part IV presents a list of laws and regulations of States containing provisions relating to aircraft accident investigation. It replaces the list which appeared in Accident Digest No. 14 and includes all amendments to that list received by ICAO up to 9 January 1967.

The material for this Digest has been obtained from various sources, is printed for information only and does not necessarily reflect the views of the International Civil Aviation Organization.

Digests are now published twice yearly at approximately six-monthly intervals. The first volume contains summaries and air safety articles. The second volume, in addition to containing further summaries, provides other accident data such as classification tables, statistics, lists of laws pertaining to accident investigation and air safety articles.

COMMENTS ON ACCIDENT SUMMARIES AND CLASSIFICATION TABLES - 1963

Forty-five accident reports are summarized in Volumes I and II of Digest 15 because they satisfy one or more of the following criteria:

1) World-wide interest in the accident, due to either

   a) major disaster aspect which resulted in wide publicity, or
   b) special nature of the accident and possibility of remedial action;

2) Suitability of the original report for preparation of a summary;

3) Interest as an example of good accident investigation practice.

Among these forty-five summaries, one is a summary of the report of an accident to a C-46F of Trans American Air Transport which occurred in Argentina on 17 May 1960 (Volume I, Summary No. 6) and the classification of this accident appears at the end of the summary. The other forty-four are summaries of reports of accidents which occurred in 1963; they include 39 accidents during commercial air transport operations, one accident during a training flight (Volume I, Summary 1), one accident during a test flight (Volume II, Summary 7) and three accidents during ferry flights (Volume I, Summary 13 and Volume II, Summaries 1 and 2*). Although these five summaries do not appear in classification tables A and B, they have been classified according to pages 16 - 20 of the ICAO Manual of Aircraft Accident Investigation - Doc 6920-AN/855/3 (Third Edition), and the classifications appear at the end of each summary concerned.

The accidents which occurred during commercial air transport operations may be classified as follows:

Scheduled operations	29
International	10
Domestic	19
Non-scheduled operations	9
International	3
Domestic	6
Total	38**

The classifications in tables A and B follow closely the suggestions contained in the ICAO Manual of Aircraft Accident Investigation. They have, however, been based on accident reports founded on a variety of reporting and analysing techniques. Only a

* Collisions between aircraft are normally counted as two accidents. However, one collision appearing in this Digest has been counted as a single accident. In this instance one of the aircraft involved was a military aircraft (Volume II, Summary 2).

** No information regarding the type of operation was contained in one report. (Volume II, Summary 13) portion of the total number of accidents investigated by States is either released for general publication or sent to ICAO. Due to the smallness of the total samples (39) no attempt has been made in this publication to prepare classification tables according to the type of operation being conducted, for instance, whether scheduled or non-scheduled; and no differentiation is made between accidents occurring on domestic and on international flights. However, a notation on the type of operation being conducted, where known, is included in Table A. While the tables may serve a useful purpose in indicating causal trends, the numbers are too small to be significant for statistical purposes and readers are warned not to place too much reliance on the trends so indicated without comparison with other sources, such as those published by other international organizations and national administrations.

Although considerable care has been taken in drawing up Table A to ensure that the classification conforms with the findings of the reports from States, the very brevity of the table might give a wrong impression in some instances. The reader is, therefore, always invited to refer to the summary in the Digest and, if necessary, the report from which it is derived.

A survey of the 39 commercial air transport accident summaries for 1963 suggests that the following features are worthy of attention:

i) 44% of the accidents occurred during the approach and landing stages. This is 2% less than the figure which was shown for 1962 landing accidents. Of these 25% were undershoot accidents, 12% were due to loss of control and another 12% were due to collision with trees. The remaining 51% were due to various types of accidents.

ii) 33% of the accidents occurred en route. Of these 46% were collisions with rising terrain and 15% were airframe failures in the air. Severe turbulence in a mountain wave caused two accidents. There were two instances of navigation error.

iii) 23% of the accidents took place during take-off. Loss of control accounted for 33% and 22% were airframe - air.

TABLE A. - ACCIDENT CLASSIFICATION - 1963 (based on phase of operation)

Phase* of Operation	No.	Type of Accident	No.	Description	Type** of Operation	Digest 15 Vol. I Summary No.	Digest 15 Vol. II Summary No.
Take-off (23%)	9	Ground loop	1	Loss of control during an attempt to ground-loop the aircraft after the take-off was abandoned for undetermined reasons.	S	7	
		Overshoot	1	Believing that the elevator control system was defective, the pilot abandoned the take-off at a speed and position on the runway which made it impossible to stop the aircraft on the runway length remaining.	S		6
		Stall	1	Destruction of essential parts of the aircraft structure by a fire resulting from over-heating of brakes during taxiing.	S		20
		Loss of control	3	Loss of control during an attempted take-off into a severe thunderstorm.	S	18	
				Probable emergency following a simulated three-engine condition after take-off.	NS		4
				Undetermined. An unprogrammed extension of the pitch trim compensator was the most probable cause for the pilot's having applied nose-down trim which initiated the chain of events that culminated in the crash.	S		8
		Airframe - Air	2	Contamination of the lubrication system in the aft transmission assembly caused fatigue failure of the drive quill shaft.	S	19	
				The unfavourable interaction of severe vertical air draughts and large longitudinal control displacements which resulted in a longitudinal "upset" from which a successful recovery was not made.	S		11
		Emergency condition Engine failed - take-off	1	Following a malfunctioning of the port engine, the pilot abandoned the take-off but could not stop the aircraft on the remaining portion of the runway.	S	5	
En route (33%)	13	Collision - aircraft - both airborne	1	The Viscount descending under IFR struck the C-47 returning VFR from a training detail from the rear at an angle of 40°.	S&M	8	
		Collision - rising terrain	6	The pilot flew the aircraft into a prohibited sector at too low an altitude and did not check his navigation sufficiently when flying on instruments near a mountain.	S	9	
				VFR flight was attempted in marginal weather conditions below the minimum altitude indicated in the flight plan.	S	14	
				Navigation error - various factors contributed	NS		9
				A strong downward current in the lee of a mountain range carried the aircraft below the level of the crests where, under the conditions prevailing at the time, it encountered an area of extreme turbulence in which the pilot could not regain effective control and recover height.	S		14
				Navigaton error.	S		16
				Various causes.	S		17
		Stall	1	Possible malfunction of the autopilot or failure of the electrical power.	S		21

* Percentages are based on the total number of 1963 accidents classified - 39

** S - Scheduled NS - Non-scheduled M - Military

TABLE A. - ACCIDENT CLASSIFICATION - 1963 (based on phase of operation) (Contd)

Phase* of Operation	No.	Type of Accident	No.	Description	Type** of Operation	Digest 15 Vol. I Summary No.	Digest 15 Vol. II Summary No.
En route (33%) (contd)		Airframe - Air	2	Fatigue failure of the front eyebolt on the left wing strut.	unknown		13
				Structural failure of the aircraft following overstressing as a result of loss of control, caused by improper rigging of bungee system or autopilot.	S		18
		Turbulence	1	The aircraft encountered severe turbulence in a mountain wave.	S	20	
		Emergency condition - forced landing	1	Pilot-in-command failed to effect a proper and timely assessment of the situation when the front master rod bearing of No. 2 engine failed during flight.	NS	15	
		Undetermined	1	Not sufficient evidence available to determine the probable cause of the accident.	NS	12	
Landing (44%)	17	Ground loop	1	Pilot switched lights on when landing in fog and visual reference was lost. An unintentional change of direction resulted.	S	2	
		Wheels-up landing	1	Failure of pilot to maintain a positive rate of climb and the premature retraction of the landing gear during a go-around in fog.	S		15
		Gear collapsed	1	Failure of a component of the nose gear during a flapless landing. Probable contributing factor - a local weakening of the component.	S	22	
		Undershoot	4	Continuation of an instrument approach after adequate visual reference was lost below authorized minima.	NS	3	
				Pilot-in-command failed to maintain the approved minimum altitude on approach. Contributing factor - co-pilot did not monitor the final stages of the approach.	S	23	
				On final approach, the pilot failed to execute the approved instrument entry procedure and the aircraft struck trees.	S		10
				Wrong indication of pilot's altimeter.	S		22
		Overshoot	1	Improperly executed approach and landing procedures during an emergency single-engine operation.	NS	17	
		Collision - object - tree	2	Descent below a safe approach path during an ILS approach without use of the glide path at night in low cloud.	NS		3
				Exceptionally bad weather and possibility of flash of lightning having temporarily blinded or incapacitated the crew.	S		19
		Stall	1	Following an emergency warning the pilot feathered No. 2 engine and used improper procedure when unfeathering it. This resulted in the windmilling of No. 2 engine and it was impossible to maintain altitude.	S	21	
		Loss of control	2	While aircraft was turning in severe, turbulent and rainy conditions, loss of control occurred.	S	11	
				An undetected accretion of ice on the horizontal stabilizer which, in conjunction with a specific airspeed and configuration, caused a loss of pitch control.	S		5

* Percentages are based on the total number of 1963 accidents classified - 39
** S - Scheduled NS - Non-scheduled

TABLE A. - ACCIDENT CLASSIFICATION - 1963 (based on phase of operation) (Contd)

Phase* of Operation	No.	Type of Accident	No.	Description	Type** of Operation	Digest 15 Vol. I Summary No.	Digest 15 Vol. II Summary No.
Landing (44%) (contd)		Fire and explosion in flight	1	Lightning-induced ignition of the fuel/air mixture in the No. 1 reserve fuel tank with resultant explosive disintegration of the left outer wing and loss of control.	S		12
		Propeller failure	1	Improper maintenance practices and inspection procedures resulted in a propeller power unit malfunction and inflight reversal of No. 3 propeller.	NS	16	
		Emergency conditions - forced landing	1	Improper handling of an emergency situation precipitated by a mechanical malfunction. Also, radar approach control failed to provide complete, accurate airfield data.	NS	4	
		Other - left the taxiway	1	Because of improper braking and poor tire grip on the wet runway, the aircraft reached the end of the runway at an excessive speed. Also, there was an insufficient steering effect of the nose wheels.	S	10	

* Percentages are based on the total number of 1963 accidents classified - 39
** S - Scheduled NS - Non-scheduled

TABLE B. - ACCIDENT CLASSIFICATION - 1963 (based on accident causes)

Causal Factor	No.	Description	No.	Digest 15 Vol. I Summary No.	Digest 15 Vol. II Summary No.
Pilot (44%)*	17	misjudged distance	2	17, 23	
		failed to observe aircraft	1	8	
		improper IFR operation	6	9	3, 10, 15, 16, 17
		improper in-flight planning	5	4, 15, 21	6, 9
		continued VFR into unfavourable weather	1	14	
		continued into known unfavourable conditions	1	3	
		improper use of miscellaneous equipment	1	2	
Power plant (8%)	3	engine structure	1	19	
		propeller and propeller accessories	2	5, 16	
Airframe (8%)	3	flight control system	1		18
		wing	1		13
		essential parts	1		20
Landing gear (2%)	1	nose gear	1	22	
Equipment and accessories (2%)	1	instrument - altimeter	1		22
Weather (21%)	8	turbulence in flight	3	11, 20	11
		thunderstorm	2	18	19
		icing conditions	1		5
		lightning	1		12
		downdraught	1		14
Airport terrain (2%)	1	runway partially wet	1	10	
Undetermined (13%)	5	-	5	7, 12	4, 8, 21

* the percentages are based on the total number of 1963 accidents classified (39)

PART I

SUMMARIES OF AIRCRAFT ACCIDENT REPORTS

No. 1

Purdue Aeronautics Corporation, DC-3, N 386T, accident at Morgantown, West Virginia, U.S.A., on 29 November 1963. Civil Aeronautics Board (U.S.A.) Aircraft Accident Report, File No. 1-0017, released 19 November 1964.

1. Investigation

1.1 History of the flight

The aircraft departed Purdue University Airport, Lafayette, Indiana at 0836 hours central standard time and was being ferried to the Municipal Airport, Morgantown, West Virginia where it was to take on passengers for a charter flight. According to its instrument flight rules flight plan it was to cruise at 5 000 ft, however, this was later changed to 7 000 ft. The aircraft flew above cloud until it encountered light rain en route at which time the crew went on instruments, and 25° of carburettor heat were applied. During the flight the pilot-in-command noted a difference of about 15° between the magnetic compass and the remote indicating compass. Having reviewed the instrument approach charts for the Morgantown Airport he decided to make a VOR approach and selected the VOR/DME approach chart. On the depiction of the final approach course from the VOR station to the airfield he noted a position called "DECK* or 3.5 miles", took a cross bearing on this point from the Grantsville VOR and selected the 273° radial of this station to give him an indication of passing "Deck". When approaching Morgantown, the Cleveland Air Route Traffic Control Centre (ARTCC) gave the flight the 1035 hour weather observation for Morgantown and immediately cleared it for an ADF approcah. Shortly thereafter, when requested, ARTCC cleared the flight for a VOR approach. At 1052, the latest altimeter setting of 29.43 was provided to the flight by the Morgantown Flight Service Station. The flight departed the VOR, outbound to the procedure turn, at 5 000 ft descending to 4 000 ft, which was maintained until the procedure turn was completed and the aircraft was inbound to the VOR, at which time the flight descended to 3 000 ft. The co-pilot was flying the aircraft while the pilot-in-command, with the approach chart in his lap, monitored his flying technique. The co-pilot's VOR receiver was tuned to the Morgantown VOR with the 337° radial selected, and the pilot-in-command's VOR receiver was tuned to the Grantsville VOR with the 273° radial selected. After passing the VOR inbound the pilot-in-command instructed the co-pilot to descend to 2 400 ft. The altitude was maintained between 2 450 and 2 500 ft and because of a cross-wind from the right, a heading of 345-350° was required to maintain a track of 337°. About 2-1/2 minutes after passing the VOR inbound the pilot-in-command's VOR indicator centred. He told the co-pilot to "ease it down", turned on the windshield wipers; and advised the co-pilot that the minimum altitude was 1 856 ft. The last altitude the pilot-in-command recalled seeing on the altimeter was 2 200 ft. Trees suddenly appeared, and the pilot-in-command pulled the yoke back, but the aircraft struck the trees nose-high and crashed at 1110 hours, 2.5 NM from the Morgantown VOR, on the 340° radial.

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* A fix along the final approach course at Morgantown beyond which DME-equipped aircraft may descend to minimum instrument approach altitude.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1		
Non fatal	2		
None			

1.3 Damage to aircraft

The aircraft was damaged beyond repair.

1.4 Other damage

No objects other than the aircraft sustained damage.

1.5 Crew information

The pilot-in-command, age 50, held a valid air transport pilot's certificate and was qualified to fly DC-3 aircraft. He had flown a total of 23 553 hours including 3 899 hours on the DC-3. He had never had any formal training on the type of approach charts he was using on this flight, however, he had used them in the course of his duties for more than two years before the accident. He held a valid first-class medical certificate with the limitation that he wear corrective glasses while exercising the privileges of his airman's certificate.

The co-pilot, age 21, held a valid commercial pilot's certificate with instrument and DC-3 ratings. He had flown a total of 966 hours which included 207 hours on the DC-3. He held a valid second-class medical certificate with no limitations or waivers.

The stewardess, age 19, had qualified to fly in that capacity on DC-3 aircraft on 1 November 1963. She was fatally injured in this accident.

The flight crew testified that they had adequate rest before the flight and that neither of them had taken any medications before take-off or been under a doctor's care.

1.6 Aircraft information

The aircraft had flown a total of 12 241 hours which included 126 hours flown since the last major inspection. On the morning of the flight the aircraft was given a pre-flight inspection by the Chief Inspector of the Company. No maintenance was required or performed. Also, the aircraft underwent a visual inspection by the crew prior to take-off, and no discrepancies were noted.

There were no passengers or cargo aboard the aircraft and the weight and centre of gravity were within the prescribed limits.

The visual inspection included a fuel check which showed that 794 gal of fuel were aboard, however, the type of fuel being used was not stated in the report.

1.7 Meteorological information

Both pilots checked the weather reports and forecasts prior to the flight, and the pilot-in-command received a comprehensive briefing from the Federal Aviation Agency personnel assigned to the Lafayette Flight Service Station.

As stated, when approaching Morgantown the flight was provided with the 1035 hour weather observation which was as follows: ceiling: 600 ft, broken clouds; visibility: 1-1/2 miles in light rain and fog; wind: from the north at 10 kt. He also received the 1036 Morgantown weather which was about the same.

The daytime minima for instrument approaches to Morgantown Airport are:

ADF	600 ft ceiling, 1 mile visibility
VOR/DME	600 ft ceiling, 1 mile visibility
VOR	1 400 ft ceiling, 1 mile visibility

By 1057 the altimeter setting was reported as 29.43 in. Hg and the temperature and dew point were 40° F.

Eight minutes after the accident a special observation was taken which indicated the following: "... balloon ceiling, 600 ft broken, 800 ft overcast, visibility 2 miles, light rain, fog, wind north 12 kt, gusts 20 kt, altimeter setting 29.42, ceiling ragged. These conditions were essentially as forecast and given by the Flight Service Station personnel to the pilot prior to take-off.

The accident occurred in daylight.

1.8 Aids to navigation

The following aids were available: ADF, VOR and DME, and there was an NDB north of the airport.

A flight check of the facilities at Morgantown was performed within 24 hours after the accident and revealed no discrepancies. No attempt was made to ascertain the position of "Deck" by radial presentment from the Grantsville VOR as it was not a suggested or approved procedure. During the flight checks it was found that the terrain clearance between the VOR and the airport did not conform to the criteria established by the United States Manual of Criteria for Standard Instrument Approach Procedures.

A few days after the accident a flight check, consisting of three VOR approaches, was made using an FAA DC-3 aircraft. The approaches were conducted utilizing the 337° radial of the Morgantown VOR and the 273° radial of Grantsville VOR. After passing Morgantown VOR at 3 000 ft amsl inbound to Morgantown Airport on the 337° radial, a descent to 2 400 ft amsl was begun. Immediately the Grantsville VOR signal strength dropped below tolerance causing unreliable course indications. One approach was made maintaining 3 100 ft amsl from the Morgantown VOR to the Morgantown Airport along the 337° radial. The Grantsville VOR signal strength was satisfactory throughout the approach and the 273° radial of Grantsville crossed the 337° radial of the Morgantown VOR at a point 4 NM from the Morgantown VOR transmitter. The 4 NM point was an average due to slight roughness of the Grantsville signal. It is noted that 1° at 37 NM (the distance from "Deck" to Grantsville) is about 0,649 NM in width.

The radio equipment aboard the aircraft consisted of VOR and ADF navigation receivers. No DME equipment was installed in the aircraft.

1.9 Communications

The aircraft carried VHF communication transceivers. The flight was in contact with the Morgantown Flight Service Station during the approach, and no difficulties were reported.

1.10 Aerodrome and ground facilities

The ground (navigational) facilities at Morgantown are discussed in paragraph 1.8. No other information concerning Morgantown Municipal Airport was contained in the report.

1.11 Flight recorders

No mention of flight recorders was made in the report.

1.12 Wreckage

It was located 2.5 NM from the Morgantown VOR on the 340° radial oriented along a line 340° magnetic. It was determined that the aircraft first struck trees at an altitude of 2 040 ft amsl, then proceeded 230 ft and struck other trees at about 2 050 ft amsl. The first ground impact was 320 ft further along the wreckage path, and the fuselage came to rest 550 ft from the first trees struck.

1.13 Fire

Fire broke out following impact.

1.14 Survival aspects

The stewardess, who was fatally injured, was found in the aft cabin.

1.15 Tests and research

Wreckage examination revealed no discrepancies in the aircraft, powerplants, or aircraft systems which might have contributed to the accident. The pilot-in-command's altimeter was set at 29.43 and the co-pilot's at 29.44 in. Hg. (The altimeter setting at Morgantown Airport at the time of the accident was 29.43.) There was no evidence of instrument difficulties except the 15° difference between the magnetic compass and the remote indicating compass. Bench checks showed that the altimeters, the vertical speed indicator and the VOR receivers were operating satisfactorily.

2. Analysis and conclusions

2.1 Analysis

The instrument approach procedure charts current at the time of the accident were reviewed. They revealed that straight-in approaches from the VOR to runway 36 were not authorized. ADF approaches made from the NDB north of the airport could be made straight-in to runway 18, or circling to any runway. However, the ADF approach minima were the same for straight-in or circling approaches.

The pilot-in-command explained that he selected the "VOR/DME" approach chart because he wanted to make a VOR approach so he could "tie down the radial" and that "with a difference of 15° between the two compasses we could not be positive of our track making an ADF approach under these conditions". He further stated that he thought of "the VOR/DME chart as two approaches on one chart, similar to an ILS/ADF chart". Because the VOR/DME chart had a later date than the VOR chart he said he thought the VOR chart was obsolete. The pilot-in-command also testitied that he did not see the note indicating "if aircraft not equipped with operational VOR and DME equipment, procedure not authorized", which was printed on the chart.

Confusion in the pilot-in-command's mind as to the meaning of the designation VOR/DME on the chart, coupled with his lack of familiarity with the type of charts furnished for his use, led him to select an approach procedure for which the aircraft was not instrumented. The approach charts had been authorized for use by the FAA. All the required information, including a note that operational DME equipment was required in the aircraft, was displayed on the chart. However, either due to the location or format of the note the pilot-in-command did not see it.

The air traffic control procedures utilized by the ARTCC controller were compared with those contained in the then current FAA Air Traffic Control Procedures manual. A review of the transcript of the radiocommunications between ARTCC and the crew indicated that the controller did not advise the crew, as he should have done, that the reported weather was below the published minima for the chosen approach. The FAA controller made the same type of error as the crew. He testified that when he received the request for the VOR approach from the crew he checked his sector binder, saw a U.S. Coast and Geodetic Survey (C and GS) approach chart with a southeast procedure turn, and read the minima of 600 ft and one mile. He believed that this was the VOR approach chart. However, the controller identified the VOR/DME chart as the one which he had used to determine the minima. The Board believed that had the controller noted this discrepancy and used the VOR approach chart to check the minima he would have advised the crew that the weather was not suitable for a VOR approach.

The pilot-in-command's attempt to use a radial from the Grantsville VOR to establish the location of "Deck" shows a lack of understanding, on his part, of the display of navigational information on the approach chart he was using, as well as the inherent limitations on the use of a VOR station. He took no cognizance of the effect of distance and terrain on the emissions of very high frequency radio transmitters which broadcast essentially on a line of sight basis. His inability to differentiate between instrument centring brought about by weak signals, as opposed to a course interception, coupled with an inaccurate estimate of his ground speed to give him an erroneous position indication.

The apparent passing of the "Deck" fix was compounded by the pilot-in-command's lack of knowledge regarding the head wind in the approach area. At the time he believed he was at the "Deck" fix, 3.5 NM from the VOR, he had actually travelled only 2.5 NM. He stated that he had begun his timing after passing the cone of ambiguity over the VOR.

The aircraft crashed on the 340° radial of the VOR rather than the 337° radial which put it about 1/2 NM right of the centre line of the approach radial. Had the aircraft been on track it would have cleared all terrain between the VOR and the airfield. Furthermore, had the minimum altitude for the approach been established as it is now, the aircraft would have cleared the terrain en route to the airport, even though it was not exactly on track.

2.2 Conclusions

Findings

The crew were physically fit and properly certificated for the flight.

A pre-flight inspection of the aircraft was carried out on the morning of the subject flight, and the aircraft also underwent a visual inspection by the crew prior to take-off. No discrepancies were noted. The weight and centre of gravity of the aircraft were within the prescribed limits.

There was no malfunction of the aircraft, the powerplants or the aircraft systems.

The weather services provided to the crew and controller were adequate. At the time the approach was attempted, the weather was satisfactory for either an ADF or a VOR/DME approach; however, it was below minima for a VOR approach.

The navigational equipment, both on the ground and in the aircraft, was operating satisfactorily.

The pilot-in-command was not certain as to the meaning of the designation VOR/DME on the approach chart and had limited experience on the type of charts being used. This caused him to select an approach procedure for which the aircraft was not instrumented.

He could not differentiate between instrument centring brought about by weak signals as opposed to a course interception. This, combined with an inaccurate estimate of his ground speed, gave him an erroneous position indication. He also was not aware of the head wind in the approach area. The aircraft descended into trees during the instrument approach and caught fire.

Cause or
Probable cause(s)

The probable cause of this accident was the pilot's execution of an instrument approach in an aircraft not equipped with navigational instrumentation appropriate to the ground facilities being used.

3. Recommendations

No recommendations were contained in the report.

4. Action taken

Following the accident a card was prepared for each sector position at the Air Route Traffic Control Centre (ARTCC) which depicts the minima for each instrument approach procedure in the sector.

An FAA witness testified that the terrain altitude information used to prepare the original VOR/DME approach chart was taken from a U. S. Geological Survey quadrangle chart dated 1931. During the investigation of this accident the FAA became aware that more recent charts depicted higher terrain elevations in the approach area at Morgantown. As a result of this information and the observation of higher than reported terrain in the area between the VOR and the airport it was found that the terrain clearance between the VOR and the Morgantown Airport did not conform to the criteria established by the United States Manuel of Criteria for Standard Instrument Approach Procedures, the minimum altitude between the VOR station and the "Deck" fix was raised from 2 400 to 2 700 ft amsl.

FAA witnesses further testified that the minimum crossing altitude at the VOR station was increased from 3 000 ft to 3 300 ft amsl under the provision of Civil Air Regulations amendment 60. 21/29. This amendment was promulgated to provide an additional 500 ft of VFR airspace below the floor of controlled airspaces for use by VFR flights.

Following the accident the C & GS VOR/DME approach chart for Morgantown was changed to reflect the higher minimum altitudes. Also, "VOR/DME" was printed on the face of the chart above the note that indicates the "... approach authorized only for aircraft with installed operational VOR and DME equipment." The approach chart used by the carrier had, and still has, a "Note 1. If aircraft not equipped with operational VOR and DME equipment, procedure not authorized." The pilot-in-command of the subject flight stated that he did not see this note until after the accident occurred.

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Non-commercial ferry flight, domestic
Landing
Undershoot
Pilot - improper IFR operation

ICAO Ref: AR/850

No. 2

Delta Air Lines, Inc., DC-7, N 4875C collided, while taxiing, with U.S. Air Force C-123B, AF 540589 at Memphis Municipal Airport, Memphis, Tennessee U.S.A. on 13 January 1963. Civil Aeronautics Board (U.S.A.) Aircraft Accident Report, File No. 1-0001, released 29 October 1964.

1. Investigation

1.1 History of the flight

Delta Air Lines Flight 8715 was to be a domestic ferry flight from Memphis, Tennessee to Jackson, Mississippi. Five crew members were aboard the aircraft when the engines were started for the IFR flight to Jackson. The hydraulic pressure was normal (3 000 psi), and the wing flaps were lowered to 30° prior to taxi. Shortly after 0229 hours central standard time, Memphis Ground Control gave taxiing instructions to the flight. While taxiing out the flaps were raised to the take-off setting of 20°. During the taxiing neither the flight engineer nor the co-pilot monitored the hydraulic system pressure gauge at any time. Shortly thereafter the flight asked Memphis Ground Control, "... do you want us to go all the way down the east-west or cross over the west?" Memphis Ground Control replied, "Turn right ahead taxi east past the north-south and after you pass the north-south runway turn left the second taxiway and taxi parallel to the east-west and hold short of two seven at the end." The flight acknowledged the message. The aircraft proceeded east on runway 9 to taxiway D where it made a left turn to the north. When the position of the aircraft on taxiway D was detected by the ground controller he initiated the following message, "... turn right on the ramp ahead and taxi east and hold short of two seven at the end." The flight did not acknowledge this message. Shortly thereafter the ground controller saw a C-123B aircraft in the landing light beam of the DC-7, and he transmitted a message to the latter warning it to use caution when taxiing on the military ramp. The message was not acknowledged. The flight engineer stated that while the aircraft was proceeding north on taxiway D he heard the pilot-in-command exclaim, and he understood this to mean he had lost power. However, the engines were operating normally, and he realized that the pilot-in-command could not steer the aircraft.

The flight engineer and the co-pilot testified that the pilot-in-command then pulled the reverse throttle lock release aft and down and pulled the throttles into the reverse range. After a few seconds, when the propellers were slow going into reverse, he moved them out of reverse range into normal idle range just a few seconds before 0233 hours central standard time when it collided with the left wing of a C-123B, which was parked on taxiway D. The left wing rear spar of the C-123B penetrated the upper nose section of the DC-7 slightly below the pilot-in-command's windshield. A portion of this spar broke off, and the remainder of the wing was deflected upward and over the top of the DC-7. When the spar penetrated the nose section, it collapsed the instrument panel, sheared the control yoke and impaled the pilot-in-command.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1		
Non fatal	3		
None	1		

No one was aboard the C-123B at the time of the collision.

1.3 Damage to aircraft

Damage to the DC-7 was confined generally to the nose section and cockpit interior.

The C-123B was extensively damaged.

1.4 Other damage

No damage was sustained by objects other than the two aircraft.

1.5 Crew information

DC-7

The pilot-in-command, age 42, had flown a total of 15 707 hours which included 3 250 hours in DC-6/7 aircraft. He held a valid airline transport pilot's certificate with numerous ratings including one for the DC-7. His last line check on the DC-7 was on 3 April 1962, and his last proficiency check on 16 November 1962 was on a Convair 440 aircraft. He satisfactorily passed a first-class FAA flight physical on 23 December 1962, without waivers.

The co-pilot, age 28, had flown 2 979 hours as a pilot and 1 742 hours as a flight engineer. On DC-6/7 aircraft he had flown 7 hours as pilot. He held a valid commercial pilot's certificate with multiengine and instrument rating. His most recent proficiency check on 9 January 1963 was his original qualification on DC-7 aircraft. He passed an FAA first-class flight physical on 22 October 1962, without waivers.

The flight engineer, age 28, had flown 3 720 hours as pilot and 42 hours as a flight engineer, 29 hours of which were on DC-7 aircraft. On 4 December 1962 he was rated by the Company as a DC-7 flight engineer. He held a valid flight engineer' certificate and an airline transport pilot's certificate with a rating for Constellation aircraft. On 30 November 1962 he received his last proficiency flight check, and on 14 December 1962 he passed an FAA first-class physical, without waivers.

Also aboard the flight were two stewardesses who were physically fit. They had completed training in fire fighting, emergency evacuation, ditching and emergency procedures on DC-7 equipment.

1.6 Aircraft information

The DC-7 aircraft had flown a total of 26 055 hours of which 2 294 hours had been accumulated since the last major inspection.

Prior to departure a preflight check of the aircraft revealed a leak at the hydraulic line connexion with the Meletron pressure switch*. The switch was disconnected and capped and additional hydraulic fluid was added to the system. A walk around inspection of the aircraft was carried out by the flight engineer, and a normal pre-start checklist was executed. He used the electrically driven auxiliary hydraulic pump to build the hydraulic pressure to 3 000 psi in the accumulators, and the emergency hydraulic pump selector valve lever was placed in the normal forward (brakes only) position. The by-pass lever** was in the down position in accordance with the checklist. On boarding the aircraft the pilot-in-command was advised that the checklist had been completed, and he then set the parking brakes. A mechanic explained the modification that had been made in disconnecting the Meletron switch and capping the hydraulic line to the switch. At his request the pilot-in-command operated the auxiliary hydraulic pump and it operated normally.

The aircraft's gross weight and centre of gravity at the time of departure were not mentioned in the report.

The type of fuel being used was not stated in the report.

1.7 Meteorological information

The existing meteorological conditions were not relevant to this accident.

1.8 Aids to navigation

They were not relevant to the accident.

1.9 Communications

Memphis Ground Control was in contact with the DC-7 up until approximately 0230 hours when an IFR clearance was acknowledged by the flight. Following this the ground controller transmitted additional taxi instructions and then sent a message advising the DC-7 to use caution when taxiing on the military ramp. However, the crew of the DC-7 did not acknowledge either of these two messages. Numerous attempts were also made by the Memphis Tower to contact the aircraft after it came to a stop on the military ramp, however, they were unsuccessful.

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* The Meletron switch is an added component in Delta DC-7 aircraft. This switch automatically cuts in the electrically operated auxiliary hydraulic pump when the hydraulic pressure in the brake lines reaches 2100 plus or minus 50 psi.

** The by-pass valve mechanically operated by the hydraulic system by-pass lever permits hydraulic fluid to be by-passed directly from the engine-driven pumps to the reservoir. The lever is placed down during ground operation and up in flight when pressure to the various hydraulic units is not desired. The lever is spring loaded to the down position.

1.10 Aerodrome and ground facilities

See Figure 1, diagram showing area of collision at Memphis Municipal Airport.

1.11 Flight recorders

No mention of flight recorders was made in the report.

1.12 Wreckage

See paragraph 1.3, Damage to aircraft.

1.13 Fire

There was no fire.

1.14 Survival aspects

When the DC-7 came to a stop, the co-pilot, after seeing that the pilot-in-command was beyond help, opened the forward crew compartment door. While attempting to use the emergency escape rope he lost his balance, fell from the aircraft and was injured. The flight engineer, after shutting down the engines and aircraft systems, went aft with one of the stewardesses to the passenger door where they remained until help arrived. The other stewardess jumped to the ground from the open doorway of the crew compartment.

When the Memphis Tower was not able to contact the aircraft, emergency equipment was sent to the site of the accident.

1.15 Tests and research

Examination of the DC-7's engines revealed no evidence to indicate pre-impact failure, operational distress or malfunction. Investigation further revealed that the hydraulic system, emergency air brake system, and the aircraft's landing lights were capable of normal operation prior to impact.

Examination of the hydraulic system revealed:

1) Previous maintenance log pages did not indicate any pertinent system discrepancies.

2) The system repair at the Meletron switch location was subsequently checked and found to be free of leaks.

3) The hydraulic pressure regulator was functionally tested and found to operate within tolerance.

4) The hydraulic system by-pass lever was found in the down position. The by-pass lever installation was checked, and the spring tension was within tolerance.

5) The capping of the hydraulic line to the Meletron switch did not adversely affect the normal operation of the aircraft's hydraulic system.

6) The emergency air brake pressure indicator read "O". The handle of the valve located above the left instrument panel had been pulled out of the body assembly by the left wing spar of the C-123B, thus opening the air pressure line to the bottle.

2. Analysis and conclusions

2.1 Analysis

There was no evidence of hydraulic system, powerplant or structural failure.

The control tower instructed the DC-7 to turn left at the second taxiway after passing the north-south runway. This instruction was misinterpreted by the pilot-in-command, and the aircraft arrived on taxiway D in position for the subsequent collision with a C-123B which was parked there.

The flight engineer, during a pre-start check of the aircraft, tested the emergency hydraulic pump selector valve in its three positions and then placed it in the "brakes only" position. He did not move the by-pass lever. When the pilot-in-command indicated an emergency, the co-pilot reached for the by-pass lever, but the flight engineer had already reached it. It was believed, however, that this valve was in the "down" position at the time, which was normal for ground operation.

The crew apparently did not use the hydraulic brakes, the auxiliary hydraulic pump or the emergency air brake system when attempting to stop the aircraft.

Prior to turning right on the military ramp the pilot-in-command would have used the normal hydraulic braking to slow the aircraft and if the brakes had not been working at that time he would probably have said so. The auxiliary hydraulic pump should then have been turned on in order to build up pressure for the brakes, and the aircraft could have been stopped.

Neither of the surviving flight crew members remembered any deceleration which might be associated with brake application. They had not noticed the pilot-in-command attempting to use the brakes. It was assumed that the normal hydraulic brakes were never used, and no explanation was found for their not being used. Also, no reason was found for the co-pilot's failure to use the brakes available to him. He assumed that since the pilot-in-command allegedly could not steer the aircraft, it meant there was no pressure available for the brakes. According to his statement, he reached for the hydraulic by-pass handle to check its position, however, he did not check the hydraulic pressure gauge to see whether he actually had hydraulic system pressure. Furthermore, he made no attempt to turn on the auxiliary hydraulic pump in order to obtain brake pressure.

Neither of the crew members monitored the hydraulic system pressure gauge during the taxiing. Also, they did not respond to two important radio transmissions by the ground controller. Testimony of one of the stewardesses indicated that she saw the C-123B in front of the DC-7 shortly before the collision and the former was certainly visible to the crew of the DC-7. The foregoing indicates that the crew were not paying sufficient attention to the radio and to the operation of the aircraft, and they probably were preoccupied in the cockpit. The co-pilot stated that he saw the aircraft only after the pilot-in-command allegedly indicated he could not steer the aircraft.

2.2 Conclusions

Findings

The crew were properly certificated.

A pre-flight check of the aircraft revealed a leak at the hydraulic line connexion with the Meletron pressure switch so the latter was disconnected and capped. This did not interfere with the normal operation of the hydraulic system. No mention was made in the report of the aircraft's gross weight or centre of gravity at the time of departure.

The crew of the DC-7 misinterpreted the taxi instructions provided by the tower controller. While taxiing, they were not paying attention to the radio and did not maintain an adequate lookout. The pilot-in-command did not take proper braking action, and the aircraft collided with a C-123B parked on taxiway D.

Cause or Probable cause(s)

The accident was attributed to the crew's inattention to duty while taxiing on an unfamiliar taxiway at night and the pilot-in-command's failure to stop the aircraft in sufficient time to avoid striking a parked aircraft.

3. RECOMMENDATIONS

No recommendations were made in the report.

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Commercial (ferry flight) domestic and military.
Taxiing
Collision - aircraft on ground

Pilot - failed to observe aircraft
misuse brakes

ICAO Ref: AR/845

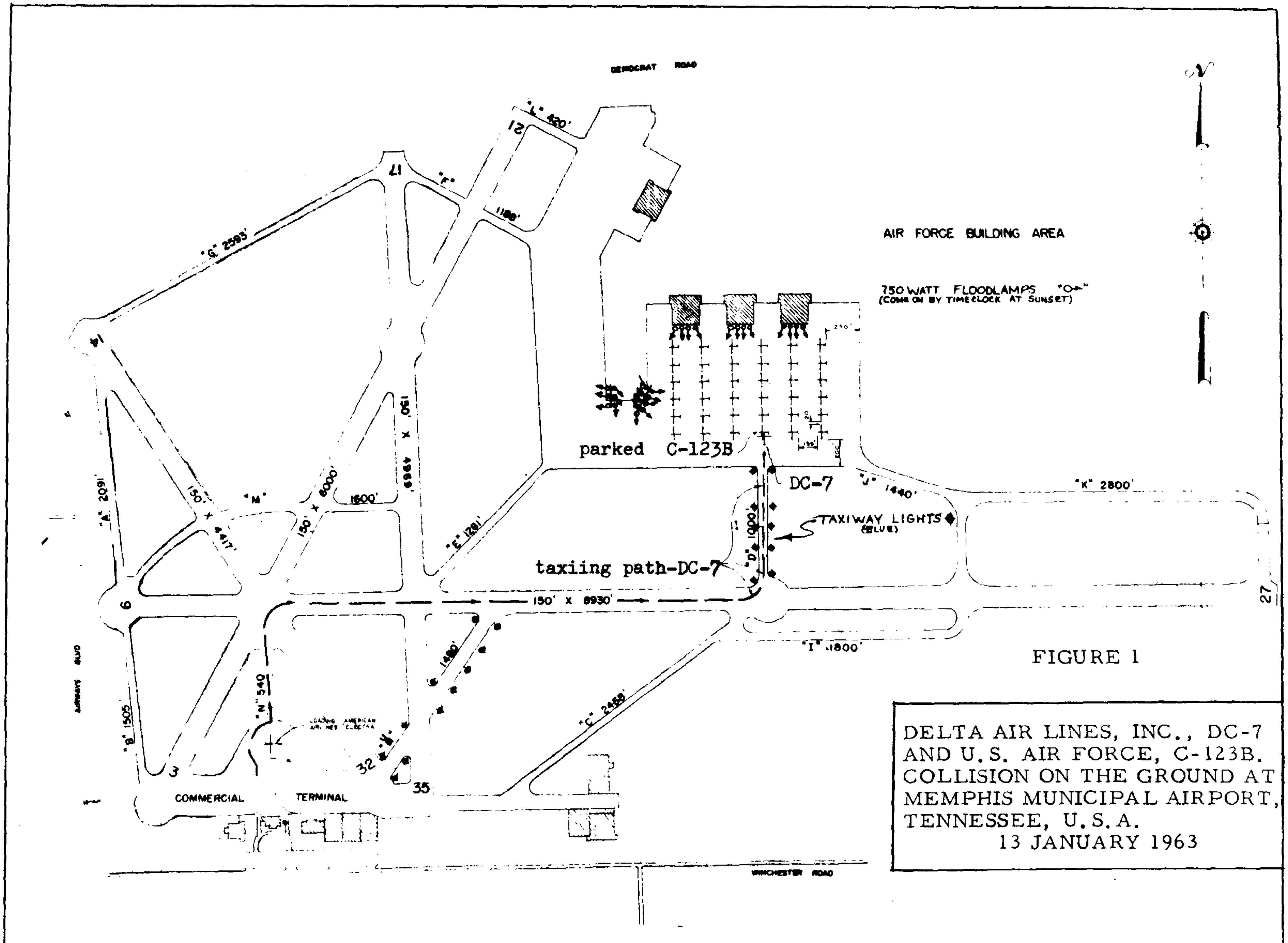

FIGURE 1

DELTA AIR LINES, INC., DC-7
AND U.S. AIR FORCE, C-123B.
COLLISION ON THE GROUND AT
MEMPHIS MUNICIPAL AIRPORT,
TENNESSEE, U.S.A.
13 JANUARY 1963

No. 3

AVIACO (Aviación y Comercio, S. A.), Lockheed 1049G (Super Constellation), EC-AMQ, accident at London (Gatwick) Airport, England on 2 September 1963. Aircraft Accident Report No. EW/C/032, dated September 1964, released by The Ministry of Aviation, United Kingdom - C. A. P. 218.

1. Investigation

1.1 History of the flight

Flight 1120 departed Barcelona, Spain, at 2305 hours on 1 September for London, England. It was a non-scheduled (charter) international flight arranged by a British travel agency with AVIACO. Although the aircraft and the crew members belonged to IBERIA, the operator was AVIACO.

The flight was uneventful until the aircraft commenced the approach procedure at Gatwick Airport. At 0138 hours it reported over the Lydd VOR at FL 38. One minute later the Gatwick approach controller provided the flight with the latest weather information and with radar positioning directions for an ILS approach to runway 09. When the aircraft was on base leg at 2 000 ft, the pilot asked the controller whether the glide path transmitter of the ILS was working properly and on being given an affirmative reply he informed him that the glide path equipment in the aircraft was inoperative. After acknowledging this message, the controller cleared the aircraft to descend to 1 500 ft (QFE 997) and advised the pilot when to turn on to the ILS localizer. The localizer was intercepted at a range of 6 miles after which the aircraft was cleared to descend to 1 000 ft and cleared to land. After the pilot reported over the outer marker, the controller cleared the aircraft to descend to critical height. He also informed the pilot that the obstacle clearance limit was 470 ft and added that there were 4-1/2 miles to go. The pilot-in-command, who was flying on instruments from the left-hand seat, stated that he crossed the outer marker at a height of 1 400 ft and thereafter maintained a rate of descent of 800 ft/min. As the aircraft crossed Russ Hill, a tree-covered ridge running north-south across the approach path to runway 09, it brushed the tops of trees, adjacent to a hazard beacon, about 220 ft above and 1-3/4 miles from the runway threshold. At this time the co-pilot, who had been instructed to keep a lookout for the aerodrome lights, saw a red light to his left which he could not distinguish as being either steady or flashing. The pilot-in-command increased the engine power slightly and almost immediately afterwards the airfield lights became visible. No difficulty was experienced in controlling the aircraft, and a successful landing was made without further incident. Whilst taxiing to the terminal, hydraulic pressure was lost, and the aircraft was stopped by means of the parking brake system. The accident occurred at night at 0154 hours.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Non fatal			
None	7	75	

1.3 Damage to aircraft

The aircraft was slightly damaged.

The landing light of the left wing was broken, and pieces of the light were found near the beacon. Six inches of the tip of a blade of No. 3 propeller were broken off and fragments of a propeller, which matched the No. 3 propeller fractures, were also found near the beacon. No. 3 engine nacelle was dented. Twigs and foliage were found in the No. 3 engine cowling and attached to the right landing gear strut. Both pilots' altimeters were set at 1 003.7 mb.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The crew consisted of a pilot-in-command, a co-pilot, first and second flight engineers, two stewards and a stewardess.

The pilot-in-command, age 31, held a valid airline transport pilot's licence endorsed for Lockheed 1049G aircraft and an instrument rating. He also held a licence to operate radiotelephony. His total flying experience at the time of the accident was 8 761 hours including 1 064 hours in command of Lockheed 1049G aircraft. He had flown to Gatwick on five previous occasions.

The co-pilot, age 37, held a valid senior commercial pilot's licence endorsed for Lockheed 1049G aircraft and an instrument rating. At the time of the accident he had flown 618 hours as co-pilot on Lockheed 1049G aircraft. He also held a valid flight radio operator's licence and had 11 615 hours of experience in this capacity.

1.6 Aircraft information

The aircraft's certificate of airworthiness, issued by the Spanish Civil Aviation authorities, was valid until 5 November 1963. The aircraft was maintained in accordance with a programme approved by the Spanish Civil Aviation authorities, and it had flown a total of 18 089 hours.

Its gross weight and centre of gravity were within the prescribed limits.

The type of fuel being used on the subject flight was not stated in the report.

1.7 Meteorological information

Approximately 15 minutes before the time of the accident Gatwick approach control passed the following weather report to the flight:

wind: 070°/5 kt; visibility: 4 NM; weather: drizzle;
cloud: 5/8 at 700 ft, 8/8 at 1 000 ft; QNH: 1 004 mb;
QFE: 997 mb

At 0217 hours, i.e. 23 minutes after the accident, the conditions were about the same except for the wind which veered to 090° and the clouds which were 6/8 at 600 ft and 8/8 at 700 ft.

At Gatwick, visibility is measured with the Gold visibility meter and the farthest visible standard light, which is supplemented by estimation of the visibility in other directions on the airfield, by the relative clarity of airfield lighting, and the low level sky illumination visible on most nights. The meteorological observer, who was on duty at the time of the accident, stated that he also uses the flashing beacon on Russ Hill when estimating visibility. He believed that it was most unlikely that the beacon would not have been visible to him when reporting a visibility of 4 NM. The reported cloud was of layer type, and its height was measured by means of the cloud searchlight near the centre of the aerodrome. The Meteorological Office stated that it was conceivable that the combination of very high humidity, stable lower air and light drift of wind on to the flank of the ridge on which Russ Hill stands produced a local patch of cloud lower than that above the aerodrome.

1.8 Aids to navigation

Runway 09 at Gatwick is equipped with ILS. The glide path has a 3° slope and at the outer marker, 4-1/4 NM from the threshold of the runway, there is a non-directional radio beacon.

The aircraft carried duplicated VHF radio navigation equipment which was fitted for use with ILS and VOR, however, no glide path receiver was attached to VHF navigation receiver No. 2.

1.9 Communications

The aircraft was in normal contact with Gatwick approach control during the approach.

1.10 Aerodrome and ground facilities

The aerodrome elevation at Gatwick is 194 ft. A hazard beacon is positioned on a tower where the extended centre line of the runway crosses the ridge. The beacon is 227 ft above aerodrome level and 1-3/4 NM from the threshold of runway 09.

1.11 Flight recorders

No mention of flight recorders was made in the report.

1.12 Wreckage

As stated, the aircraft struck trees on Russ Hill, a ridge running north-south across the approach path to runway 09.

The trees adjacent to the hazard beacon had their top branches broken off at a height lower than the top of the tower over an area about 150 ft long and 70 ft wide.

1.13 Fire

There was no fire.

1.14 Survival aspects

None.

1.15 Tests and research

Examination of the radio equipment revealed that the glide path receiver attached to VHF navigation receiver No. 1 was defective.

2. Analysis and conclusions

2.1 Analysis

The ILS procedures for Gatwick (contained in the Air Pilot) provide, among other things, that aircraft should not descend below a height of 490 ft above aerodrome level at the middle marker, located .8 NM from the threshold, during an approach with the glide path inoperative. PAR (precision approach radar), which has a 3° glide path, is also available and can be brought into operation within about ten minutes if requested. PPI (plan position indicator) step-down approaches can also be provided by the Gatwick director.

The section of the Air Pilot concerned with runway 09 lists obstacle clearance limits in relation to landing aids as follows:

ILS (localizer and glide path)	180 ft
ILS (localizer only)	290 ft
PAR (azimuth and elevation)	180 ft
PAR (azimuth only)	400 ft
PPI (step-down)	470 ft
NDB	590 ft

Any operation undertaken by IBERIA is always based on the instructions contained in the U.K. Air Pilot.

Since precision approach radar was available at Gatwick the pilot-in-command should have requested this facility when he realized that his ILS glide path receiver was unserviceable. However, the decision to continue the approach on the ILS localizer without glide path information in the reported weather conditions was not one which in itself warrants criticism. It was, however, essential that the heights associated with such a procedure be maintained.

Primary responsibility for initiating the use of precision approach radar lay with the pilot-in-command but in the absence of such a request the air traffic controller might reasonably, as a matter of prudence, have reminded him that PAR was available. The controller put into effect an abbreviated form of PPI step-down approach. The pilot-in-command stated that he believed that the progress of the approach was also being monitored in elevation by radar. However, the obstacle clearance limit (470 ft), which was passed to him, should have alerted him to the need for attention to his height.

According to the IBERIA operations manual, which was used by Aviaco for this flight, the weather minima to be used for runway 09, when the full facilities of the ILS were available, were 250 ft (critical height) and 1 mile RVR. It did not specify the minima to be used when making an approach to land with the ILS localizer only, nor was guidance given on the amount by which the ILS minima should be raised in these circumstances.

The critical height of 400 ft selected by the pilot-in-command was greater than the obstacle clearance limit of 290 ft with localizer only but to ensure a safe approach when glide path information is not available regard must also be had to the procedure notified in the Air Pilot for this type of approach; this requires a minimum height of 490 ft above aerodrome level to be maintained at the middle marker. The operations manual made no reference to this.

The hazard beacon is 227 ft above aerodrome level, and trees in the vicinity were cut off below beacon level while the aircraft was breaking cloud during the approach. Since the airfield lights did not become visible to the pilot-in-command until subsequent to the brush with the trees, it appears that the approach was continued, without visual reference to the ground, well below the critical height of 400 ft which the pilot-in-command had set himself, and also below the critical height of 250 ft laid down by the operator for a normal ILS approach.

It was considered that there was no justification for the pilot-in-command's assumption that the approach was being monitored in elevation by radar. This accident illustrates the undesirability of a controller not adhering to standard procedures, particularly when the language spoken is not the pilot's mother tongue. Also, the obstacle clearance limit passed was that of a standard PPI step-down. If the full procedure is not followed, the obstacle clearance limit may to some extent be invalidated. (This did not contribute to the subject accident).

The possibility of confusion between QFE and QNH altimeter settings was considered. IBERIA normally sets its altimeters to QNH during landing. The pilot-in-command should have been used to adding the aerodrome elevation to the critical height when determining the height at which an overshoot should be commenced. He should also have had no doubts concerning interpretation of the obstacle clearance limit. Testimony of the pilots gave no indication that there was any mistake between QFE and QNH values. Apparently insufficient attention was paid to the altimeter indications.

2.2 Conclusions

Findings

The pilots were properly licensed and sufficiently experienced to carry out the flight.

The aircraft's documentation was in order. The glide path receiver attached to VHF navigation receiver No. 1 failed before the final approach was commenced. There was no other failure of the aircraft, its engines or equipment. The weather conditions over the airport, which were passed to the pilot-in-command, were above the ILS weather minima. The cloud base and visibility in the vicinity of the hazard beacon on Russ Hill were probably lower than those reported for the aerodrome.

The operations manual did not specify weather minima for an approach to land using ILS without glide path information nor provide any guidance on the amount by which the full ILS minima should be raised in these circumstances.

The pilot-in-command did not maintain the notified minimum height for the middle marker and descended below his critical height without having visual reference to the ground.

Cause or Probable cause(s)

The aircraft struck tree tops when the pilot-in-command descended below a safe approach path whilst making an ILS approach to land without use of the glide path at night in low cloud conditions. Lack of information in the operations manual for such an approach was a contributory factor.

3. Recommendations

No recommendations were made in the report.

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ICAO Ref: AR/852

No. 4

Trans-Mediterranean Airways, Avro York 685 Freighter, OD-ACZ, accident 16 miles west of Mehrabad Airport, Tehran on 15 March 1963, Accident Report dated 20 July 1963 released by the Director General of Civil Aviation, Iran.

1. Investigation

1.1 History of the flight

On 14 March 1963 the aircraft carried out a non-scheduled, international freight flight Beirut/Kuwait/Tehran. Several test manoeuvres were carried out on the Kuwait/Tehran section of this flight because the aircraft carried a check pilot who was examining the pilot-in-command and the co-pilot for renewal of their licences. The flight arrived at Mehrabad Airport, Tehran, at 1740 hours GMT and the pilot-in-command decided to make an overnight stop there, for the purpose of crew rest. The aircraft was unloaded immediately and then loaded with freight for the return flight, in accordance with the pilot-in-command's instructions. On the morning of 15 March, a fully routine preparation for the return flight to Beirut was made. The pilot-in-command inspected the load and certified that he was satisfied with the load distribution and trim sheets. The flight took off normally at 0530 hours GMT with the pilot-in-command in the left-hand seat. Just after take-off the Air traffic controller instructed the flight to switch over to Approach Control on 119.7 Mc/s and to report when 25 miles out from Mehrabad. This was acknowledged by the flight. However, as the flight failed to report when 25 miles out on course as requested, continuous and unsuccessful attempts, commencing at 0540, were made by the controller to establish radio contact. At 0545 smoke rising to the west of the airport was observed from the Control Tower and another aircraft on local flight confirmed that a crash had occurred. The Airport Fire Service proceeded to the reported location, 16 miles on a heading 280^{o} west of the airport and discovered the burning wreckage of the aircraft. The accident occurred at about 0540.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4		
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was completely destroyed.

1.4 Other damage

No other damage was reported.

1.5 Crew information

The crew consisted of the pilot-in-command, co-pilot, check pilot and radio officer.

The pilot-in-command, age 55, held a Lebanese airline transport pilot's licence which was valid but due to be renewed in four days. He had ratings on DC-4 and York 685 aircraft. At the time of the accident he had 16 553 hours flying experience, of which over 6 000 had been in York 685 aircraft and 59 of these were in the 90 days prior to the accident.

The co-pilot, age 28, held a Lebanese commercial pilot's licence with rating on York 685 aircraft. This licence had expired the day previous to the accident. At the time of the accident he had flown 4 714 hours, over 4 000 of which were in York 685 aircraft. In the 90 days prior to the accident he had flown 175 hours in York 685 aircraft.

Both the pilot-in-command and the co-pilot had their latest instrument and medical checks in September 1962.

The third pilot on board, age 34, was a check pilot who was checking the performance of the pilot-in-command and the co-pilot for the renewal of their licences. He held a valid Lebanese airline transport pilot's licence, had ratings on Douglas DC-3 and DC-4 and had completed 11 899 hours of flight.

The fourth crew member was a radio officer, age 29, who had 4 294 hours of flight experience.

1.6 Aircraft information

The aircraft held a certificate of airworthiness valid until 16 November 1963 and also a certificate of maintenance which had been issued two days prior to the accident. The maintenance of the aircraft had been properly carried out in accordance with the York Aircraft Maintenance Schedule approved by the Aviation Safety Service, Directorate of Civil Aviation, Lebanon. The pilot-in-command had not reported any defect of the aircraft or made any request for technical attention to the aircraft during the transit stop at Mehrabad and nothing abnormal was noted on the aircraft at any time.

The weight at take-off, 30 309 kg, was below the maximum permitted. Although some computation errors were noted in the load distribution and trim sheet, the actual centre of gravity on this flight was well within the prescribed limits.

The type of fuel being used on the flight was not specified in the report.

1.7 Meteorological information

Weather conditions in the area of the airport and crash site at the time of the accident were as follows:

Ceiling:	Unlimited
Visibility:	20 km
Wind speed:	5 kt
Wind direction:	120°
Temperature:	14°C
Dew point:	-7°C
Turbulence:	Negligible

1.8 Aids to navigation

Not mentioned in the report.

1.9 Communications

Normal communication took place between the aircraft and Mehrabad Control Tower. No call was made to denote any abnormal or emergency flight condition.

1.10 Aerodrome and ground facilities

Aerodrome and ground facilities were adequate.

1.11 Flight recorders

No flight recorder was mentioned in the report.

1.12 Wreckage

The wreckage was dispersed over flat, open terrain within an area 505 ft in length and extending progressively from a sharp furrow in the loose gravel at the point of initial ground contact to a maximum width of approximately 140 ft. Examination of the furrow and of the torn-off starboard wing tip showed that the aircraft was in a decidedly steep starboard-wing-down attitude at the moment of impact. Between 180 and 200 ft after the point of initial ground contact the condition of the ground surface and the heavy concentration of debris gave positive evidence that the aircraft hit the ground in a steep nose-down, starboard-wing-down attitude. The impact force caused the aircraft to completely disintegrate and wreckage and freight were widely scattered over the area beyond. A study of the wreckage and subsequent search in the area indicated that no major structure had broken and dropped from the aircraft prior to the accident.

1.13 Fire

Widespread fire consumed or melted much of the wreckage because of the spillage of fuel and oil and the inflammable nature of the freight. As soon as the Control Tower at Mehrabad reported smoke rising to the west of the airport, the Airport Fire Service proceeded to the reported location; however, because of the inaccessibility of the crash site and its distance from the airport (16 miles) the wreckage was extensively burnt before any fire-fighting action could be taken.

1.14 Survival aspects

Survival aspects were not mentioned in the report.

1.15 Tests and research

The engines and their propellers were brought to Mehrabad for detailed examination. Examination of the propellers revealed that the engines were not under power at the time of the accident and that No. 1 propeller failed in full fine pitch (25°), No. 2 in almost full fine pitch (28°), No. 3 in a fully feathered position (91°) and No. 4 at 56°, i.e. between full coarse pitch 50° and fully feathered.

Examination of the engines did not reveal any probable malfunction of the engines prior to the accident. However, since doubts existed on No. 2 engine and what was believed to be its supercharger Nos. 2, 3, and 4 engines together with wheel case assemblies as salvageable and the above referenced supercharger were sent to Rolls-Royce Limited, Glasgow, Scotland. Rolls-Royce issued defect investigation reports stating that the doubtful supercharger belonged in fact to No. 1 engine and that investigation had not revealed any mechanical failure within the engines except as a consequence of impact and fire damage.

2. Analysis and conclusions

2.1 Analysis

The pre-flight preparation, taxiing and take-off were normal. The aircraft took off from runway 29 under excellent weather conditions. There is substantial evidence that No. 4 propeller was feathered soon after take-off and that the aircraft continued to maintain its approximate take-off course at an altitude estimated to be around 250 ft over flat and open terrain possessing the same elevation as the airport - terrain suitable for controllable forced landing with a minimum of hazards.

Examination of the aircraft indicated that the undercarriage and the flaps were fully retracted at the time of impact and that the elevator trim was in a fully down position. No evidence of pre-crash defects or failure were found in the aircraft or its elevator and rudder control systems.

Examination of the engines and their propellers revealed that they were not under power at the time of the accident and that No. 3 propeller was in a fully feathered position and No. 4 propeller at 56°, i.e. between full coarse and fully feathered. No evidence of any pre-crash mechanical failure within the engines was found.

The facts that on 14 March, prior to landing at Kuwait and again at Tehran, certain check flight exercises were carried out and that during the fatal flight no abnormal flying conditions were reported by the aircraft to Mehrabad suggest that No. 4 propeller was intentionally feathered soon after take-off for simulating an engine failure condition at take-off, in the course of a crew checking exercise.

The fact that technical investigation established that at impact No. 3 propeller was fully feathered and No. 4 at a pitch between fully feathered and full coarse pitch suggested that during this exercise an emergency condition developed which necessitated the feathering of No. 3 propeller and the subsequent unfeathering of No. 4 propeller.

2.2 Conclusions

Findings

There were three pilots in the crew; the pilot-in-command who had a valid licence which was due to be renewed in four days, the co-pilot whose licence had expired the day previous to the accident and a check pilot who had a valid licence and who was testing the other two pilots for renewal of their licences.

The aircraft had a valid certificate of airworthiness and had been properly maintained.

The weight of the aircraft at take-off was below the maximum permitted and the centre of gravity was within the prescribed limits.

The weather conditions at the time of the accident were excellent.

No positive evidences of a pre-crash mechanical defect, or failure that could have adversely affected the safe flight conditions of the aircraft were found.

There was evidence that No. 4 propeller was feathered soon after take-off, presumably to provide a simulated engine failure condition in the course of a crew checking exercise. However, the positive findings from technical examination are that at the time of impact the No. 3 propeller was in a fully feathered position and No. 4 propeller was in a position between the full coarse and feathered positions.

Cause or Probable cause(s)

The position of the propellers at the time of impact would indicate that, at a time when the No. 4 engine power was off, an emergency condition developed which necessitated the feathering of No. 3 engine and the unfeathering of No. 4. Alternatively, a loss of power on the starboard engines could have occurred from an erroneous manipulation of the feathering switches during the course of this assumed crew checking exercise.

In view of the fact that the fully loaded aircraft was flying at a low altitude after taking off from Mehrabad Airport which has an elevation of 3 900 ft, it is evident that the aircraft would not have had sufficient altitude for the pilot to take effective recovery action and so avoid a crash resulting from the above mentioned loss-of-power conditions.

3. Recommendations

Meticulous attention should be given to the compilation of Load Distribution and Trim Sheets and pre-departure details, such duties should be done or be supervised by a fully trained and qualified Supervisor.

A responsible Operator's Supervisor should be in attendance whenever an aircraft departs and must be readily available and remain on airport stand-by duty for a reasonable period after the operator's aircraft has departed.

It is suggested that pilots should be discouraged from carrying out any abnormal operating procedures from a high altitude runway during a commercial operation. Crew check duties should preferably be conducted at the Operator's Base.

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ICAO Ref: AR/843

No. 5

Continental Air Lines, Inc., Vickers Viscount 812, N 242V accident at Kansas City Municipal Airport, Kansas City, Missouri on 29 January 1963. Civil Aeronautics Board (U.S.A.) Aircraft Accident Report, File No. 1-0002, released 17 June 1964.

1 Investigation

1.1 History of the flight

Flight 290 was a scheduled domestic flight from Midland, Texas to Kansas City, Missouri with various intermediate stops including Tulsa, Oklahoma. After an uneventful flight the aircraft reached Tulsa at 2120 hours central standard time where it was refuelled. It took off from Tulsa at 2154 with a crew of three and five passengers and was cleared for an IFR flight to Kansas City, which was routine up until the approach to land. After it reported passing Pleasant Hill at 5 000 ft, the flight was turned by Olathe Radar Approach Control over to Kansas City Approach Control and instructed to maintain 5 000 ft and depart Blue Springs (VOR) on a heading of 315°, which was a radar vector to the ILS final approach course. The altimeter setting was given as 30.32, the wind as 360°/9 kt, and the flight was instructed to circle and land on runway 36. These instructions were acknowledged. The flight was then cleared to 2 500 ft, vectored to a point one mile north of the outer marker on the final approach and transferred to the local controller, who cleared it to land. Having been advised by the controller that it could make a straight-in landing, if desired, and that the wind was 360° at 6 kt the flight crew stated that it would land straight in on runway 18. Nothing further was heard from the aircraft.

Based on eyewitnesses' statements and flight recorder information the final portion of the flight was reconstructed (see Figure 2). The aircraft passed over the runway threshold, with its landing gears extended, at a height of about 80 ft and at an airspeed of 132 kt. It then flew over the 7 000 ft runway in what appeared to be a go-around. Its altitude remained practically constant up to a point 3 000 ft after the runway threshold where it started to loose height progressively, reaching a height of 50 ft, it then climbed again up to a height of approximately 90 ft which was reached shortly after passing the end of the runway, at that point the aircraft nosed over sharply into a steep dive and crashed. During that same time the airspeed which remained relatively constant during the first 700 ft over the runway started to decrease progressively, reaching 118 kt at a point approximately 2 200 ft past the runway threshold, it then increased steadily to reach 138 kt at the time of the nose-over. The acceleration "G" trace varied little from a point about 750 ft after the runway threshold to the point at which the aircraft nosed over. However, at the time the nose-over occurred, the trace showed a negative excursion, which was terminated at -0.9G by the impact. During the flight over the runway the aircraft's heading remained within 2° of the published ILS localizer heading of 184° magnetic. The aircraft struck a blast mound* with its nose gear about 23 ft right of the extended runway centre line and 284 ft beyond the south end of runway 18 on a heading of about 184° magnetic. The aircraft's attitude at impact was more than 22° below the horizon, wings level. The aircraft slid over the crest of the blast mound, sailed over the perimeter road, struck the side of a river dike and skidded over the top of the dike towards the Missouri River. The main wreckage came to rest 680 ft beyond the end of the runway. The accident occurred at 2244 hours.

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* A large mound of dirt that shelters the airport perimeter road from jet blast and propeller wash of aircraft taking off on runway 36.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3	5	
Non fatal	0	0	
None	0	0	

1.3 Damage to aircraft

The aircraft was destroyed by impact and subsequent fire.

1.4 Other damage

No damage was incurred by objects other than the aircraft.

1.5 Crew information

The flight crew consisted of a pilot-in-command and a co-pilot.

The pilot-in-command, age 47, held a valid airline transport pilot's licence and was qualified on several aircraft types including the Viscount 812. He had flown a total of 18 611 hours which included 3 409 hours on the Viscount. His last proficiency check was given on 5 October 1962 and his last line check was on 29 January 1963, the day of the accident. He held a valid first-class medical certificate with no waivers or limitations.

The co-pilot, age 36, also held a valid airline transport pilot's licence. He was qualified as a pilot-in-command on DC-3 aircraft and as a co-pilot in DC-3 and Viscount aircraft. His total flying time amounted to 5 761 hours, including 2 648 hours on Viscounts. His last proficiency check was given on 5 October 1962. On 28 January 1963 he was issued a first-class medical certificate with no waivers or limitations.

Both of the flight crew had more than 24 hours rest before leaving Dallas, Texas on the day of the accident.

A third crew member was also aboard, however, no information concerning this person was contained in the report.

A toxicological examination of the flight crew members following the accident produced no evidence of carbon monoxide, alcohol, drugs or food poisoning. No determination could be made as to the heart conditions of the pilot and co-pilot.

1.6 Aircraft information

The aircraft had flown a total of 12 860 hours. The last major inspection was accomplished 3 317 hours before the accident, and the last line maintenance 58 hours before the accident.

No maintenance was requested or performed at Tulsa.

At the time of take-off from Tulsa the aircraft weighed 57 483 lb, which included 11 040 lb of fuel and 9 030 lb of payload. Its gross weight and centre of gravity were computed to be within the allowable limits at the time of departure.

While at Tulsa the aircraft took on 1 391 lb of fuel. The type of fuel being used was not stated in the report.

1.7 Meteorological information

The weather forecast issued to the crew included the following terminal forecast information for Kansas City:

1445 hours mountain standard time:	2 000 ft scattered variable to broken; 3 500 ft overcast, visibility 10 miles with occasional very light snow; wind north to north-northwest at 10 kt, gusting to 20 kt
1900 hours:	3 500 ft scattered variable to broken; 10 000 ft broken; visibility 10 miles; wind north-northwest 15 kt gusting to 22 kt
2100 hours:	little change, wind northwest 15 kt, temperature range 25° to 5°F.

The Continental Air Lines Conditions Aloft Forecast valid until 0200, 30 January 1963 predicted "moderate to heavy mixed icing below 5 000 ft in southern Kansas and Oklahoma".

A weather observation made at Kansas City Municipal Airport by the U.S. Weather Bureau at 2231 hours (13 minutes prior to the accident) showed the following conditions: measured ceiling 3 000 overcast; visibility 12 miles; temperature 17°; dew point 8°; wind north 10 kt; altimeter setting 30.32. Another observation made 3 minutes after the accident was the same except that the wind was north-northwest at 6 kt.

A weather bureau witness testified that light rime ice was possible in clouds along the route from Tulsa to Kansas City and a layer of moderate icing conditions might have existed in the Kansas City area. Heavier icing could be expected east of the Kansas City area.

Pilots operating other aircraft into the Kansas City area, shortly after the accident indicated that an icing layer existed in the Kansas City area from the cloud tops (6 000 ft amsl) to their bases at approximately 3 500 ft amsl and reported light to moderate icing during let-downs and climbs. The temperature in this region ranged from -2° to 12°C. The subject flight was in this icing region 8 to 10 minutes.

1.8 Aids to navigation

The airport was equipped with an instrument landing system for landings on runway 18. The inbound heading of the ILS localizer is 184° magnetic. The 3° glide slope intercepts the outer marker, which is 5.5 NM from the approach end of the runway, at 2 558 ft amsl.

The day after the accident an FAA flight check of the ILS was carried out, and it showed that all components of the system were operating correctly.

1.9 Communications

The flight was in contact with Kansas City Approach Control from shortly after 2225 hours up until the time the crew advised that they would land straight in on runway 28.

1.10 Aerodrome and ground facilities

Runway 18 is 7 000 ft long, 150 ft wide and is constructed of concrete. Airport lighting consists of a rotating green and white beacon, approach, runway and taxi lights with a lighted wind tee. All lights are manually controlled with variable intensity of the approach and runway lights available. All the airport lighting was "on" and operating satisfactorily during the time of arrival of the subject flight. The runway was clear and dry at the time of the accident.

1.11 Flight recorders

The flight recorder was recovered after approximately two hours exposure to ground fire. It did not appear to have received severe impact damage and the fasteners were locked and safetied. A readout of the recorder tape revealed that fifteen minutes before the accident there were nearly continuous excursions of the "G" trace ranging generally from a ± 0.2G from the normal mean of 1.0G. These excursions stop about six minutes before the accident. The altitude trace showed a descent from 6 000 to 3 750 ft amsl, and the airspeed indicated an erratic decrease from 255 to 198 kt during this period of time. The heading trace indicated a heading change from approximately 360 to about 295°, 2 - 3 minutes before the accident the heading stabilized on the inbound, ILS localizer heading. Approximately 70 seconds before the accident the altitude trace showed a break in the descent approximately 100 ft above the runway elevation when the airspeed trace was indicating about 140 kt. Following this, both the altitude and airspeed decreased slowly. The altitude trace showed a descent to about 80 ft above the runway threshold and the airspeed trace indicated a decrease to 132 kt at that point. From the threshold on, the flight continued as previously described under paragraph 1.1.

1.12 Wreckage

The wreckage was distributed over an area approximately 600 ft long and 230 ft wide along a general line of 184° magnetic and all major components of the aircraft were found in that area.

1.13 Fire

Fire broke out following impact.

1.14 Survival aspects

No information regarding survival aspects was contained in the report.

1.15 Tests and research

Wind tunnel tests carried out by the manufacturer to determine the effects of various ice formations on the handling characteristics of the aircraft disclosed that horn type ice formations can be developed on the leading edge of an unheated airfoil in an ambient temperature range of -5°C to -10°C.

In this temperature range the tests indicated that the time required to produce 1-1/2 inch horn lengths was about 20 minutes with the continuous maximum liquid water concentration required by the British Civil Airworthiness Requirement (0.72 grams per cubic meter with a mean water droplet size of 20 microns), or ten minutes with twice this concentration of water.

The manufacturer's wind tunnel tests indicated that horn type ice of the above magnitude on the horizontal stabilizer leading edge had a severe effect on the handling characteristics especially at large angle of attack of the horizontal stabilizer. The aircraft anti-icing system has demonstrated capability to prevent the formation of horn type ice or to shed the ice if it has been allowed to form before anti-icing is turned on.* These tests indicated that small isolated runback refreeze areas would occur on the tail if severe ice were allowed to accrue and then normal heat was applied. The amount of runback icing collected during the test, however, produced no significant lift distribution or hinge moment changes.

Previous Viscount accident and incidents that involved flight in icing conditions were reviewed during this investigation.

One pilot testified concerning an incident to a Continental Air Lines, Viscount 812, N 250V involving undetected structural icing in the Colorado Springs area on 20 February 1963. When 40° of landing flaps were selected, from the 32° position, at 145 kt, landing gear down, the aircraft became extremely nose heavy and he had to request the assistance of the co-pilot to bring the nose back to the desired descent angle. The nose steadied for a very short period of time and then went to an extreme nose high attitude, again requiring the efforts of both pilots on the controls to force the aircraft back to the approach attitude. A second series of similar oscillations occurred at approximately 130 to 135 kt and then the aircraft began to handle in a normal manner with no more control difficulties encountered during the remainder of the approach and landing.

After landing, the aircraft was examined and light rime ice was found on the wings and radome, the propellers were clean and dry, and the horizontal stabilizer and vertical stabilizer had a concave, cup-shaped buildup of rough rime ice, approximately one inch thick with horns extending diagonally upward and downward approximately one and one half inches into the airstream (see Figure 3).

This flight had operated in clouds for about 10 minutes. The temperature in the clouds varied from -3°C at 7 000 ft amsl to -5°C at the cruising altitude of 10 000 ft. Propeller, windshield, and engine cowling anti-icing equipment was used but airfoil anti-icing was not turned on. The crew checked the aircraft visually when clear of the clouds at cruising altitude and saw no ice. The total time in clouds following this observation was estimated by the pilot-in-command to be about 2 minutes. The readout of the flight recorder tape was examined by the Civil Aeronautics Board and showed that the aircraft lost about 200 ft during the approach oscillations and the acceleration reached a maximum of -.76G and +2.3G before control was regained.

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* With the airframe anti-icing system operating normally, the complete heated areas on upper and lower surfaces can be maintained clear of ice. Small isolated runback ice accretions will occur behind the heated area. With one heat exchanger inoperative, enough heat is available to keep the leading edge clear of ice, although a spanwise ridge of runback ice will form (on the heated area). If horn-like formations are allowed to build up they can be shed within one minute after application of heat to the tailplane.

The possibility of the propellers going into ground fine in flight was examined as a possible cause of the sudden nose-over of the subject flight. Tests were conducted in a Viscount which revealed that with all protective devices removed, the propeller blade angle will not fine off* to the critical range and cause a pitch down when aborting a landing and initiating a go-around under the conditions that existed in this accident.

2. Analysis and conclusions

2.1 Analysis

Examination of the recovered control surfaces and of the available control linkage showed that they were intact at the time of impact. No sign of binding or interference to normal movement were found. The elevator trim was found at 1/4 unit nose up and the rudder trim at neutral. No evidence of fretting, binding or malfunction were found in the elevator gust lock assemblies.

Examination of the landing flaps, their slides, the gear box and the flap selector components revealed that the flaps were at 32° at impact and that they had reached that position by being retracted rather than by being extended.

The landing gear handle, selector valve actuator shaft and the selector valve slide were all in the "up" position. Also the manual bypass valve was found closed. However, evidences indicated that the nose gear was just out of the down and locked position at impact and that the main landing gears were in the locked position, although the down locks in the left gear were 9/16 of an inch out of the locked position.

Recovered components of the aircraft systems including the autopilot, fuel system, de-icing system, flight control, and the hydraulic system showed no evidence of other than impact damage, except the high pressure hydraulic filter cap retaining bolts. Three of the eighteen bolts in each filter cap were broken. Laboratory examination indicated that one and possibly two of these bolts showed evidence of fatigue failure. There was evidence of fire between the cap and the filter body near the failed bolts.

The autopilot controller, elevator main surface servo, rudder main surface servo, and associated wiring aft of the pressure bulkhead were given a functional test which indicated normal operation was available. The pitch control section of the pedestal controller had broken away from its mounting and could not be tested. The mechanical autopilot connections between the elevator and rudder were in place and secure.

Examination of the engines did not reveal any evidence of pre-impact failure, fire or malfunction. The throttle levers were found in an intermediate position and from a series of four successive propeller blade slash marks near the initial point of impact it was deducted that all four propellers were rotating at the same speed which was computed to be around 15 000 RPM. The position of the jet-pipe hot air door actuators and heat exchanger bypass valve actuators indicated that the airfoil anti-icing heat was not being used at impact.

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* "fine off" is a British term referring to propeller blade angle as it moves toward its minimum angle or flat pitch.

No evidence was found of operational distress or pre-impact malfunction of any engine or electrical driven accessories, and the radios were tuned to the appropriate frequencies.

The pilot's and co-pilot's altimeters were respectively set at 30.23 and 30.37.

Air traffic control communications, transcripts and witness statements indicated that the flight was normal until the aircraft reached a point at or near the outer marker. From the outer marker to the field the aircraft made a VFR approach significantly below the ILS glide path and with a consistently high airspeed until shortly before reaching the runway threshold. If the crew was having any difficulty at this time they made no apparent attempt to execute a go-around. When the aircraft reached the runway threshold the crew was in a position to land. Even though the airspeed was 22 kt higher than prescribed, they were within 80 ft of the ground. With no obstructions on the runway the only reasons for the crew's failure to land must have been either an unsafe landing gear indication or a misjudged landing approach due to the relatively long, low, flat, high speed, down wind, final approach. An unsafe landing gear indication could have been the result of hydraulic leaks in the high pressure hydraulic filters at the points where the filter cap bolts failed. There is nothing in the evidence to indicate that, at this point, the crew was having a pitch control problem. There was no erratic manoeuvres. The pilot increased his descent angle at approximately the time he intercepted the glide slope of the ILS from underneath and he apparently had an adequate amount of control and power necessary to establish a constant altitude from the Bluff Fan Marker to the runway. During this time neither crew member made any radio transmission.

The airspeed and height of the aircraft remained constant for about the first 750 ft of travel over the runway. This was followed by a sharp decrease of the airspeed at a rate of 1.73 kt/sec with little change in height. The maximum deceleration which can be obtained by extending flaps from 0 to 46° is 0.86 kt/sec. The deceleration obtainable by a sudden reduction of power from that required for level flight to flight idle is 2.8 kt/sec with 20° of flaps and 3.1 kt/sec with 32° of flaps. It was therefore concluded that the decrease in airspeed was probably due to both a reduction of power and an extention of flaps.

The height of the aircraft remained nearly constant up to a point 3 000 ft after the runway threshold where it started to decrease. The minimum height, about 50 ft, was reached approximately 5 000 ft down the 7 000 ft runway. Then the height of the aircraft increased. The Board concluded therefore that a go-around was initiated at this point. However, the prescribed procedure: full-power, flaps retracted to 20°, landing gear retracted when a rate of climb is established, were not apparently followed; the flaps were not retracted to 20° and the landing gear remained extended until the time of the accident. This might have resulted from the previously mentioned hydraulic leaks in the high pressure hydraulic filters. The maximum height reached by the aircraft just after the end of the runway, where it suddenly nosed-over was 90 ft. With all engines operating normally and with its landing gear extended, the aircraft at full power should have been able to climb at a rate of 960 ft/min with 40° of flaps and of 1 160 ft/min with 32° of flaps. The fact that the aircraft did not gain more than 40 ft indicated either that the crew did not apply full power or that an abnormal drag did not allow the aircraft to perform normally. The fact that the aircraft was accelerating and climbing in a normal altitude rejected the possibility of a wing stall.

The possibility that any of the pitch control systems of the aircraft might have induced the sudden nose-over was examined. A Vickers representative testified that with the elevator fixed and incapable of movement the elevator servo tab and elevator trim tab were each capable of providing the equivalent of one degree of elevator deflection nosedown. He said that this amount of deflection would be insufficient to force the aircraft into a 22-degree nosedown descent angle in the altitude available at the time of the accident. Furthermore, the autopilot which is limited to 2.5^{o} elevator angle at 136 kt and 3.5^{o} at 109 kt cannot create such a nose-over rotation within the 90 ft altitude available. To rotate the aeroplane to more than 22^{o} nosedown, utilizing autopilot input only requires at least 350 ft.

The only ways the aircraft could pitch down to an attitude of more than 22 degrees below the horizontal, in the altitude available, was by a loss of down loading on the horizontal tail surfaces, or by pilot induced manoeuvre. There is no evidence to indicate that such a pilot induced manoeuvre did occur. The testimony at the hearing indicated that horn shaped or concave ice formations on the leading edge of the horizontal stabilizer can produce a strong nosedown pitching moment when flaps are lowered. This type of ice was reproduced in tunnel tests by the manufacturer, and these tests have shown that a negative angle of attack of the horizontal tailplane increases when the flap angle is increased at a given airspeed, or when the air speed is increased with a given flap setting, or when the weight is reduced at a given airspeed and flap setting. Each of these conditions requires more negative lift on the tailplane to maintain longitudinal trim. A stability test performed by the manufacturer showed conclusively that horn shaped ice formations can produce drastic reduction in the maximum lift obtained by the horizontal tailplane and that the tailplane approaches a stall condition.

In addition, the tests revealed that with the reduction of negative lift there is a change in lift distribution such that elevator hinge moments (and therefore wheel force) are increased more than normal as up elevator is applied to counteract the pitch. Additionally, up elevator could increase the flow separation to the point of reducing tail load still further, resulting in a sharper nosedown pitching moment.

The evidence indicated that moderate icing was possible in the clouds in the Kansas City area from 6 000 ft down to approximately 3 500 ft. While no determination can be made of water droplet size or water density in the cloud, the temperature ranges in the cloud were those which have been established by tunnel tests as having been conducive to the formation of horn type rime ice. The tunnel testing indicated that from 10 to 20 minutes was required to establish horn-like ice formations of the size described by witnesses. However, a Continental Air Lines pilot's testimony indicated that this type of ice formation can occur within 2 or 3 minutes. CAL 290 was in icing conditions from 6-8 minutes, long enough to have accumulated ice as described by other Viscount crews and developed during the tunnel tests.

The Continental Air Lines Viscount Aircraft Flight Manual prescribed the following procedures for use of the anti-icing systems:

1. Airfoil Anti-icing "ON" prior to entering icing conditions.

2. Do not operate Airfoil Anti-icing System on the ground.

3. Do not operate continuously in flight at temperature above 10^{o}C.

4. Wing (and tail) heat "OFF" for landing.

5. Windshield Anti-icing will be on "LOW" at all times for bird-proofing.

6. The powerplant anti-icing system may be turned on and left running in flight. It must be turned on prior to entering icing conditions.

The testing by the manufacturer indicated that the operation of either one of the two heat exchangers produces sufficient heat at the tailplane to prevent icing even under the extreme conditions tested. Heat applied following a buildup of horn type ice will remove the ice in one minute or less. Runback ice may form under certain conditions of de-icing (as opposed to anti-icing), and during the tests ridges of as much as 3/4 inch were produced. These tests did, however, show that there was no appreciable change in elevator hinge moment from this type formation. The weather information furnished to the crew indicated moderate to heavy icing over southern Kansas and Oklahoma, but did not call for icing in the Kansas City terminal area. However, the terminal forecast did indicate cloudiness in the Kansas City area with sub-freezing temperature at the surface. Assuming that the pilot-in-command followed the established company procedure for using the windshield heat in the low position throughout the flight it is possible that no ice would form on the windshield. This is normally the first indication the crew has that ice is forming on the aircraft. Testimony and testing indicated that the only way a horn type of ice formation could occur on the horizontal stabilizer would be if the de-icing system were not used in flight through the clouds, or if the system had failed and no heat was provided to the tail surfaces. There is no evidence to substantiate a failure of the anti-icing system. The crew should have expected icing in the clouds. However, as was the case with the Colorado Springs crew, if the windshield anti-icing system was "on" they may never have seen any indication of ice on the aircraft and therefore not turned on the airfoil anti-icing system.

The Board believed that flaps were lowered to 20° at some point during the approach; most probably at or near the outer marker. The ice shape was such that this amount of flap, at the airspeed involved was not detrimental to aircraft trim. The remainder of the approach was made at 20° of flaps until over the runway. When over the runway the power was reduced and the flaps were further extended, probably to 40°. When the crew realized that a landing could not be made, power was applied for a go-around, the flaps were raised to 32°, and the gear handle was actuated. As the airspeed increased the nosedown pitching moment increased to a point where it could no longer be counteracted. This may have been due to either a progressive loss of negative lift or a tail stall induced by extreme up elevator. At this point the aircraft pitched over and crashed.

2.2 Conclusions

Findings

The crew were properly trained and certificated. Crew rest requirements before the subject flight had been met, and there was no evidence of any crew incapacitation.

The aircraft was airworthy and had been properly maintained and dispatched. Its gross weight and centre of gravity were within the allowable limits at time of departure.

Icing conditions were existing in the Kansas City areas, with temperature ranging from -2°C to -12°C. The aircraft was in the icing region 8 to 10 minutes.

No evidence of fire, malfunction or failure of the aircraft, its engines, or its equipment prior to impact were found. However, three of the eighteen retaining bolts on each of the high pressure hydraulic filter caps were found broken. This might have caused hydraulic leaks and a failure of the hydraulic system.

The Board believed that the aircraft accumulated ice during its descent to Kansas City. The airfoil anti-icing system was not turned on and the crew was unaware of the icing accumulation because the windshield anti-icing system was used continuously. In this instance the aircraft did not reach the angle of attack critical for the horn type ice formation being carried on the horizontal stabilizer leading edge, until it passed over the south end of the runway and the airspeed increased to approximately 138 kt. At this point a combination of airspeed and flap position resulted in an angle of attack at which the tailplane down loading was lost and the aircraft pitched over. Although the evidence indicated the pilot was attemptingrecovery when the aircraft struck the blast mound, the pitch over started in an altitude too low to render such action effective.

Cause or
Probable cause(s)

The probable cause of this accident was an undetected accretion of ice on the horizontal stabilizer which, in conjunction with a specific airspeed and configuration, caused a loss of pitch control.

3. Recommendations

No recommendations were contained in the report.

4. Action taken

Following this accident the Federal Aviation Agency took the following corrective action:

1. An alert bulletin was issued to all domestic Viscount operators and FAA regional offices advising that both airframe anti-icing heat exchangers should be turned on whenever the indicated outside air temperature is 10°C or below, if there is any possibility of encountering airframe icing;

2. It proposed amending all Viscount aircraft flight manuals as follows:

   a) Requirement to use both heat exchangers whenever OAT is 10°C or below;

   b) A recommendation to carry higher power on inboard engines during descent to increase hot air mass flow to wing and tail surfaces. (Airframe anti-icing heat exchanger on the inboard engine)

Additional corrective action taken by the manufacturer included a flight manual change that required both heat exchangers to be on at all times when the indicated outside air temperature is +10°C or below unless it is certain that no icing conditions will be encountered.

Also, the Civil Aeronautics Board reviewed the evidence in the record of the investigation of an aircraft accident involving a Capital Airlines, Inc. Viscount 745, N 7437 which occurred at Freeland, Michigan on 6 April 1958*. It then amended the probable cause of the accident to read as follows:

> "The probable cause ... was an undetected accretion of ice on the horizontal stabilizer which, in conjunction with a specific airspeed and aircraft configuration, caused a loss of pitch control."

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* A summary of this accident appeared in Aircraft Accident Digest No. 10 (ICAO Circular 59-AN/54).

ICAO Ref: AR/824

ACCIDENT TO VISCOUNT 812, N242V, OF CONTINENTAL AIR LINES, INC., AT KANSAS CITY, MISSOURI, U.S.A.
29 JANUARY 1963

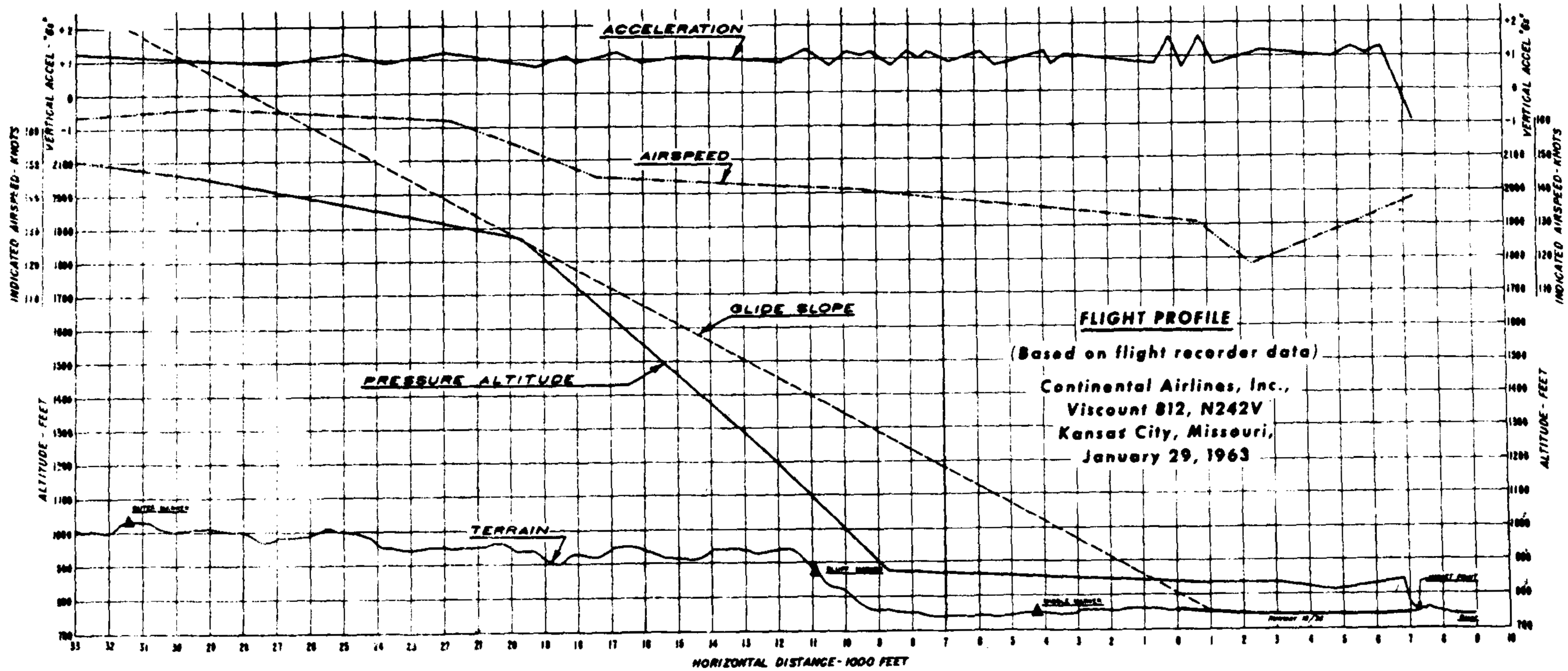
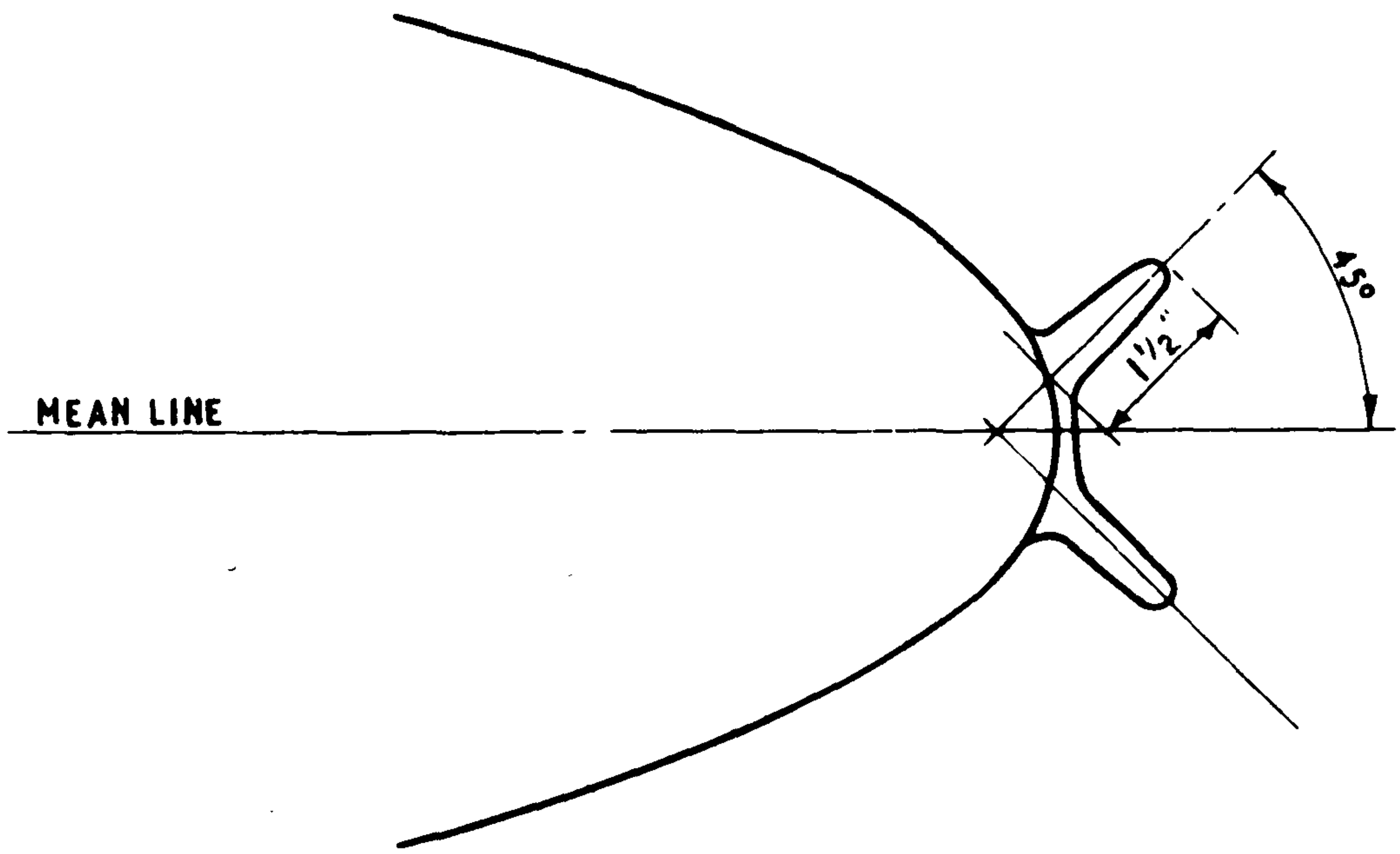


FIGURE 2

CONTINENTAL AIR LINES, INC., ACCIDENT TO VISCOUNT 812, N242V, OF CONTINENTAL AIR LINES, INC., 29 JANUARY 1963

A TYPICAL PILOT SKETCH OF HORN TYPE ICING



(b) PILOT'S SKETCH

SCALE ½

THE TAILPLANE AEROFOIL AT STN. 76

FIGURE 3

No. 6

Trans-Canada Airlines, Douglas DC-8F-54, CF-TJM, accident at London (Heathrow) Airport, England on 6 November 1963. Report No. EW/C/040, dated December 1964, released by the Ministry of Aviation, United Kingdom. (C.A.P. 223)

1. Investigation

1.1 History of the flight

Flight 861 was to depart London, England for Montreal, Canada at 2015 hours GMT on a scheduled international flight but was delayed because of fog. At 2045 the aircraft was ready to depart from runway 28L. Before lining up the pilot-in-command carried out the take-off check, including the flying controls. The runway visual range at that time was 150 yd. The take-off run was commenced at 2052 hours but was aborted after approximately 500 yd because the pilot-in-command could not see enough lights. He informed the control tower that he would turn around and hold until enough lights were visible. While backtracking he asked permission to take off from runway 10R (the reciprocal direction) where the fog had been dispersed by his previous run, but he was refused because of inbound traffic on runway 28R. As the RVR on runway 28R had been reported to be 500 yard or better during the previous 45 minutes and when it was established by the co-pilot that the length of this shorter runway (9,312 ft.) was suitable for take-off considering both the aircraft's weight and the air temperature, the pilot-in-command decided to take off from that runway. The aircraft received radar assistance to taxi to the holding point. At 2114 hours, the take-off run was commenced. The aircraft accelerated normally; as the speed increased the nose wheel started hammering on the centre line lights and this became a matter of concern to the pilot-in-command. He tried to move the aircraft slightly to the left to relieve the hammering but with further increase in speed it did not diminish. When the indicated airspeed was about 132 kt, he moved the control column back approximately 5 inches in order to relieve the hammering, but since this was ineffective he moved it back a little more, still without results. After checking the selection of the flaps and the position of the gust lock lever, he made two further forward and backward movements of the control column but obtained no response. The pilot-in-command later stated that the controls felt as if they were disconnected. He therefore closed the throttles, applied the wheel brakes and attempted to apply reverse thrust, but the levers kicked back. The aircraft overran the end of the runway at high speed. The captain maintained wheel braking and kept his hand on the reverse thrust levers. The aircraft ran over the clearway, traversed the raised surface of the airport perimeter road demolishing the frangible fence, struck the concrete foundation of a former road breaking its nose landing gear, struck the ILS localiser with its right wing, slid across a ditch 8 ft wide and 5 ft deep where the main landing gear collapsed and finally came to rest in a cabbage field, 2400 ft from the end of runway 28R approximately on the extended centre line and at a heading of 293° magnetic.

The accident occurred at 2115 GMT, during the hours of darkness.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Non fatal	1	4	
None	6	86	

1.3 Damage to aircraft

The aircraft was extensively damaged.

1.4 Other damage

The frangible fence on each side of the airport perimeter road was broken through by the aircraft. A 40-ft length of the ILS localizer installation and a substantial amount of approach lighting were demolished.

1.5 Crew information

The crew consisted of the pilot-in-command, co-pilot, second officer, navigator, purser and two stewardesses.

The pilot-in-command, age 46, held a valid Canadian airline transport pilot's licence endorsed for DC-8 aircraft and a current Class I instrument rating. At the time of the accident his total flying experience was 21 428 hours of which 2 321 hours were in DC-8 and 140 in DC-8F. He had flown approximately 13 hours in the seven days before the accident and had a 36-hour rest period in London before this flight.

The co-pilot, age 43, held a valid Canadian airline transport pilot's licence endorsed for DC-8 aircraft and a current Class I instrument rating. At the time of the accident his total flying experience was 15 032 hours of which 530 hours had been as co-pilot in DC-8 and DC-8F aircraft. He had flown approximately 14 hours in the seven days before the accident and had a 36-hour rest period in London before this flight.

The second officer, age 29, held a valid Canadian commercial pilot's licence. His total flying experience amounted to 5 824 hours of which 1 307 had been obtained as a second officer in DC-8 aircraft. In the previous seven days he had carried out approximately 19 hours flying and had had a 36-hour rest period in London before this flight.

The navigator was also fully qualified. The purser and the two stewardesses had been trained and examined with success on emergency and evacuation procedures.

1.6 Aircraft information

The aircraft had a valid certificate of airworthiness, which was issued by the Canadian Department of Transport on 1 February 1963. The aircraft had been maintained in accordance with an approved system of continuous maintenance, had flown a total of 1 958 hours, and had been checked and certified at London before the subject flight.

At the time of take-off from runway 28R it was calculated that the take-off weight was 307 956 lb and the centre of gravity 25.3% MAC, both within the prescribed limits.

Over 16 000 gal of JP-4 fuel were aboard the aircraft.

1.7 Meteorological information

At 2124 hours, nine minutes after the accident, the following special observation was made by the meteorological office at London (Heathrow): wind: calm; visibility: 50 yd; weather: fog; cloud: sky obscured; QNH: 989 mb; QFE: 986 mb; temperature: +10C; dew point: +10°C. The runway visual range (RVR) was variable but in general it was lower on 28L than on 28R. When the aircraft commenced its take-off on 28R the RVR was reported as 800 yards.

Rain had fallen during the day and with very wet ground, cloud thinning and temperatures gradually falling, the air had become nearly 100% humid, and dense patches of fog had formed. Visibility was extremely variable.

1.8 Aids to navigation

N/A

1.9 Communications

Communications between the aircraft and control tower were normal.

1.10 Aerodrome and ground facilities

Runway 28R is 9 312 ft long and 300 ft wide and has a 500-ft grass clearway. Runway lighting includes a row of bidirectional lights spaced 80 ft apart 75 ft either side of the runway centre line, and centre line lighting consisting of a row of bidirectional white lights spaced 100 ft apart along the full length of the runway. The brilliancy of these lights is variable. The last 2 000 ft of the contact lights (side lighting) are yellow whilst the remainder are white. The runway threshold bar consists of sixteen green lights spaced 10 ft apart which are switched on with the contact lights. All of these lights were on full brilliancy during the take-off attempt.

1.11 Flight recorders

No flight recorder information was contained in the report.

1.12 Wreckage

Nil.

1.13 Fire

When the aircraft came to rest small fires were burning in No. 1 and No. 2 engines. Attempts were made to shut off the high pressure fuel cocks and to operate the fire-wall shut-off valves, but some of the selectors would not move the full length of their travel due to crash damage. All engine fire extinguisher handles were pulled. Efforts were then made to extinguish the fires with portable fire extinguishers. The No. 2 engine fire was reduced by a CO_2 extinguisher, however the dry chemical extinguisher and a small water glycol extinguisher did not work. The dry chemical fire extinguisher was examined and found to operate satisfactorily. It was considered that initial failure to operate may have been due to an insufficient charge of gas or compactness of the dry powder or both.

The Airport Fire Service, having been alerted by the Control Tower within a couple of minutes of the crash, set out, guided by an Airfield Surface Movement Indicator, but were stopped approximately 200 yards before reaching the aircraft by a 8-ft wide ditch. Alternate routes were found, and the first fire service vehicle reached the aircraft some 23 minutes after the accident, the other fire and rescue vehicles arrived 2 minutes later.

1.14 Survival aspects

Upon impact with the ditch all the normal lighting in the aircraft was extinguished and the emergency lighting came on. When the aircraft came to a stop the purser opened the main passenger door on the left-hand side and seeing the ground about 3 ft below, he believed that the escape chute would be likely to obstruct the doorway and did not use it. He then opened the galley door on the right-hand side. The emergency lighting was not bright enough to enable passengers to read instructions for opening exits or, in some cases, to release their seat belts quickly. This caused some delay, but the passengers were evacuated in an orderly manner, using the exits opened by the purser and two doors at the rear of the aircraft and an emergency exit on the right-hand side, which was opened by passengers. The crew left by the forward main door, and one passenger made his way past the cargo to the forward door. The crew supervised the evacuation and made sure it was complete. Passengers were collected at a point well away from the aircraft, and those with minor injuries were cared for by the stewardesses.

An unnecessary waste of time resulted for some passengers from an attempt to push out an emergency exit designed to be pulled in. The addition in bold letters of the directions "PULL IN" visible in emergency lighting could help to prevent a repetition of such a delay. It was fortuitous that it was on the left wing that two engines were on fire for over 20 minutes, particularly as there were over 16 000 gal of JP-4 fuel on board. It is in the knowledge of these facts that it must be considered whether there were enough exits. No injury was sustained as a result of a shortage of emergency exits, but if the fire had developed rapidly it might well have been otherwise (See Figure 4).

A pertinent aspect of the evacuation was the reaction of the passengers to the need to evacuate the aircraft quickly. This varied from hysterical anxiety at one extreme, to concern only for their hand baggage at the other.

All passenger and crew seats in the cabin remained in position except for one row of three passenger seats which was displaced slightly inboard. The top corner of the back rest of one other seat was bent forward.

1.15 Tests and research

Nil.

2. Analysis and conclusions

2.1 Analysis

Examination of the engines showed no evidence of pre-crash malfunction or bird strike. The thrust reversers in Nos. 1 and 2 engines were in the reverse position, whilst Nos. 3 and 4 engines were in the forward thrust position.

The two airspeed indicators were found to operate within the required tolerances and nothing indicated that they were not working properly at the time of take-off.

The tail plane was found in a setting just over 1 3/4°. The emergency air brake lever was wire-locked in the "off" position and the anti-skid switch was caged in the armed position. The main wheel impressions on the 800 ft grass clearway showed scuff marks at irregular intervals consistent with anti-skid brake operation.

The first attempted take-off (on runway 28L) was made when the RVR was less than 1/4 mile - the minimum stated in the operations manual for take-off. The RVR at the commencement of the take-off attempt (on runway 28R) during which the accident occurred was greater than the minimum required.

The information passed to the aircraft by the operator's despatch office was that the weight was 310,771 lb. and the centre of gravity was 26.5% MAC. In determining the data for the take-off on runway 28R no allowance was made by the crew for the fuel burned off in taxying and the first attempted take-off. It has been calculated that when the aircraft reached the point of take-off on runway 28R its weight was 307,956 lb. and the centre of gravity was 25.3% MAC. The trim setting for this weight and centre of gravity position should be about 2 1/4° nose-up but the trim setting during the attempted take-off was 1 3/4° nose-up, the setting derived from data given to the crew by the despatch office on boarding the aircraft. However, it is not considered that the incorrect trim setting contributed to the cause of this accident since the magnitude of the discrepancy was small and its effect would not be noticeable at the speeds encountered during the attempted take-off.

Damage to the electrical and hydraulic systems. sustained when the aircraft crossed the 8-foot ditch, precluded movement of the tail plane in response to any subsequent flight deck action. There is no reason to believe that the tail plane position was altered after having been set before the take-off was commenced. The small discrepancy of 1/4° between the tail plane position indicated by the trim indicator in the cockpit and that measured on the extension of the tail plane screw jacks was not more than the acceptable tolerance laid down in the maintenance manual.

The pilot-in-command's initial attempt to stop the nose wheel hammering on the centre line lights by means of a directional correction was not successful, but greater persistence in steering the aircraft to one side of the lights while the aircraft was travelling at a relatively low speed would have eliminated his motive for lifting the weight from the nose wheel. In connection with the latter action it should be remembered that in circumstances of high aircraft weight and a bare sufficiency of runway length any rotation made at a speed significantly different from V_R will decrease the safety margin. The pilot-in-command stressed that at no time was any attempt made to rotate the aircraft for take-off.

The pilot-in-command abandoned the take-off because he believed there was a serious fault in the elevator system. It has been established that the aerodynamic hinge moment contribution to the control column forces at V_R is less than 3 lb at any centre of gravity position. By far the greatest proportion of the control column force is derived from the elevator centring spring which was inspected and tested and found to produce values within the maker's tolerances. Close examination of the elevator control system has revealed no significant defect; it is concluded that the pilot-in-command made an error in his assessment of its effectiveness, and that the reason the aircraft did not respond to pulling back on the control column is that the control movements were not sustained sufficiently long to be effective.

According to the flight manual data the runway distance required to enable the aircraft at a weight of 307,956 lb to be accelerated to a V_1 of 137 knots and then brought to a stop is 7,850 feet in the conditions which prevailed at the time of the accident, except that this figure does not make any allowance for a wet runway. In addition the flight manual data are based upon the use of spoilers but no reverse thrust when the take-off is abandoned, but it has been established that in this case a degree of reverse thrust was used but the spoilers were not. However, the dominant factor in the disparity between the flight manual data and the distance from the commencement of take-off to the position at which the aircraft came to rest is the airspeed at which the take-off was discontinued. The flight manual data assume decelerating action is initiated three seconds after V_1 (137 kt in the accident case) but the take-off was not in fact abandoned until about 11 seconds after 140 kt was seen on the co-pilot's airspeed indicator. It has been calculated that an indicated airspeed of about 170 kt was achieved by the time the take-off was abandoned and that the aircraft had then travelled 7 730 ft, so that only 1 582 ft of runway remained. In these circumstances there was no possibility of the aircraft being brought to a stop before the end of the runway.

The following factors may have contributed to a build up of tension in the pilot in command's mind:

- the prospect that the take-off would be made near maximum weight in fog at night on a wet runway;
- a wait of half-an-hour for start-up clearance;
- concern over the sufficiency of the runway visual range on 28L;
- the need for radar assistance to taxi to the beginning of the runway to be used;
- misunderstanding between the aircraft and the Tower over the extent of the centre line lighting on runway 28L;
- the abandoned take-off on runway 28L;
- the refusal of permission to take-off on runway 10R;
- anxiety about the marginal runway length available on runway 28R;
- the frequent R/T instructions and broadcast of runway visual ranges;

- the difficulty of taxying in low visibility and the risk of taxying into obstructions or other aircraft;
- the implied request to expedite take-off on runway 28R because of a landing aircraft on final approach; and
- the repetitious thumping of the nose wheel on the centre line lights which the captain was unable to stop.

However, the extent, if any, to which these factors did influence his actions cannot be determined.

2.2 Conclusions

Findings

The crew were properly licensed and sufficiently experienced to carry out the flight.

The aircraft had a valid certificate of airworthiness and had been properly maintained. There was no pre-crash failure of the aircraft, its engines or equipment.

Visibility at the time of the take-off was better than the prescribed minima.

The pilot-in-command abandoned the take-off at a speed substantially in excess of the V_1 of 137 kt although he was unaware this was so.

Extension of the spoilers, in accordance with the drill for an abandoned take-off, would have made the braking action more effective and reduced the speed at which the aircraft overran the end of the runway.

Cause or
Probable cause(s)

The pilot-in-command, in the mistaken belief that the elevator control system was defective, abandoned the take-off at a speed and position on the runway which precluded the possibility of bringing the aircraft to a halt in the runway length remaining.

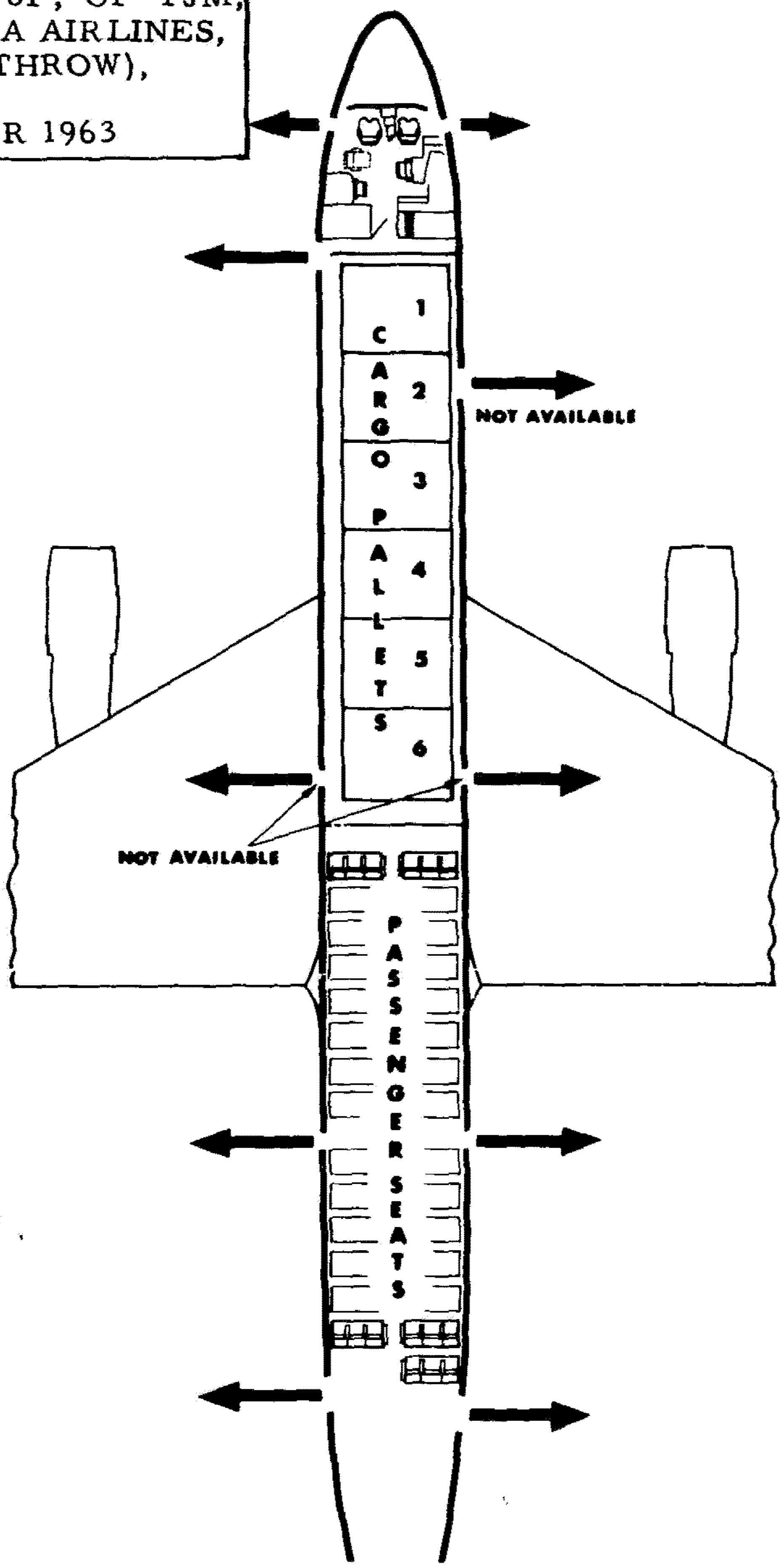
3. Recommendations

No recommendations were contained in the report.

- - - - - - - - - - -

ICAO REF: AR/858

ACCIDENT TO DC-8F, CF-TJM, OF TRANS-CANADA AIRLINES, AT LONDON (HEATHROW), ENGLAND.
6 NOVEMBER 1963



EMERGENCY EXITS

FIGURE 4

No. 7

British Aircraft Corporation Ltd., BAC 111, Series 200, G-ASHG, accident at Cratt Hill, 1-1/4 miles NNW of Chiclade, Wiltshire, England on 22 October 1963. Accident Report No. EW/C/039, dated November 1964, released by the Ministry of Aviation, United Kingdom. (C.A.P. 219)

1. Investigation

1.1 History of the flight

The aircraft took off at 1017 hours GMT from runway 10, at Wisley Aerodrome on its fifty third test flight. It was to carry out stalling tests in all configurations with the centre of gravity at 0.38 SMC (standard mean chord), the furthest aft limit for which the aircraft had then been cleared. Based on the radio-telephony conversations recorded in the Wisley Tower and the flight recorders carried aboard the aircraft, the flight was reconstructed. Following take-off the aircraft climbed in visual meteorological conditions on a westerly heading to 17 000 ft while monitored by Wisley radar. At 1026 the co-pilot reported that they were about to commence tests at flight level 170. By 1035, four stalls had been completed with the undercarriage and flaps up. The co-pilot acknowledged a fix from Wisley at 1036 hours and nothing further was heard from the aircraft. The flaps were then lowered to 8^{o} to investigate the stalling characteristics in this configuration. The stall was initiated about two minutes after the last contact, when the aircraft was between 15 000 and 16 000 ft. Approach to the stall appears to have been normal. When attempting recovery, the elevators responded initially to the control movement but subsequently floated to the fully up position in spite of a large push force on the control column. The aircraft then descended in a substantially horizontal fore and aft attitude at about 180 ft/sec. During the descent it banked twice to the right and once to the left and at one stage the engines were opened up to full power. This action resulted in a large nose-up pitch which was followed by a pitch down when power was taken off. The aircraft then assumed the substantially horizontal attitude in which it made impact with the ground.

The final portion of the flight was observed by numerous eye witnesses who commented on the low level of engine noise and a sharp report from the aircraft which was heard while it was in the air. The aircraft had approached from the southwest, in a stable stalled condition, and crashed at about 1040 hours in a flat attitude. Following impact, the aircraft moved forward about 70 ft and some 15 ft to the right before coming to rest. It exploded and caught fire.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	7		
Non fatal			
None			

1.3 Damage to aircraft

Fire destroyed the fuselage and starboard wing.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The crew was made up of the following: a pilot-in-command, a co-pilot, 3 flight test observers, an aerodynamicist and a designer.

The pilot-in-command, age 43, was deputy chief test pilot of Vickers-Armstrongs (Aircraft) Ltd., and the senior project pilot on the One-Eleven. On 20 August 1963 he flew as co-pilot on the first flight of the One-Eleven and had subsequently taken part in almost all the test flying of this aircraft, as either pilot-in-command or co-pilot. He had taken part in each of the flights during which stalls had previously been carried out. He was a Ministry of Aviation approved test pilot. He had flown a total of 5 385 hours, over 2 000 of which were flown on multi-engined aircraft and included 78 on the One-Eleven.

The co-pilot, age 46, joined Vickers-Armstrongs as a test pilot in 1953. His first flight on the One-Eleven was made on 20 September 1963 when he flew as co-pilot with the subject pilot-in-command and since that time had flown for 13-1/2 hours as co-pilot and two hours as pilot-in-command. He had flown a total of 9 648 hours. He was also a Ministry of Aviation approved test pilot.

No information was contained in the report regarding the other persons aboard the aircraft.

1.6 Aircraft information

G-ASHG was the first One-Eleven to be completed by Vickers-Armstrongs (Aircraft) Ltd. and flew for the first time on 20 August 1963. Since that time it had flown 52 test flights which involved 81 hours of flying. At the time of the accident it was carrying out a flying programme prior to obtaining a certificate of airworthiness for airline service. It was being flown under the B Conditions of the Air Navigation Order, 1960; a certificate of safety for flight had been completed on the day of the accident at 0900 hours.

The elevators of the aircraft were aerodynamically operated by tabs controlled by a duplicated cable control system. They were in two independent sections but linked through their control systems at the top of the fin and at the flight deck. A hydraulic artificial feel simulator was coupled to the right-hand elevator control circuit in the rear fuselage to give control feel in flight.

Longitudinal trim was effected by a variable incidence tailplane powered by duplicated hydraulic motors. The range of the tailplane setting was from 3° leading edge up to 12° leading edge down.

Lateral control was by means of servo-tab operated ailerons supplemented by hydraulically operated spoilers which also acted as air brakes when deflected symmetrically.

Special test instruments shown to the pilot included elevator angle indicators which showed the position of both the port and starboard elevators. There was also an angle of incidence indicator which gave the aircraft's body incidence. A vane on the side of the fuselage provided the sensing unit and the indicator was calibrated in accordance with the results of wind tunnel tests. The scale on its dial read from 20° to -10°, but the instrument was capable of indicating to 25°. It is not known how the instrument would have behaved when body incidence exceeded 25°.

The aircraft's gross weight was 70 125 lb, i. e. below the maximum permissible of 73 500 lb. As stated, the centre of gravity was 0.38 SMC, the furthest aft position for which the aircraft had been cleared. The design range of the centre of gravity was 0.11 to 0.41 SMC.

The aircraft carried 2 200 gal of kerosene.

1.7 Meteorological information

Weather conditions had no bearing on the accident.

1.8 Aids to navigation

Not relevant to the accident.

1.9 Communications

Communications between the aircraft and Wisley tower were recorded. The co-pilot was in contact with the tower up until 1036 hours, i. e. about 4 minutes prior to the accident.

1.10 Aerodrome and ground facilities

Not relevant to the accident.

1.11 Flight recorders

The following types of flight recorders had been installed in the aircraft for accident investigation purposes:

1) a Midas Type CMM/24/7S/E; and

2) a Colnbrook Instruments Development Ltd. (CID) Type 02E

The Midas is a magnetic tape recorder capable of dealing with 270 inputs and on this occasion was being used to record 59 parameters. It was installed in the top starboard side of the rear fuselage. The associated amplifiers were fitted to one of the special bulkheads in the cabin. The recorder was a cassette type, designed to eject automatically when subjected to heat or immersion in water; the ejection mechanism was to be fired electrically by power supplied from special batteries. The sampling rate was once per three seconds for most of the parameters, but five were sampled every half second. Aircraft heading was intended to be recorded but for this flight no serviceable heading source was available. This recorder broke loose from its attachment upon impact with the ground, owing to the high inertia forces. It fell through a split in the rear fuselage onto the ground and was recovered about 15 ft behind the tail of the aircraft, untouched by the fire.

The CID recorder was fitted in the cabin inside a steel fireproof box. It recorded photographically on paper and gave continuous recording of 10 inputs, including altitude, indicated airspeed, normal acceleration (g), and elevator, aileron and rudder angles. It had no automatic ejection mechanism but relied upon its structural integrity to survive fire and crash. This recorder had been in the heart of the fire and much of the trace information was lost, but the elevator angle trace remained legible.

1.12 Wreckage

At impact the aircraft was on a heading of 324° magnetic, almost level fore and aft, banked about 3° to the left and skidding slightly to the right. The accident occurred on level ground at about 700 ft amsl.

The marks on the ground and the wreckage distribution showed that the rate of descent had been very high and the forward speed low. There was no evidence that any part of the aircraft became detached in the air.

1.13 Fire

Fire broke out following impact and destroyed the fuselage and the starboard wing.

1.14 Survival aspects

The inspector who completed the certificate of safety assisted both pilots to fasten their safety harnesses and ensured that everyone had a parachute which was properly adjusted.

Two emergency escape exits had been provided for the crew, one at the forward freight loading aperture on the lower starboard side of the fuselage and the other using the rear ventral passenger entrance situated in the aft end of the fuselage.

For the first a special door was made and was kept in position by 38 explosive bolts. A vertical tunnel led to the door from the cabin floor. The tunnel structure was spring-loaded to exert an outward pressure on the door. The explosive bolts were connected to their own battery and could be fired by a switch on the pilots' centre pedestal or from a similar switch situated at the entrance to the tunnel. It was intended that if the bolts were fired, the door should fall away allowing the tunnel structure to slide down until its upper end was level with the cabin floor and its lower end protruded into the airstream, thus providing the crew with an escape chute. Following the accident the forward freight-hold door and the remains of the door frame were found in the wreckage, both partially melted and burned. The door was not in its frame, and was inverted and trapped between the fuselage and the ground. All the explosive bolts recovered had been detonated. It is considered they were fired by action of the crew rather than by the heat of the fire, because the latter could not have resulted in the door being jettisoned and inverted and a careful search of the ground beneath the door failed to reveal any sign of the bolt heads.

The rear escape exit was a modification to the rear ventral entry door. After opening the rear pressure bulkhead door, the crew could jettison the ventral door by means of a foot-operated lever.

However, although two emergency escape exits were available and each occupant had a parachute, no one escaped.

1.15 Tests and research

The Board of Inquiry examined what theoretical and wind tunnel investigations into the stalling characteristics of the One-Eleven had been made and the extent to which they gave warning of the possibility of difficulty at high angles of incidence. In this connection the Royal Aircraft Establishment analysed the aerodynamic characteristics of the aircraft and the results of BAC wind tunnel tests, and applied the results of these analyses to the flight test data obtained from flight recorder information.

Prior to the commencement of flight testing, wind tunnel tests which were conducted into the variation of lift and pitching moment with incidences for the range 0° to 28° revealed that the stalling behaviour of the aircraft was characterised by a fairly sharp drop in lift coefficient at about 19° incidence.

The onset of the stall extended over the range 15° - 19° and towards the end of this range the aircraft's pitching moment showed a marked nose down tendency; the latter however was not very large or long-lived in terms of persistence with increase of incidence. On the contrary, by 25° incidence, there was evidence of a pitch-up tendency in the pitching moment characteristics of the aircraft.

It should be remembered that subjecting an aircraft to a sudden loss of lift is equivalent to an instantaneous decrease of normal acceleration (referred to as the g-break) which in turn leads to an increase downwards in the normal component of velocity and thus an increased incidence. It is thus possible for the incidence to increase with little or no rotation of the aeroplane. Other changes will occur in the flight condition arising from changes in drag and pitching moment but these are more indirectly related to incidence than is the g-break.

Exploration of the stalling characteristics of the aeroplane was begun in earnest of Flight 47, on 16th October, with a forward CG position. The pilot-in-command of the fatal flight was co-pilot on Flight 47. The briefing sheet for this flight gave an incidence for each of the five configurations in which stalling was to be conducted. These were:-

Configuration	Incidence
Clean	16°
8° flap, undercarriage up	15°
18° flap, undercarriage down	14°
26° flap, undercarriage down	13°
45° flap, undercarriage down	12°

The pilot's report repeated these figures, referring to them as the "limiting incidence". Twelve stalls were carried out and the pilot's report indicated the maximum incidence angles reached in the five configurations were 23°, 19°, 21°, 20° and 17°. Examination of the flight test data shows that the actual maximum figures recorded were 21°, 20 1/2°, 23 1/2°, 26° and 16° respectively. The pilot stated that he exceeded the limiting incidence figures for he considered that at the limiting figures, information gained on the flight would be small and that, in order to produce the king of data required, greater angles of incidence would have to be achieved. He believed that he had to get to, or close to, the stall in order to get any useful and necessary data on the recording film.

He therefore reached indicated angles that were considerably in excess of the limits. On none of the stalls did he have any serious qualms about the behaviour of the aeroplane, nor any difficulty in recovering.

Following Flight 47 it was pointed out that the limits set for the angles of incidence were conservative and made no allowance for scale effect which would delay the onset of changes in the flow (e. g. incidence for the maximum lift coefficient of the wing: C_L max.) by some 3° to 4° of incidence full scale compared with the wind tunnel tests.

Flight 48 was made on 18 October to measure C_L max. The pilot-in-command of that flight was the same as on Flight 53. Twenty five stalls were carried out in the same five configurations and with a forward position of the centre of gravity. According to the pilot's report the incidence angles reached were 21°, 21°, 20°, 19° and 16° respectively, whereas the flight test data showed maximum angles of 22°, 23°, 25°, 23° and 21° with the minimum speeds very much as they had been on the previous flight. The differences between the two sets of figures are explained from the fact that pitch and incidence would continue to increase by one or two degrees due to dynamic overshoot after initiation of recovery action and that the figures in the pilot's reports were readings of a small dial which was not graduated beyond 20°; the co-pilot who made the readings was also engaged in observing and recording other matters. The pilot-in-command commented in his report that apart from those with 45° flap, when the right wing drop appeared to be a limiting factor, he gained the impression in the other configurations "that it should be perfectly possible to fight one's way through the wing drop".

Following these remarks on the lateral control characteristics in turbulence on the approach, a modification to the aileron tab/spoiler linkage was made before Flight 52 to provide for only one degree of aileron movement from neutral instead of four degrees before the commencement of spoiler movement. This resulted in improved lateral control at small deflection, but the maximum rolling moment available remained essentially the same.

After the accident, more extensive wind tunnel tests were made by RAC from which lift and pitching moment coefficients over the incidence range of 0° to 45° were obtainable. The behaviour of the servo-tab-operated elevator control system was studied over the same range. From these tests a number of important deductions have been possible relating to the behaviour of the aircraft in its final stall.

The basic factor in the final pitch-up tendency displayed by the pitching moment curves is the loss of effectiveness of the tail as aircraft incidence is increased. This is accompanied by a loss of elevator effectiveness, which is sufficiently large to render recovery from an excursion into the post-stall region difficult.

An analysis of the hinge moment characteristics of the elevator shows that as body incidence is increased the up-floating tendency of the elevators increases and at large incidence (about 40°) can reach a stage when it is no longer possible to prevent the elevators moving into an up position even though the tab is held in its fully up position.

Fron static considerations it was concluded that there was insufficient elevator power to maintain a nose-down pitching moment beyond about 36° incidence and that therefore beyond this figure recovery would not be possible even with full down elevator. Furthermore at some incidence in the region of 45° with fully down elevator, and 50° with elevator fully up, it was evident that the aeroplane would "lock in" to this incidence. This latter deduction was consistent with the behaviour of the aeroplane as shown by the flight recorders.

The preceding discussion on elevator effectiveness applies to the aircraft configuration as at the time of the accident and is to a large extent independent of the type of longitudinal control used within the same tailplane geometry. As mentioned, the elevator hinge moment is appreciably affected by incidence. This effect is such that, although the amount of down-elevator that can be held by full up tab decreases progressively with increase of incidence beyond 27°, it is still possible to hold some down-elevator to somewhere in the neighbourhood of 40° incidence.

The type of longitudinal control, therefore, is a feature which does not in itself prevent recovery, but coupled with the pitching moment characteristics makes recovery more difficult. In particular if the stick is held centrally (near zero stick force), then, under static conditions, the elevator would assume an upward deflected position. Furthermore just beyond the limit of incidences reached in Flights 47 and 48, that is beyond 25°, the angle assumed by the elevator would be quite large. However in view of the much reduced elevator effectiveness this up-elevator would have a relatively small effect on the rate of build-up of incidence.

2. Analysis and conclusions

2.1 Analysis

Examination of the wreckage revealed that the landing gear and flaps were fully retracted, the tailplane at a setting of 1°33' leading edge up (i. e. trimming the aircraft nose down), the elevators up and the engines rotating at idling speed at impact. No evidence was found of:

- jamming or fouling of the elevators at their hinge points;
- pre-crash damage or defects of the servo and gear tabs, hydraulic gust dampers, aileron and rudder control system, elevator control circuit and engines.

In analysing the flight recorder traces of the final stall in the light of the results of the theoretical considerations discussed in paragraph 1.15 it must be emphasized that the recordings are open to a certain amount of variation in interpretation, largely because the sampling rate of the elevator stick force and the servo-tab angles was once every three seconds: further, the incidence recording stopped at 25°. A continuous trace of the all-important elevator angle was, however, available. A time-history for the 140 seconds before ground impact based on Midas recorder data supplemented by that from the CID recorder is shown in Figure 5. Relevant portions of this have been plotted to a time base with a zero for an incidence of the order of 16° to 17°, as shown in Figure 6.

On all the runs of this flight the elevator deflections are generally more oscillatory than on previous occasions. A number of factors would contribute to this, the pitching moment variation with incidence for incidence beyond 20° or so, the greater sensitivity of the aircraft at an aft centre of gravity and the fact that incidences where hinge moment changes were taking place were being reached just before or during recovery.

The attempt by the pilot to recover is shown by the change in direction of elevator movement at around 9 seconds on the time scale (see Figure 6). A number of things may have prompted this action and it is by no means clear what, for example, was the tab position or the stick force just previous to this. He may have been faced with an unexpected up-elevator position or he may have been alerted by the incidence meter. Whatever was the exact sequence of events it is certain that incidence would have continued to increase during the recovery attempt. According to the analysis of the hinge moment data an incidence of about 40° or more was reached, since it will be seen that at about 13-14 seconds the elevator "up-floats" to reach a fully up position shortly after.

As has been noted, beyond an incidence of about 36° a fully down elevator does not provide a sufficiently large nose-down pitching moment contribution to result in an overall pitching moment in the recovery sense. Hence, even if the elevator had been maintained in a fully down position, recovery from the flight conditions prevailing would have been ruled out. In fact with the elevator virtually locked in its up position the incidence will increase further till the aircraft reaches the stable equilibrium state at about 50° incidence.

The time history in Figure 5 indicates that as the aircraft entered the stall there was a tendency to a wing drop which was corrected by the pilot. Subsequently during the deep stall the aircraft banked successively right, left, then right again. At the high incidence conditions prevailing during the descent the aileron rolling effectiveness would fall off to such an extent that the ailerons become of little value as a roll control. Nevertheless, since the tab, aileron and spoiler movements are consistent, it can be concluded that the pilot was moving his lateral control deliberately; but it should be remembered that some movement of the ailerons would result from the incidences induced by the aircraft's motion and, in the absence of wheel and rudder pedal force records, this tends to obscure the picture. However, the movement of rudder and ailerons is not inconsistent with an attempt by the pilot to regain control by putting the aircraft into an appreciable asymmetric flight condition. At impact minus 50 seconds when the pitch angle was 4° nose-down, full power was applied from both engines and maintained for about 15 seconds. This application of power was accompanied by a rapid pitch-up reaching 17° nose-up; power was then reduced by the pilot apparently to prevent continuation of the pitch-up.

Whilst there is some lack of evidence on the pilot's intentions in this stalling test, the traces, taken together with the pilot's remark after previous stalling tests that it should be possible to fight one's way through the wing drop, are not inconsistent with an attempt to reach a stall as defined by the British Civil Airworthiness Requirements. As a result, the aircraft penetrated further into the post-stall region than it had been taken previously and reached the stable stalled condition from which recovery was not possible.

Possible contributory factors to the accident were examined as follows:

a) were the design and wind tunnel investigations carried sufficiently far:

b) were the flight tests organised and conducted with sufficient prudence to obviate unnecessary risk: and

c) were additional safeguards warranted having regard to the nature of the tests undertaken.

a) There was evidence in the wind tunnel tests of a fairly sharp drop in the lift coefficient associated with the onset of the stall, and a nose-down tendency in the pitching moment. It was expected that in flight there would be a pronounced nose-down pitch at the stall, providing the approach to the stall was gradual. The evidence of a pitch-up tendency which was appearing by 25° incidence in the wind tunnel tests was not interpreted as a matter demanding special precaution; the VC. 10 technique which it had been decided should be used in exploring the One-Eleven stalling characteristics was considered to be sufficiently cautious to avoid difficulty. Against this background it cannot be said that the design and wind tunnel investigations should have been carried further than they were.

b) The technique followed in the VC. 10 stalling programme consisted of taking the aircraft up to or just beyond the angle of incidence at which wind tunnel tests had shown C_L max to occur so that experience and information would be built up gradually. During the initial stalling tests (Flight 47) of the One-Eleven, however, the angles of incidence based on wind tunnel tests, which were provided as a guide to the test pilots, were considerably exceeded, but as explained, no allowance for scale effect had been made when establishing these incidence values. Nevertheless if the VC. 10 stall investigation technique had been closely followed in this case the One-Eleven stalling tests would not have been taken so far, so fast. The apparent lack of concern after Flight 47 appears to have been based on the expectation that a pronounced nose-down change of pitch would occur and also on the innocuous stalling behaviour reported by the pilots after that flight. Since no steps were taken either to warn them of the special features revealed at angles above 25° during the wind tunnel tests or to lay down new "limiting" angles as a guide or to fit a new incidence meter, the pilots may well have interpreted the position as one in which the stall could be explored not only at the higher angles then reached but even beyond. It appears that the pilots themselves were under the impression that an increase of incidence would be associated with a visible pitch-up which would give them adequate warning to recover; they had probably not appreciated that not only would incidence continue to increase after the g-break with no visible pitch-up but that it would increase at a much higher rate than previously. But although the pilots had not been warned that if incidence reached a sufficiently high angle a stable stall was a real possibility and recovery therefrom most unlikely, there was some knowledge among them and the aerodynamicists of difficulties that had occurred during stalling tests of military aircraft with T-tails. It seems reasonable to conclude, therefore, that as by 25° in the wind tunnel tests the nose-down tendency in the pitching moment gave way to a nose-up tendency, and as the firm had a general background knowledge of stalling problems which had arisen with T-tail aircraft, stalling tests should have been more cautiously approached, more closely controlled and more carefully correlated with wind tunnel and flight recorder data.

c) The safety devices which were provided or could have been provided aboard the aircraft were discussed:

Tail Parachute Consideration had been given in the case of the One-Eleven, as in that of the VC. 10, to the fitting of a tail parachute. The matter was being kept under review and no final decision had been made, although it had been intended that a parachute should be fitted before the aircraft made a dynamic stall, thus significantly exceeding the stalling incidence. The retention of the matter under review and deferring of a decision to fit were influenced by the time that would be taken for such a modification and acceptance that the policy of 'gradualness' in relation to stalling would ensure safety. Wind tunnel tests carried out by BAC since the accident indicate that with the elevators in effect locked up and with the aircraft in a stable stall, a tail parachute of the type it was intended to fit would not have given sufficient pitching moment to provide for recovery.

Incidence Meter As mentioned previously, the presentation of body incidence to the pilot was achieved by means of a small dial and pointer. Although the graduated range of the instrument was from 20° to -10° the pointer was free to move to a position equivalent to 25°, where it might either have stopped of flicked to some spurious reading quite unrelated to the vane position. It seems probable that the pilots were unaware of this characteristic of the instrument; the possibility that they were misled by its reading cannot therefore be dismissed although the evidence suggests they were not working to an incidence limitation but were attempting to reach a clearly defined stall. Incidence in excess of the maximum reading of the instrument had been recorded during Flights 47 and 48 and it should have been clear that the range of indication provided was insufficient to present the pilots with a means of monitoring the incidence reached during stalling trials. It would consequently have been prudent to replace the incidence meter used by one capable of registering appreciably higher incidence, irrespective of whether there was any intention of exploring this region immediately.

Escape Two emergency escape exits were provided in the aircraft and each occupant had a parachute, nevertheless, no-one escaped.

Although it may be expected that there was considerable alarm at the rapid loss of height, it seems reasonable to accept that no question of abandoning the aircraft arose until all possibilities of recovery, culminating in the application of full power, had been attempted. When this had been done the aircraft was probably at just under 5,000 feet with less than 30 seconds to go before impact. There is evidence that some attempt was made to abandon the aircraft at a very low height, probably far less than 5,000 feet, since

(i) witnesses heard a sharp report, which could have been the firing of the explosive bolts on the forward escape exit, when they estimated the height of the aircraft to be a few hundred feet; after the crash the door was found trapped between the fuselage and the ground in an inverted position still partly covering the door opening and two of the occupants were near this exit;

(ii) although the rear ventral door (second escape exit) was in position, two of the occupants were some distance towards it.

In test and experimental flying there must at times be a degree of hazard, and a pilot will continue to investigate an unusual or difficult situation while any possibility of recovery exists. Nevertheless the chance of escape might have been improved if emergency drills had been laid down and practised since this could have led the pilot to order at least some members of the crew to abandon the aircraft at an earlier stage and perhaps have enabled any escape attempt to be carried out with greater prospect of success.

Exchange of Information During the investigation consideration was given to the extent of exchange of information between research establishments and the aircraft industry, and among constructors themselves. It emerged that no formal action had been taken in respect of the experience which had accumulated from stalling problems encountered in aircraft with T-tails, although there had been some informal liaison. In respect of this particular accident the British Aircraft Corporation announced almost immediately its intention to make known to manufacturers both in this country and overseas the results of its investigations so that the knowledge gained would be of lasting benefit to the safety of aviation. It appears, nevertheless, that knowledge gained from other incidents and accidents may not always be so applied owing to the lack of effective formal or standing arrangements, and that a more regular basis for the exchange of experience among aircraft constructors and research establishments on new problems affecting safety encountered during aircraft development would have considerable value.

2.2 Conclusions

Findings

The aircraft was flying in accordance with the B Conditions of the Air Navigation Order, 1960; it had been certified as safe for the flight, and was properly loaded.

The pilots were appropriately licensed and were experienced in experimental flight test work.

There was no evidence of any pre-crash structural failure.

The nose-down pitching moment (elevator neutral) just beyond the stall was insufficient to rotate the aeroplane at the rate required to counteract the increase of incidence due to the g-break.

During the fifth stall the angle of incidence reached a value at which the elevator effectiveness was insufficient to effect recovery.

Cause or
Probable cause(s)

During a stalling test the aircraft entered a stable stalled condition recovery from which was impossible.

3. Recommendations

Although no specific recommendations were contained as such in the report paragraph 2.1 "Exchange of information" contains recommendations.

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Test flight En route Stall Airframe - Flight controls

ICAO Ref: AR/863

ACCIDENT TO BAC 111, G-ASHG, OF BRITISH AIRCRAFT CORP. LTD., AT CRAT HILL, WILTSHIRE, ENGLAND. 22 OCTOBER 1963.

TIME HISTORY FOR THE 140 SECONDS BEFORE GROUND IMPACT BASED ON FLIGHT RECORDER DATA

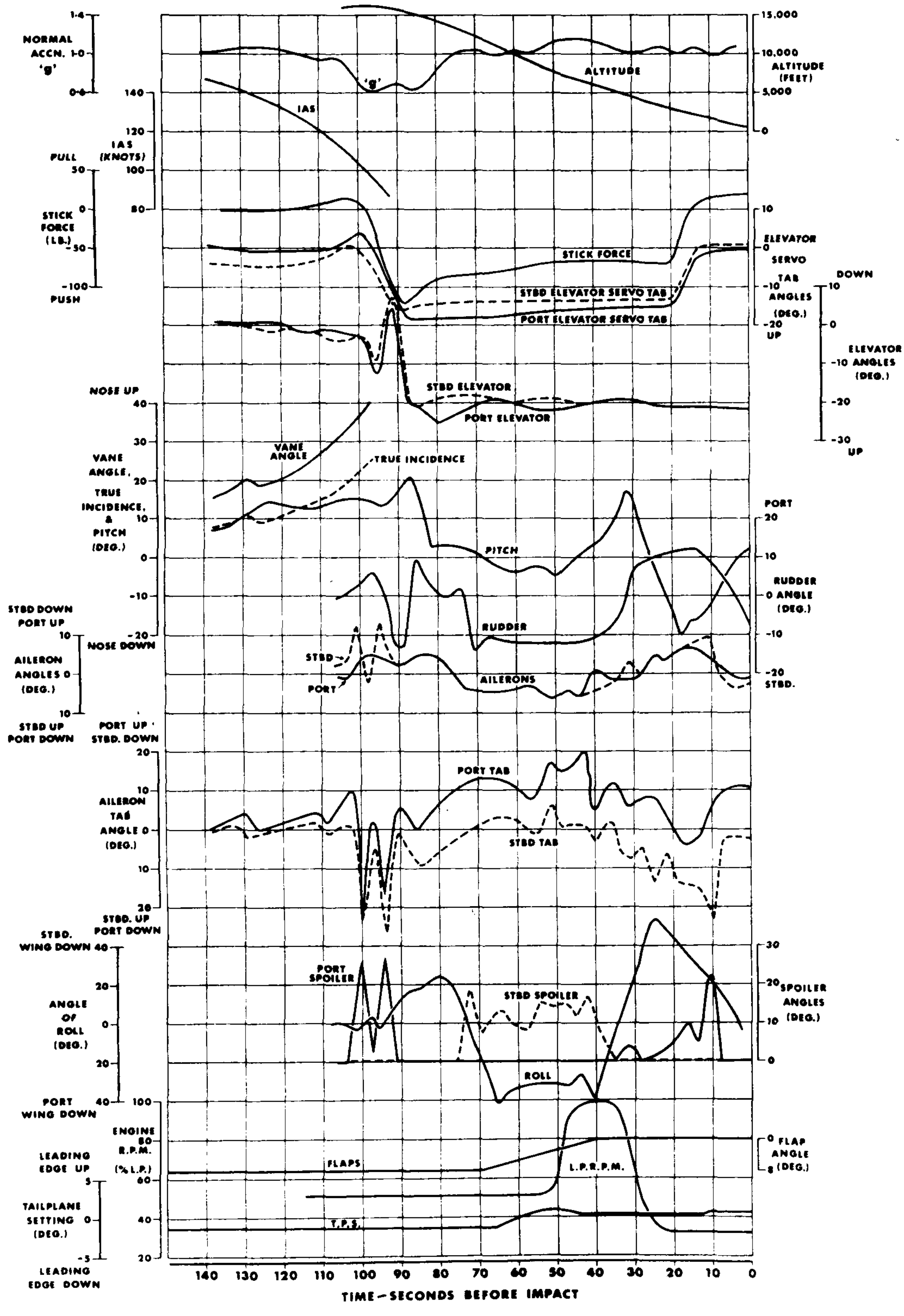

FIGURE 5

ACCIDENT TO BAC 111, G-ASHG, OF BRITISH AIRCRAFT CORP. LTD., AT CRAT HILL, WILTSHIRE, ENGLAND. 22 OCTOBER 1963.

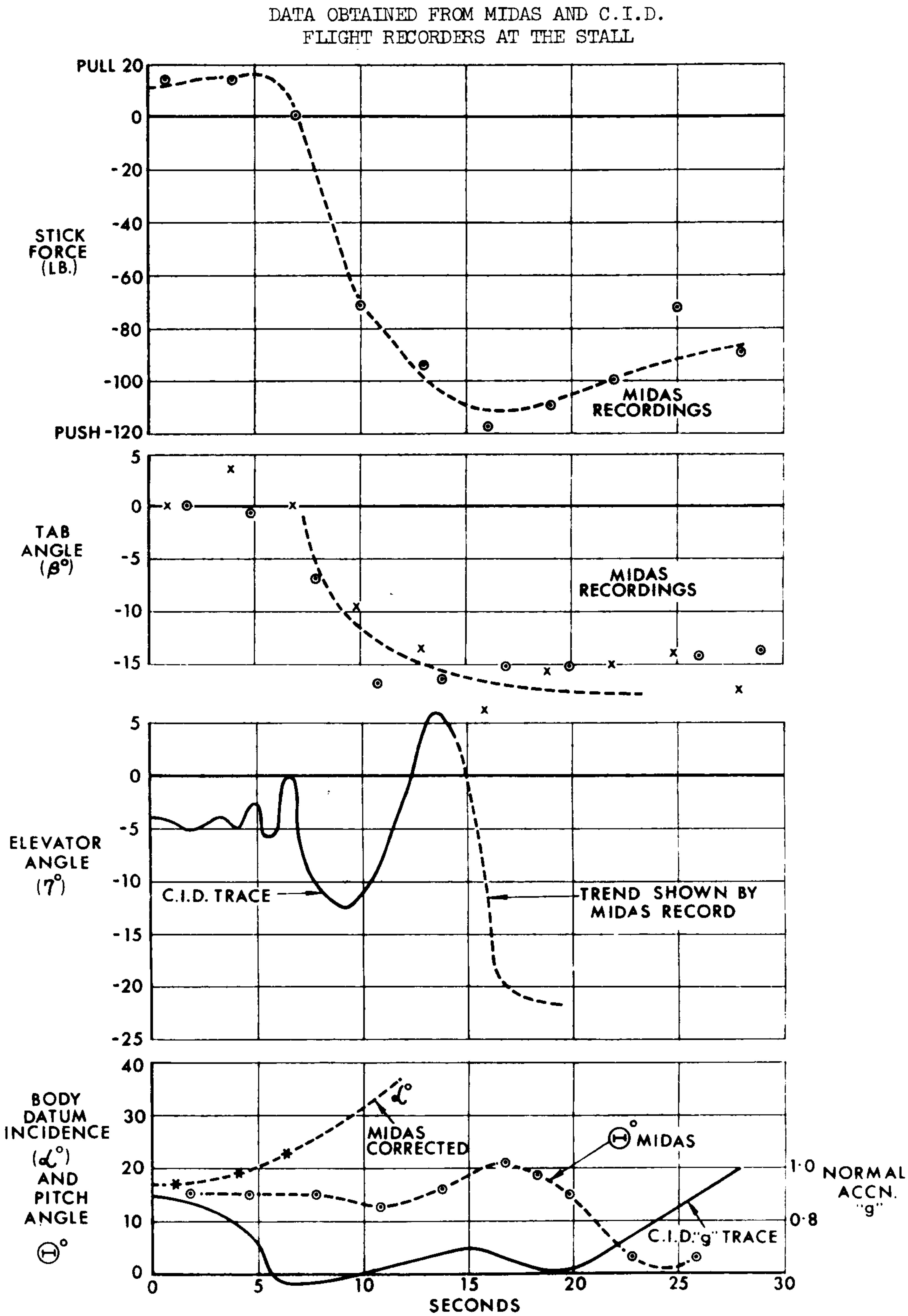

FIGURE 6

No. 8

Trans-Canada Air Lines*, DC-8F-54, CF-TJN, accident at Ste. Therese de Blainville, Quebec, Canada on 29 November 1963. Report of the Commission of Inquiry dated June 1965 released by the Department of Transport, Canada. (Order in Council, dated 8 October, 1964, P.C. 1964-1544)

1. Investigation

1.1 History of the flight

Flight 831 was a scheduled domestic trip from Montreal to Toronto. Its departure was delayed about 10 minutes because of delays to ground transportation of passengers coming from Montreal, however, the 111 passengers were finally loaded by the front door because of water on the ramp area at the rear of the aircraft. The flight was then cleared by air traffic control to Toronto Airport via the St. Eustache omni range station and Ottawa direct to Kleinburg and Toronto at a flight level of 29 000 ft, with instructions to report at 3 000 and 7 000 ft on the climbout from the airport. The take-off roll was begun on runway 06 right at about 1828 hours eastern standard time and took off normally. It reported at 3 000 ft and acknowledged a clearance for a left turn to St. Eustache, and this was the last radio contact with the flight. The flight was monitored on air traffic control radar at the airport to about 8 NM from the airport when the aircraft was in a left turn and surrounded by rain clutter on the radar and was not observed again. The flight did not report through 7 000 ft as instructed. Repeated efforts were made to re-establish radio contact with the flight, however, they were unsuccessful. The aircraft crashed at about 1833 hours approximately 4 miles north of Ste. Therese de Blainville, a few hundred yards to the west of Highway 11, about 16.9 miles from the Montreal International Airport. The co-ordinates of the site were: latitude 45°40'53"N, longitude 73°53'55"W.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	7	111	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed.

* the official name of the airline at the time of the accident - it was changed to Air Canada on 1 January 1965

1.4 Other damage

No damage was incurred by objects other than the aircraft.

1.5 Crew information

The pilot-in-command, age 47 years, held a valid airline transport pilot's licence. He had flown with Trans-Canada Air Lines as a pilot since October 1944 and his experience amounted to 17 206 hours, including 458 hours on DC-8 aircraft and 103 hours on DC-8Fs. He also held a valid Class I instrument flight rating.

The co-pilot, age 35, held a valid airline transport pilot's licence which was endorsed for DC-8 type aircraft in May 1963 and renewed on 23 September 1963. He had flown as pilot with TCA since February 1953 and his experience amounted to 8 303 hours, including 336 hours on DC-8 and 62 hours on DC-8F aircraft. His Class I instrument rating had just been renewed on 7 November 1963.

The third pilot, age 29, had been employed by TCA as a pilot since July 1957. In June 1963 he completed training on DC-8 aircraft. His total flying time as a pilot amounted to 3 603 hours, which included 133 hours on DC-8 aircraft and 144 hours on DC-8Fs. At the time of the accident he held a valid commercial pilot's licence and a Class I instrument flight rating.

The three pilots had all received at least two TCA en route flight checks during the year prior to the accident. All held valid medical certificates, and investigation following the accident showed them to be physically fit.

The records of the purser and the three stewardesses revealed nothing pertinent to the inquiry.

1.6 Aircraft information

In February 1963 the Department of Transport issued a certificate of registration to the aircraft. At the time of the accident the aircraft had flown just over 2 174 hours.

Nothing in its maintenance history suggested a cause of the accident, although the following maintenance shortcomings were found:

> Federal Aviation Agency (FAA) Airworthiness Directive 63-8-2 required that the elevator control tab push rod assembly be removed and visually inspected within 300 hours service time after 18 April 1963. However, this inspection on the subject aircraft was not made until 708 hours service time after 18 April 1963. Moreover, the assembly was not removed, but merely inspected in place. Also, FAA Airworthiness Directive 61-24-1 requires that if any JT-3D3 engine was disassembled since last overhaul to the extent of exposing any bearing compartment, the main oil screen be inspected at periods of not more than 12 hours service time until the screen was free of contamination for two successive inspections. TCA inspected the main oil screens after ground running the engines and found they were free of contamination but did not inspect them after time in service. Evidence did not indicate that either of these servicing shortcomings had any influence upon the crash.

The total weight of the aircraft was 135 030 lb, and it was properly loaded at the time of the accident.

The report states that the aircraft was supplied with the proper fuel, however, the type of fuel being used is not stated.

1.7 Meteorological information

At 1825 hours on the evening in question, the weather was reported as: overcast, light rain and fog, visibility - 4 miles, surface wind NE at 12 mph. Only light icing could be expected. Based on the weather information available and testimony of other pilots who flew in the accident area around the time of the crash, it was concluded that turbulence, in itself, would not have been severe enough to cause any difficulty. The weather conditions were suitable for the flight.

1.8 Aids to navigation

Not pertinent to the accident.

1.9 Communications

The co-pilot made all the radio transmissions and no difficulty was reported by the flight crew. The last radio contact with the aircraft was when it reported at 3 000 ft and acknowledged a clearance for a left turn to St. Eustache.

1.10 Aerodrome and ground facilities

Radio equipment and weather radar were operating normally.

1.11 Flight recorders

No flight recorders were installed on the aircraft.

1.12 Wreckage

The wreckage was distributed in two major areas: the crater area of about 17 000 sq ft and an area ahead of the crater area which will be referred to as a scatter area involving another 700 000 sq ft.

Protracted and costly salvage operations commenced on 30 November 1963 and extended until 27 April 1964. At the height of the operations, early in December 1963, over 1 500 personnel were involved.

Excavation in the crater area involved the moving and screening of 26 000 cu yd of soil under very difficult conditions. The crater area was surveyed by engineers and a grid system established, in order that the identity and location of salvage could be recorded. Recovery was extremely difficult due to the weather and the nature of the soil. It was started by manual labour but soon heavy mechanical equipment was introduced to excavate around the edge of the crater cutting gradually towards the centre. Pumps were used to dispose of water. Within a few days, the operation proceeded on a 24-hour basis by means of floodlights. As the heavy equipment progressed toward the centre of the crater, serious engineering problems were encountered because the sub-soil could not support heavy equipment and on 12 December 1963 it was decided that it was not possible to continue the excavation without constructing a coffer dam because of increasing landslides as the excavation reached the 20 to 30 ft depth. The coffer dam was completed in February 1964 and enclosed an area of 140 by 120 ft. As excavation progressed, a network of steel bracing was installed every 10 ft in order to support the walls.

All salvage when removed, was taken to a sorting area where it was separated from the clay type soil, washed, and then trucked to an empty hangar at Montreal Airport for identification and investigation. On the whole, 105 442 lb of wreckage were recovered, leaving 29 588 lb unaccounted for. It was considered that the bulk of this missing wreckage would exist in very small pieces and that its recovery would not assist in determining the cause of the accident. With the exception of the cockpit area, about 90% of the flight systems components were recovered. The material recovered was sufficient to assure reasonably firm conclusions in respect of all aspects of structural performance and integrity.

The horizontal stabilizer was at an angle between 1.65° and 2° nose down trim and had been operated to that position by hydraulic power. The pitch trim compensator actuator was in the extended position. The ailerons were in the power operated mode and in an attitude calling for right wing up. The position of the elevators at impact was not determined.

The flight path heading, as deduced from throw of dense pieces of wreckage was estimated to be 296 ± 15° magnetic. The angle of descent, as deduced from trees which were cut by the aircraft, appeared to have been about 55 ± 7°, and the estimated right wing down attitude of the aircraft at impact was 35 ± 8°.

1.13 Fire

There was no evidence of internal or external fire damage prior to impact nor was there any evidence of in-flight explosion of tires, wheels or brakes.

1.14 Survival aspects

Crew harness recovered showed evidence of being fastened, while passenger harness recovery indicates the possibility of only one-third being fastened.

1.15 Tests and research

At high subsonics Mach numbers, the airflow pattern over the wing results in the formation of local shock waves which cause the centre of lift on the wing to be shifted rearward. This causes the aircraft to nose down or "tuck" as speed increases. An up elevator movement is required to counteract the tuck, requiring greater force as airspeed increases. The pitch trim compensator system provides automatically this up elevator force to the co-pilot's control column by sensing Mach number and reaching accordingly.

The system consists basically of a Mach computer and a jack-screw-type actuator, powered by a 28 volt DC motor. The co-pilot's Pitot system supplies Pitot pressure to the computer. Static pressure is obtained from the autopilot static line. The force applied to the control column is a function of the Mach number which is computed from the Pitot static pressures. The computer controls the actuator motor which is mechanically linked to the bottom of the co-pilot's control column. A mechanical indicator on the left side of the co-pilot's control column indicates the relative amount of force being applied to the control column by the pitch trim compensator.

There is little or no force applied to the control column at computed Mach numbers below .800. Minimum force starts to be applied at Mach .800 and the force increases as Mach increases. The equivalent control column "nose up" force is about 3 lb at Mach .825 increasing to 34 lb at Mach .880.

Douglas Aircraft Company and the FAA carried out tests using a fully instrumented DC-8 to determine the stability characteristics of this aircraft type with a fully extended pitch trim compensator and with the stabilizer trimmed to .5° AND.

The tests indicated that, in this configuration the stability of the aircraft was such that a pilot could experience difficulty in maintaining proper aircraft attitudes particularly in turbulence. This problem would be accentuated when flying in cloud without visual reference to the ground or the horizon.

Although fully instrumented flight tests have not been conducted using more than .5° AND stabilizer trim with the pitch trim compensator fully extended, it is felt that larger amount of AND stabilizer trim would have a more adverse effect on aircraft stability. This was confirmed by a report of the supervising project test pilot for the FAA for Boeing 707, 720 and 727 aircraft.

A flight was carried out on a modified DC-8 (called the 4% leading edge model) to check pitch trim compensator malfunctions against those experienced in other aircraft. This aircraft would have to be loaded to a centre of gravity 2% further aft to be equivalent to the standard wing aircraft. For maximum rear centre of gravity, this would require that the aircraft be at 34% MAC. However, a flight was made on this aircraft at a nominal centre of gravity of 26% MAC. The flight showed that there was no appreciable difference in the result. However, during manoeuvring with a fully extended pitch trim compensator at a speed of about 220 kt and the aircraft trimmed to its previous extreme of full nose down (2.0° AND), it was observed that any attempt at manoeuvring the aircraft with the elevator system resulted in sharp reversals in the aircraft's manoeuvring stability. This was another strong reason for limiting the aircraft nose down stabilizer travel. These findings were further tested and confirmed by the Douglas Aircraft Company and it was felt that with the stabilizer restricted to .5 degree instead of the previous 2.0° AND there should not be serious control problem.

2. Analysis and conclusions

2.1 Analysis

One hundred and ten witnesses testified regarding the accident. An experienced bush pilot who lived seven miles from the accident site, stated, "that this jet was climbing because the engine noise was strong and then there was an abrupt cessation of power or this noise, the jet noise, and then a whistling noise that you could attribute to empennage or flying wires ... the pilot was (in his opinion) doing an expedited letdown and the whistling noise was from the passage of the aircraft through the air and not from the engines." He had heard the aircraft at about 1830 hours.

The indicated airspeed at impact, as determined by the position of the Mach corrector cams of the two independent Kollsman Integrated Flight Instrument System units, corrected to 225 ft asl at 38°F ambient air temperature, was 470 kt to a conversion accuracy of plus or minus 1%. On this basis, the velocity of the aircraft at impact was calculated as being between 470 and 485 kt.

None of the many samples of human tissue which were analysed showed any evidence of unusual toxic substances or in-flight fire. Also it was found that the throttles were manually moved to the flight idle position and the ailerons were moved to correct an angle of bank. These facts indicated that one or more pilots were conscious and capable of co-ordinated movement up to the time of impact.

Following examination of all available evidence it was concluded that at the time of impact the aircraft's main structure was intact, and all control surfaces were in place. All power plants were attached to their pylons, and the landing gear, wing flaps and spoilers were retracted. There was no evidence of mid-air disintegration due to turbulence, collision with birds or other objects, explosion or fire.

About 75% in weight of all four power plants was recovered. No anomalous deficiencies were found in the material recovered. There was no catastrophic failure of a single engine and no simultaneous interconnected failures of several engines. There was no evidence of in-flight fire, contaminated fuel, contaminated oil, bird ingestion, icing, engine flameout or water ingestion and no evidence of inadvertent or accidental application of reverse thrust. All four engines were at or near a forward flight idle condition at the time of impact and it appeared that the flight idle power setting was selected at least 10 seconds prior to impact. The engine anti-icing system was operating. All major hydraulic, electrical and pneumatic systems were available up to the time of impact. Therefore, it appears that all controls and all control surfaces were serviceable, functioning and available to the flight crew. There was no evidence of any malfunction of the drive motors or control which actuate the horizontal stabilizer.

The horizontal stabilizer was found at an angle between 1.65° and 2° nose down. Its range is from about 10° aircraft nose up (ANU) to about 2° aircraft nose down (AND). The motion of the horizontal stabilizer is obtained from two screw jacks which are driven by a hydraulic motor. Normal control of the motor and therefore control of the angle of the horizontal stabilizer is exercised by the pilot in two ways:

1) by movement of two "suitcase handles" on the central pedestal; and

2) by means of a pair of two-way switches on the control column itself.

The actual position of the stabilizer at any time cannot be determined from the position of either the suitcase handles or the control column switch. A sliding pointer moving along a scale on the central pedestal indicates the horizontal stabilizer's position. This sliding pointer is not in plain view of the pilot when in his normal flying position.

The autopilot, when engaged, will also control the movement of the horizontal stabilizer through a secondary electrical system. In case of an hydraulic failure, or when desired, the pilot can control the horizontal stabilizer's movement by electrical switches which energize the secondary electrical system.

If the secondary electrical system is used, the horizontal stabilizer movement is restricted to 1.5° AND. Following the accident the stabilizer jacks were found in a position representing more than 1.6° AND. Therefore, it was evident that the horizontal stabilizer's position was reached by using the hydraulic power system and not through the autopilot and the electrical system.

According to evidence, it is not possible for the hydraulic system to malfunction in such a way as to cause the stabilizer to move to a position which had not been pre-selected by the pilot. It was, therefore, concluded that the pilot intentionally moved the stabilizer into a position more than 1.6° AND by means of the suitcase handles or the trim switches.

In view of the considerable experience of these pilots, unintentional trimming of the stabilizer was considered highly unlikely.

With the application of more than 1.6° of AND trim, the aircraft would assume a nose down attitude and would build up airspeed at a very rapid rate. If the pilot did not attempt swift recovery action, the speed would build up to a point where actual recovery would become difficult, if not impossible. In the earlier stages of the airspeed build up, recovery could have been effected by re-trimming the horizontal stabilizer to a neutral or ANU position, or by pulling back on the control column to deflect the elevators. However, as speed increased, the force required to pull back the control also increased until it became physically impossible to apply sufficient force. Recovery could still have been effected by re-trimming the horizontal stabilizer, provided that the trimming mechanism could function. Evidence showed that at high rates of speed with a pull force exerted on the control column, the hydraulic motor which actuates the screw jacks in the horizontal stabilizer is effectively stalled and cannot overcome the aerodynamic forces. Under such circumstances, it appeared that the only possibility of recovery was to release the pressure on the control column, thereby relieving the aerodynamic forces on the empennage and unstalling the hydraulic motor which would then be able to move the horizontal stabilizer from its extreme AND position. Release of the pull on the control column would, of course, momentarily aggravate the situation and permit the aircraft to assume a steeper glide angle and increase its velocity.

If an aircraft has sufficient altitude, recovery can be effected by the aforementioned procedure. In other known cases, losses in height of upwards of 13 000 ft were required before pullout from the dive could be effected. The exact altitude of the subject aircraft at the time of the upset was not established. However it probably was not above 8 000 ft and more likely between 5 000 and 7 000 ft.

During the climb to cruising altitude, it would have been normal to trim the aircraft in a nose up attitude, and this attitude should have been maintained far beyond Ste. Rose or Ste. Therese.

The pilot would not have intentionally applied a large amount of nose down trim unless indications of the instruments or physical sensations would have indicated that a nose down attitude was required.

To determine how he could have been misled, several possibilities were considered:

1. Failure of an airspeed indicator

   Such failure is rare and should have been detected before the aircraft was put into a dangerous attitude.

2. Icing or blockage of the static system

   It was considered unlikely that both the pilot-in-command's and the co-pilot's instruments could be seriously affected by such an occurrence and that should have it occurred, indications would have alerted the pilots prior to or immediately after take-off.

3. Leakage in the static system

It was considered very unlikely that a leakage could have occurred simultaneously in both the pilot-in-command's and the co-pilot's systems. Therefore contradictory instrument indications would have been evident in time to avoid a serious upset.

4. Unwitting engagement of autopilot

If the autopilot was unwittingly engaged during climb and the pilot trimmed the aircraft nose down to achieve a less steep climb angle, the autopilot would have tend to automatically re-trim the stabilizer towards the nose up condition. However, if the pilot trimmed the stabilizer full nose down and disengaged the autopilot as the stabilizer reached the full aircraft nose down position, this could have accounted for the mis-trimmed condition. It would be unreasonable to expect that at this time the aircraft was in such an attitude and speed condition that recovery could not be accomplished.

5. Failure or icing of the Pitot system

A mechanical failure of this system is unlikely.

A failure of a Pitot heater can occur and would likely result in freezing of the Pitot head. This would result in a fairly rapid drop on the airspeed indicator associated with the blocked Pitot system. If freezing of a Pitot head occurred the pilot would probably have pushed the nose of the aircraft down in order to maintain airspeed and might have put the aircraft into a diving attitude. However, two separate Pitot systems existed on the aircraft - one which supplied Pitot pressure to the pilot-in-command's instruments and the other to the co-pilot's instruments. Therefore if only one Pitot head were frozen correct airspeed would have been indicated on the airspeed indicator associated with the unfrozen Pitot system. This should have alerted the pilots to the fact that a fault had occurred in a Pitot system and corrective action should have been taken in time to avoid a serious upset.

If the Pitot heat had not been switched on both Pitot heads could have become frozen simultaneously and both the pilot-in-command's and the co-pilot's airspeed indicators would have indicated a decreasing airspeed. In this event, the pilot could have been misled by airspeed indications to the extent that a dive could have resulted from which recovery could not be made in the altitude available.

6. Erroneous indication of aircraft attitude

If an attitude instrument failed without warning at a time when a pilot is concentrating intently on flying the aircraft, such as he would have been doing during initial climbout and manoeuvring, it is likely that the pilot would have followed the instrument until he became aware of the false information by reference to other instruments. By this time the aircraft may have been at or approaching extreme attitudes.

If an artificial horizon indicator failed through lack of electrical power or failed to truly follow the vertical gyro associated with it, a warning flag should have appeared and the pilot should have been alerted.

If its associated vertical gyro failed and the artificial horizon followed the failed gyro, a warning flag will not appear. Evidence indicated that the roll resolvers in the autopilot system showed a position which was consistent with the calculated bank angle of the aircraft on impact. Although the roll resolver reading was consistent with a correctly operating vertical gyro, it did not prove that the pilot-in-command's vertical gyro was in fact operating properly.

There was also the possibility, although remote, that the pilot-in-command's artificial horizon instrument itself failed, and the warning flag did not appear.

7. Unprogrammed extension of pitch trim compensator

The pitch trim compensator has been known to extend fully due to a fault in the system. When this occurs, it usually is detected immediately by the rearward pressure on the control column and by the clocking sound which accompanies the extension. If the pilot did not become aware of the unprogrammed extension, he would have tend to apply nose down trim to counteract the effect. If the pitch trim compensator subsequently retracted or was retracted by pilot action with counteracting nose down trim applied, there would have been a tendency for the aircraft to pitch nose down. This should immediately have been apparent to the pilot, and no difficulty should have been encountered in effecting recovery at the speeds estimated for this flight during climb.

If the pitch trim compensator extended fully and remained extended with the horizontal stabilizer trimmed to counteract the effect of "up" elevator, the aircraft's manoeuvring would have been adversely affected.

2.2 Conclusions

Findings

The aircraft took off normally and carried out the noise abatement procedure prescribed for runway 06 right at the Montreal International Airport.

The aircraft commenced a left turn, in accordance with the clearance, about 8 NM from the point where power was applied for take-off. Near Ste. Rose, a witness (with considerable bush flying experience) heard a jet aircraft reduce power abruptly at about the time the subject flight would have been in the immediate area. No other jet aircraft, civil or military, was reported to be in the vicinity at that time. The aircraft then deviated from its normal flight path about 55° to the right and descended quickly from the altitude attained during climb after passing Ste. Rose. It maintained a relatively straight course on a heading of about 330°M between Ste. Rose and the crash site, then impacted the ground at a steep angle.

The total time involved in this flight from the commencement of the take-off roll to ground impact was 5 minutes ± 15 seconds.

The flight crew were properly certificated and had sufficient experience on DC-8 aircraft to be qualified for their respective duties. They were physically fit and no evidence of possible intoxication were found.

The aircraft was properly certificated, had been maintained as required, and was correctly dispatched on the subject flight. It was also properly loaded.

Weather conditions were suitable for the flight.

No difficulty with the operation of the flight was indicated or reported by the flight crew. Since the co-pilot made all the radio transmissions, it was presumed that the pilot-in-command was flying the aircraft.

A ground and air search of the probable flight path and adjacent areas revealed no evidence of wreckage or parts having fallen from the aircraft while in flight.

The aircraft main structure was intact and functional at impact and there was no evidence of in-flight fire or explosion prior to impact. The landing gear, flaps and spoilers were retracted and the wing slots closed. The pitch trim compensator actuator was in the extended position and the horizontal stabilizer at a setting of 1.9° nose down on the right hand side and between 1.6° and 1.7° nose down on the left hand side.

No evidence of a possible malfunction or failure of the engines were found. All four engines have been set to flight idle at least 10 seconds prior to impact.

Cause or
~~Probable~~ cause(s)

The actual cause of the accident could not be determined with certainty.

The most probable chain of events which culminated in the accident as follows, for one of the reasons set out below, the pilot applied the near maximum available aircraft nose down (AND) trim to the horizontal stabilizer. The aircraft then commenced a diving descent, building up speed at such a rate that any attempted recovery was ineffective because the stabilizer hydraulic motor had stalled, thus making it impossible within the altitude available to trim the aircraft cut of the extreme AND position.

a) This first reason which might have indicated to the pilot the necessity for applying nose down trim could have been icing of the Pitot system. While the experience and competency of the crew would likely have led them to recognize the fault in time to take corrective action, the possibility that this condition caused the application of AND trim cannot be dismissed.

b) The second reason could have been a failure of a vertical gyro. The evidence indicated that it was possible to have a failure of a vertical gyro without an associated warning flag. If such a failure occurred and the aircraft was being flown with reference to the associated artificial horizon instrument, it is likely that the pilot would have been misled by the erroneous indication and could have applied nose down trim. The subject aircraft was equipped with a standby artificial horizon located on the pilot-in-command's instrument panel and this cross reference, together with the experience and competency of the crew, would likely have led them to recognize the fault in time to take corrective action. Again, the possibility that this condition caused the application of AND trim cannot be dismissed.

c) The third reason could have been an unprogrammed and unnoticed extension of the pitch trim compensator (PTC). This would have had the effect of moving the control column back, the elevators up and the aircraft to a nose up condition. The pilot would likely have counteracted the pitch up force of the elevators by trimming the horizontal stabilizer to or near to the limit of the aircraft nose down setting. The evidence showed that the simultaneous application of up elevator from the PTC and the application of as little as 0.5° of aircraft nose down trim on the horizontal stabilizer has an adverse effect on aircraft stability and can create a difficult control problem. The problems of instability and control are more serious as further AND trim is applied. In the subject aircraft, 2.0° of AND trim were available, and it appears that the pilot applied at least 1.6° of the available trim. It is unlikely that the flight crew were aware of the serious stability and control problems that can result from the combination of extended PTC and AND trim, even if they had been aware that the PTC had extended. The aircraft would then be in a condition where a slight displacement from its trim point would lead to divergent oscillations. In other words, a minor change of attitude, easily caused by the existing turbulence, would build up into large displacements. The inadequate control available to the pilot and the lack of an external horizon reference would likely result in the aircraft eventually assuming a dive attitude.

It was concluded that an unprogrammed extension of the pitch trim compensator was the most probable cause for the pilot having applied aircraft nose down trim.

3. <u>Recommendations</u>

Based upon the evidence the Board recommended that:

1. a flight data recorder be installed as soon as possible at least in all transport category turbine-powered aircraft engaged in commercial operations in Canada;

2. DC-8 pilots be made fully aware of the stability characteristics of the DC-8 with the full extension of the pitch trim compensator and with the stabilizer trimmed to counteract this effect;

3. an improved vertical gyro warning system be installed in DC-8s which would give the pilot immediate warning of any type of failure which would affect aircraft attitude indications;

4. the Pitot heat circuit in the DC-8 be modified so that a positive warning is provided to the pilot if the Pitot heat is either not switched on or has failed;

5. an improved means of indicating horizontal stabilizer position to the pilots of DC-8s be provided;

6. the advisability of making the use of check lists mandatory be studied by the Department of Transport (Evidence showed that it was not normal practice to use a check list after take-off, and the advisability of checking without the aid of a check list was questioned);

7. airworthiness directives be followed and that appropriate procedures be instituted to ensure that this be done.

4. Action taken

Douglas Aircraft Company issued Service Bulletin No. 27-161 on 9 September 1964 which called for a relocation of the stabilizer trim stop. The relocation of this stop reduces the amount of aircraft nose down trim available from 2^{o} to about $.5^{o}$. The reason for this modification was to minimize the possibility of mis-trimming.

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ICAO Ref: AR/870

No. 9

Trans Mediterranean Airways, DC-4 (C-54A), OD-AEB, accident in the Koh-i-Safid Mountains, Afghanistan on 12 December 1963. Report, dated November 1964, released by the Afghan Air Authority

1. Investigation

1.1 History of the flight

The aircraft was on a non-scheduled international cargo flight from Beirut, Lebanon to Kabul, Afghanistan via Kuwait, carrying a crew of three. The trip to Kuwait was uneventful, and it arrived there at 0036 hours GMT on 12 December. Departure from Kuwait for Kabul was at 0256 hours and the flight reported passing Kandahar at 0838 and Kalat at 0900 flying at flight level 110. While en route the aircraft was provided with the Kandahar and Kabul weather. At 0942 hours it reported passing Ghazni at 0940, flying at flight level 150 and estimated its arrival time at Kabul as 1010 hours. However, at 0958 (i.e. 12 minutes before ETA) it reported overhead Kabul and requested the latest weather situation which was provided. As the aircraft could not land at Kabul because of the weather conditions it reported at 0959 hours that it was diverting to Lahore. Shortly thereafter it reported it was proceeding to Zahedan via Ghazni (ETA 1025), Kandahar (ETA 1130) Zahedan (ETA 1315). It would maintain flight level 150 to Ghazni, 130 to Kandahar and 110 to Zahedan. At 1003 hours the Kabul tower passed the Kandahar weather to the flight and 5 minutes later the flight reported it was 25 miles out from Kabul, at flight level 150. The aircraft was then cleared by Kabul tower to route frequency and nothing further was heard from it. The wreckage of the aircraft was first sighted on 16 August 1964, after the snow had melted, at an elevation of 13 940 ft amsl in the Koh-i-Safid Mountains 50 NM west of Ghazni and 42 NM from the approved air route. The coordinates of the accident site were estimated to be 33° 37'N 67° 35'E (See Figure 7). The time of the accident was some time after 1015 hours GMT on 12 December 1963.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3		
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The pilot-in-command joined TMA in January 1963. In April 1963 he failed to pass his first check flight with the Company, and it was stated that he needed more practice on instrument flying. However, he passed the check in May 1963 and again in November 1963. He held a valid Lebanese airline transport pilot's licence at the time of the accident. His total flying experience amounted to 9 957 hours which included 3 193 hours on DC-4 aircraft and 8 000 hours flown in command. He had been given three months' notice of termination of his employment due to a reduction in the Company's activities and was making his last flight for the Company. He had previously worked for at least five other aircraft operators, and the prospect of changing once more might have occupied his mind.

The co-pilot had been discharged three times from the Company as a result of adverse reports on his flying and for not being able to keep up his licence. However, since 1961 ha had shown definite improvement and had managed to restore his professional pilot's licence and pass a DC-4 flight check in August 1963. He had flown over the route to Kabul on numerous occasions. He had flown 2 842 hours including 743 hours on DC-4 aircraft.

The third crew member was also flying in the capacity of co-pilot. He also held a professional pilot's licence and had flown 2 655 hours including 29 hours on the DC-4. Most of his flying experience was acquired as second pilot on DC-3 and Viscount aircraft.

The aircraft was scheduled to take-off from Beirut at 1900 hours GMT on 11 December, and the crew had, therefore, been on duty for at least sixteen hours. They had been flying for about 2-1/2 hours in an unpressurized aircraft at 15 000 ft and the pilot-in-command had mentioned to another pilot while en route that his oxygen was getting very low. Therefore fatigue and a lack of oxygen may have contributed to the accident.

1.6 Aircraft information

The aircraft's certificate of airworthiness was valid until 23 January 1964. No information was contained in the report concerning the aircraft's maintenance history aside from the times since last overhaul of the engines and propellers.

Errors were found in the weight and balance sheet as to the amount of fuel carried from Kuwait. This indicated possible carelessness or fatigue on the part of the pilot. On departure from Kuwait the aircraft carried a load of 3 201 kg and an estimated 3 306 U.S. gal of fuel. The latter was incorrectly entered as 3 000 gal.

1.7 Meteorological information

Evidence indicated that the pilot took off from Kuwait at 0256 hours for the flight to Kabul without obtaining any route or terminal weather forecast. In fact, none was available at Kuwait. However, he filed a flight plan indicating that after passing the Iran/Afghan frontier it would be under VFR, with Kandahar as the alternate.

Almost the entire route to Kabul via Kandahar and Ghazni coincided at this time with the line of a cold front which was slowly moving eastwards and was followed by a secondary front.

At 0900 hours when the aircraft had passed Kandahar, bad weather extended over the north, east, southeast and central parts of Afghanistan.

Kabul was overcast with continuous rain and the lowest clouds were at 600 m. Ghazni and Maimana were overcast with snow. By 1200 hours the main cold front had passed east of Kabul and Ghazni with occluded front conditions between. Kabul still had continuous rain. Ghazni had cloud down to 600 m but no precipitation at that time. Kandahar had rising dust, and the sky was not visible. Zahedan, Birjand, and Herat were clear.

While en route, Kandahar Flight Information Centre passed several weather reports to the flight concerning the weather conditions at Kabul and Kandahar. The pilot advised that he was proceeding to Kabul and if he was unable to land there, he would divert to Lahore. At 0900 hours the flight was provided with the following weather forecast for Lahore:

> "scattered thunderstorms/rain accompanied by gusty winds with moderate turbulence associated with 24/8 CB at 3 500 ft likely Lahore FIR period 120550. 121800 surface wind NE/may rise to 40 kts and visibility may fall to one mile or less in rain gust."

At 0955 hours the flight contacted Kabul Tower and was provided with the following actual weather situation:

> "cloud 8/8 surface wind 270/2kt. Visibility 1 NM snow and rain. Cloud 8/8 NS 250 metres relative humidity 100%. Temperature - 2°C."

The actual weather picture for 1000 hours followed shortly thereafter:

> "Cloud 8/8 NS. 300 metres visibility 1-1/2 NM slight rain, QNH 29.90 inches."

The flight then reported that it could not land at Kabul and was diverting to Lahore and it requested the actual weather at Kandahar. Having been advised by the pilot of Iranian Airways Flight 422 flying from Tehran to Zahedan and Kabul, that Zahedan was clear, it finally decided to divert instead to Zahedan.

At 1003 hours Kabul Tower provided the flight with the 0900 hour weather reports for Kandahar and Ghazni as follows:

Kandahar: "Sky invisible, surface wind 150°/18 kt gusting to 24 kt. Visibility 200 m, duststorm, QNH 1011.1."

Ghazni: "Cloud 8/8, surface wind 360°/2 kt. Visibility 10 km, snowing clouds 5/8 SC at 3 300 ft, 8/8 NS at 4 000 ft."

At 1004 hours the flight was heard relaying these two reports to Iranian Flight 422, as requested by Kabul Tower.

1.8 Aids to navigation

There were MF beacons in the accident area as well as at Kabul. The pilot of Flight 422, flying in the area around the time of the accident said that reception of the MF beacons was very good. Also, the subject flight was apparently able to home on the Kabul beacon during the inbound flight.

1.9 Communications

The aircraft was in contact with Kandahar Flight Information Centre (on HF) and with Kabul Tower (on VHF) during the flight. At 1008 hours it reported it was 25 miles out from Kabul at flight level 150 and was cleared by Kabul Tower to route frequency. Nothing further was heard from the flight. Flight IR 422 was in VHF contact with the aircraft up until approximately 1015 hours.

1.10 Aerodrome and ground facilities

They were not relevant to this accident.

1.11 Flight recorders

No flight recorder information was contained in the report.

1.12 Wreckage

The aircraft wreckage was scattered over a wide area of mountainside (See Figures 8 and 9) at an elevation established by an altimeter as 13 940 ft amsl. The aircraft appeared to have struck the top of a ridge when flying in a southwesterly direction and to have disintegrated. It then fell down a steep slope on the other side of the ridge.

All four engines had broken away from the wings, and the propellers had broken away from the engines. The manner in which the propeller blades were bent by the impact indicated that the engines were developing power at the time of the accident. There were no sings that any one of the propellers had been feathered at impact. The fuselage had broken into many pieces.

1.13 Fire

There was no fire following impact.

1.14 Survival aspects

Heavy snow on the mountains covered the wreckage. An extensive aerial search covered the scene of the accident, but it was not possible to find the wreckage of the aircraft until after the snow melted. It was first sighted on 16 August 1964, i.e. 8 months after the accident occurred.

Two experienced search parties reached the accident site, however, both encountered considerable difficulty in getting there because of the mountainous terrain in which the aircraft had crashed.

1.15 Tests and research

No information of this sort was contained in the report.

2. Analysis and conclusions

2.1 Analysis

A number of charts from Jeppesen route guides were recovered by the search party from the wreckage. The latest of these showed a non-directional radio beacon located at Ghazni. However, it had not been operating since March 1962. This was confirmed by a Class I Notam (No. 018, dated 25 March 1962). The flight plan from Kuwait indicated that the aircraft was equipped with ILS, VOR and radio compass. However, none of the ADF tuning units were recovered from the wreckage and it was therefore impossible to establish which beacons were used by the crew at the time of the accident.

The following tracks could have been followed by the aircraft between Kabul and Zahedan:

Kabul - Ghazni	212°T
Kabul - Zahedan direct	237°T
Kabul - site of the crash	239°T

The wreckage was found 42 NM from the centre line of the route via Ghazni. The pilot may, therefore, have intended to take the direct route.

Following an examination of the pilot-in-command's log book which was recovered from the wreckage it was believed that he had little knowledge of the route and might not have been aware of the inadequacy of the maps found in the aircraft. The maps were of the 1:1 million topographical World Aeronautical Chart series published by the U.S. Air Force in 1951 and 1952 with amendments up to 1957. Sheet No. 431 of this series showing the position of the accident, was not found in the wreckage, but a copy issued by World Aeronautical Chart Series - U.S.A., supplied by the airline through the Lebanese authorities showed the highest ground in the area of the crash as 12 000 ft. The elevation of the wreckage was accurately measured as 13 940 ft.

A more recent map issued by the U.S. Air Force (Operational Navigation Chart - 06, on the scale 1:1 million, shows a spot height of 14 500 ft in the area, and a recent aerial photogrammetric survey shows terrain in the area of heights exceeding 15 800 ft.

An analysis was made of the groundspeed and track vectors shown in the various sectors of the Kuwait-Kabul flight plan and the reported details of the return from Kabul to Zahedan in order to discover the wind speed and direction used by the pilot.

These vectors, when plotted, revealed that the pilot was counting on a mean tail wind component of 10 kt. This was also true for the second half of the flight from Langeh to Kabul. The plotted vectors also suggested that during the second half of the flight the pilot probably counted on a mean wind direction of about 240°.

The pilot made various position reports between Kandahar and Kabul which indicated a wide and unaccountable fluctuation in ground speeds. After reporting over Ghazni at 0940, the pilot reported over Kabul at 0958. This would have indicated a groundspeed of 240 kt.

It appeared that the winds used to calculate the flight plan were reasonably accurate as far as Kandahar but while in flight from Kandahar to Kabul the pilot was probably unable to maintain visual contact with the ground and became confused about the actual wind speed and direction.

Estimated times given by the pilot for the diversion to Zahedan were as follows:

Reporting point	Time GMT	Next reporting point	Distance NM	ETA GMT	EET Min	G/s kt
Kabul	0959	Ghazni	72	1025	26	166
Ghazni	1025	Kandahar	181	1130	65	167
Kandahar	1130	Zahedan	282	1315	105	169

These groundspeeds suggested that the pilot was expected about the same wind speed and direction for his diversion to Zahedan as he had calculated for his inbound flight to Kabul although he reported flying at 15 000 ft from Kabul compared with an average of 11 000 ft for the inbound flight.

A viscount which diverted from Kabul back to Zahedan at an altitude between 19 000 and 16 000 ft took 2 hours 55 minutes. Its groundspeed was, therefore, only 185 kt although its true airspeed is believed to have been 245 kt.

The pilot-in-command of that flight (IR 422) stated, following the accident that the only check on winds aloft was made between Kandahar and Zahedan at flight level 160. This was found to be 315°/72 kt. It was found necessary to maintain exactly 30° drift correction on that segment of flight between Kandahar and the FIR. At the FIR, a radical wind change was noted, and the drift correction was lessened to 10° and maintained at such for about 10 minutes until overhead Zahedan. The wind on the surface at Zahedan at the time of arrival of IR 422 was 300°/12 kt.

If such high winds actually occurred after the pilot of the subject flight diverted from Kabul, it is obvious that his groundspeed must have been lower than expected and his estimated time over Ghazni would have been wrong.

The Committee then considered reports by two eye witnesses from villages between Kabul and Ghazni to the effect that an aircraft was seen turning towards the south or southwest in the afternoon. At first these reports were considered too vague to be positively associated with the TMA aircraft since the witnesses could not state the actual time, and it did not agree with the pilot's reported intention to stay at 15 000 ft until after passing Ghazni. However, the Committee also noted that at about this time the secondary cold front was just passing over Ghazni, and the weather behind it was becoming clear.

The pilot had reported to IR 422 while en route that his oxygen was very low and the Committee considered that it was probable that:

a) He assumed that he had reached Ghazni when in fact he was still north of that town;

b) The cloud cover was beginning to break with the passing of the cold front;

c) He endeavoured to find a hole in the cloud cover to get below it, or he steered a westerly course where the sky was getting lighter.

Since the only other aircraft flying on the Kabul-Ghazni route was known to have remained at 19 000 ft, the Committee considered that the evidence of the two separate witnesses on the ground could be taken to support possibility (c) above.

Other circumstances were considered which might have contributed to an error of navigation and the desire of the pilot-in-command to avoid continued flying at high altitude or in cloud. The various crew members' flying histories were studied and it was felt that the pilot-in-command may have been preoccupied with the prospect of changing his position once more to the exclusion of the more urgent aspects of this last flight.

The flight was being continued to Kabul although the pilot had received ample warning of the bad weather which extended over the route and at Kabul and Kandahar airports. Lahore was given as the new alternate to Kandahar although the weather situation there was unsatisfactory and the frontal conditions were moving eastwards over Afghanistan and would lie across the diversion route to Lahore. These facts convinced the Committee that the pilot-in-command could not have understood the meteorological situation over Northern India and Afghanistan at the time and that this might well have been a contributory cause for a subsequent navigational error.

Errors were found in the calculation of the dead reckoning positions on the flight between Kandahar and Kabul and in the amount of fuel carried from Kuwait as shown in the weight and balance sheet. These errors indicate either carelessness or fatigue on the part of the pilot-in-command.

The crew had been on duty for at least 16 hours and had been flying for about 2-1/2 hours in an unpressurized aircraft at 15 000 ft. Also oxygen supply was getting very low. Fatigue and lack of oxygen, may therefore, have contributed to cause an error in navigation and the desire to descend to a lower altitude.

The following hypotheses were also considered:

a) the pilot may have intended taking the direct route, since the accident site was practically on the direct route from Kabul to Zahedan;

b) icing;

c) engine failure or malfunctioning which forced it to descend.

They were not finally considered as being probable causes to the accident because:

a) at least one pilot knew the route well and must have been aware of the high mountains along this route. Also, the pilot had worked out and reported ETAs over Ghazni and Kandahar. The actual saving in distance is only 17 NM.

b) neither the TMA pilot nor the pilot of the Viscount which flew in the same area reported any icing conditions.

c) the pilot had reported no difficulty, and following the accident the condition of the propellers indicated that the engines were under power at the time of impact.

2.2 Conclusions

Findings

The crew were properly certificated and had considerable flying experience. At the time of the accident they had been on duty for about 16 hours, the last 2-1/2 hours of which were flown in an unpressurized aircraft at 15 000 ft with a very low supply of oxygen. Due to a reduction in the Company's activities the pilot-in-command was making his last flight for the Company. This may have been on his mind at the time of the accident.

The aircraft's certificate of airworthiness was valid until 23 January 1964. Errors were found in the weight and balance sheet as to the amount of fuel carried from Kuwait. This indicated possible carelessness or fatigue on the part of the pilot. No evidence of malfunction or failure of the aircraft or its equipment were found.

On take-off from Kuwait the pilot had not obtained any route or terminal weather forecast since none was available. Yet he intended to fly VFR after passing the Iran/Afghan border. He was kept informed while en route of the weather conditions to be expected, and he made several position reports between Kandahar and Kabul which showed unaccountable fluctuations in groundspeeds. Because he was probably unable to maintain visual contact with the ground, he became confused about the wind speed and direction. His log book which was recovered, indicated that he had little knowledge of the route. Also, he may not have been aware that the charts carried aboard the aircraft were inadequate. An error in navigation was the end result, and the aircraft struck a mountain at an elevation of 13 940 ft amsl.

Cause or
Probable cause(s)

A wrong estimation of the wind speed and direction resulted in a navigation error which brought the aircraft 42 NM from the approved air route. Possible contributing factors were: lack of weather forecast prior to take-off, personal worries, fatigue and lack of oxygen, inadequate charts and maps.

3. Recommendations

Following this accident the Investigating Committee made the following recommendations:

1) the Company should ensure in future that adequate meteorological information is made available to all their pilots before entering Afghan territory.

The Committee has been informed that this can be arranged in Kuwait with the Meteorological Office, Bahrein, provided that the Company's agent gives the Kuwait authorities adequate warning of the requirement.

2) The pilot-in-command of the subject flight filed a flight plan indicating a flight under VFR after entering Afghan territory. This could not be justified by the actual and forecast weather reports. The Company's attention should therefore be drawn to the provisions of Annex 6 to the Convention on International Civil Aviation and in particular to para. 4.3.2.1 (Fifth Edition).

"A flight to be conducted in accordance with visual flight rules shall not be commenced unless current meteorological reports or a combination of current reports and forecasts indicate that the meteorological conditions along the route or that part of the route to be flown under visual flight rules are, and will continue to be such as to make it possible for the flight to be conducted in accordance with visual flight rules."

3) After passing Kandahar and in spite of receiving adverse weather reports indicating that conditions would be below VMC at both Kabul and Kandahar, the pilot continued his flight indicating that he would divert to Lahore if unable to land at Kabul. In fact, Lahore had not been shown in the flight plan as an alternate and the weather forecast there was unsatisfactory. The Company's attention should therefore be drawn to the provisions of para. 4.4.1 of Annex 6 (Fifth Edition), and to the Afghanistan AIP-RAC Section 5-1-1, para. 1.1.

"A flight shall not be continued towards the aerodrome of intended landing unless the latest available meteorological information indicates that conditions at that aerodrome will, at the expected time of arrival, be at or above the meteorological minima specified for such aerodromes in the Operations Manual."

"<u>AIRCRAFT OPERATIONS IN ACCORDANCE WITH VFR</u>

All aircraft operations shall be conducted in accordance with the visual flight rules as specified in Annex 2 to the Convention of Civil Aviation, Chapter 4, Table 1, except outside of control zones or control areas where Table 2 will apply. Page 5.1-3 shows the Visual Flight Rules in chart form.

Except when an air traffic control clearance is obtained from an air traffic control, VFR flights shall neither take off or land at an aerodrome within a control zone, nor enter the aerodrome traffic zone or the traffic pattern of such an aerodrome if the ground visibility is less than 8 km (5 miles) or if the ceiling is less than 450 m (1 500 ft)."

4) When in the vicinity of Kabul the pilot reported that his oxygen supply was very low. It is recommended that the Company ensure that all future flights are provided with sufficient oxygen to meet the requirements of para. 4.3.4 of Annex 6. An effort should also be made to check how many oxygen bottles were carried in the aircraft and when they were last replenished. Two were found in the wreckage.

5) The Committee recommends that all maps of Afghanistan which have been issued to the Company's pilots or which are used for briefing purposes should be withdrawn for checking. The USAF World Aeronautical Chart in the 1:1 million topographical series published over ten years ago is inaccurate in several important details and should be marked or over-printed accordingly.

6) Section 5.12 of the TMA Operations Manual relates to minimum flight altitudes and levels in IMC and specifies a clearance of at least 1 000 ft above the highest point of ground within 10 NM of the desired track. Whenever more than one hour elapses without an accurate fix the minimum clearance should be increased to 2 000 ft above the highest ground within 20 NM of the track. Since the possibility of navigational error increases only longitudinally and laterally with increasing distance from the last positive fix, there does not appear to be any mathematical justification for increasing the vertical clearance above known ground elevations.

On the other hand ground elevations in certain areas of Afghanistan are not accurately shown on existing aeronautical maps, and the Committee recommends that a note to this effect should be added to the TMA Operations Manual. The additional 1 000 ft clearance is not sufficient to cover inaccuracies in existing maps. A corollary to this is that pilots must not attempt to fly in IMC over Afghan territory until minimum en route flight levels have been established by the appropriate authority, and this should also be emphasized in all route manuals.

7) The Afghanistan AIP section RAC 5.1-2, para. 1.6 requires pilots when flying between 3 000 ft above ground level and less than flight level 290 to maintain cruising levels according to the quadrantal rule. In this case the TMA aircraft should have been flown at a flight level appropriate to the 180°-269° quadrant and the Committee recommends that this should be brought to the attention of the Company.

8) Map sheet ME(H/L)3 of the Jeppesen route guide dated 8 October 1963 showed a non-directional beacon in use at Ghazni on 293.5 kc. This beacon had not been in use since March 1962 and notification of this was given in Afghan Class I Notam No. 018, dated 25 March 1962. The Committee recommends that this should be brought to the attention of the publishers of the guide book.

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ICAO Ref: **AR/857**

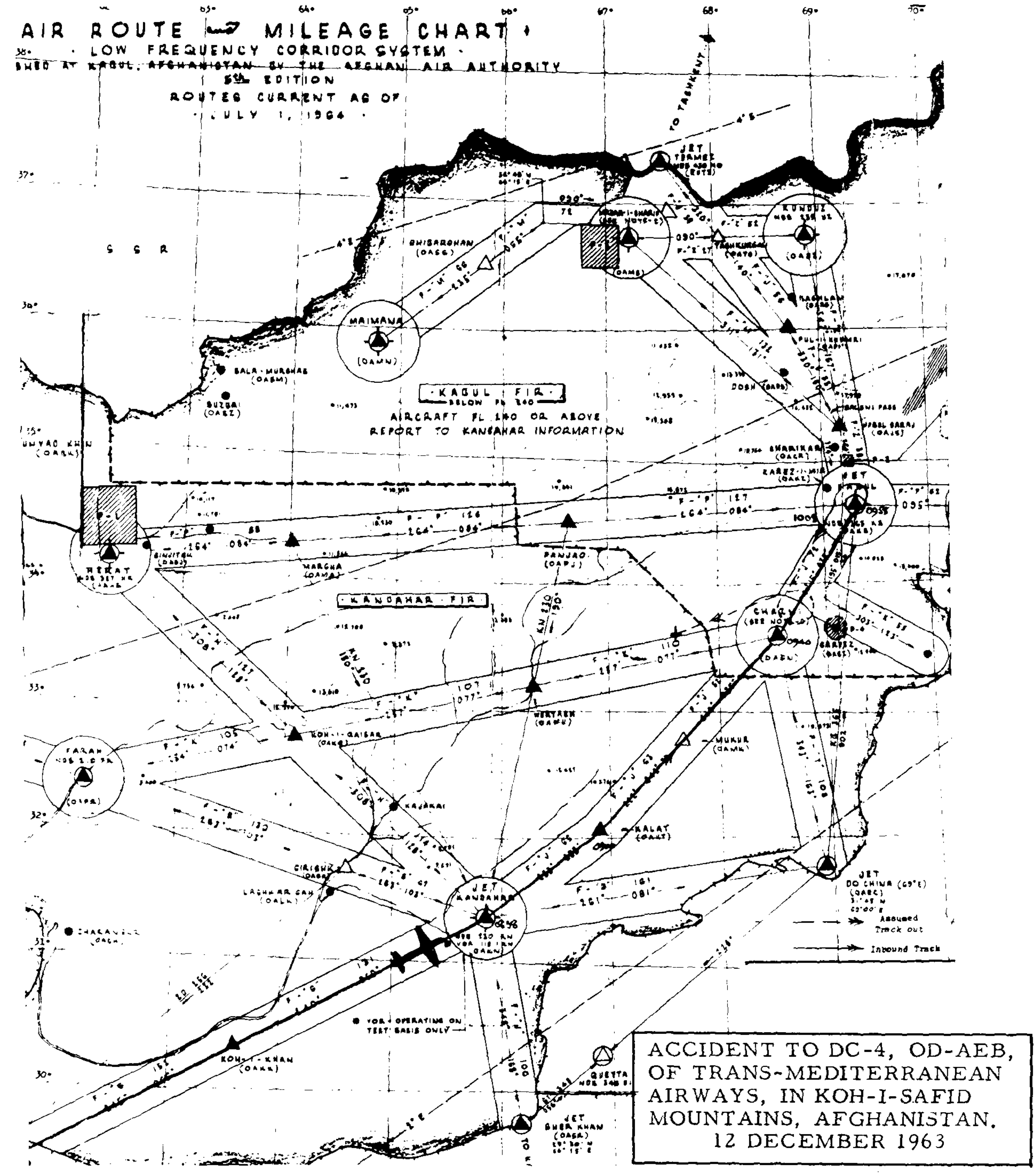
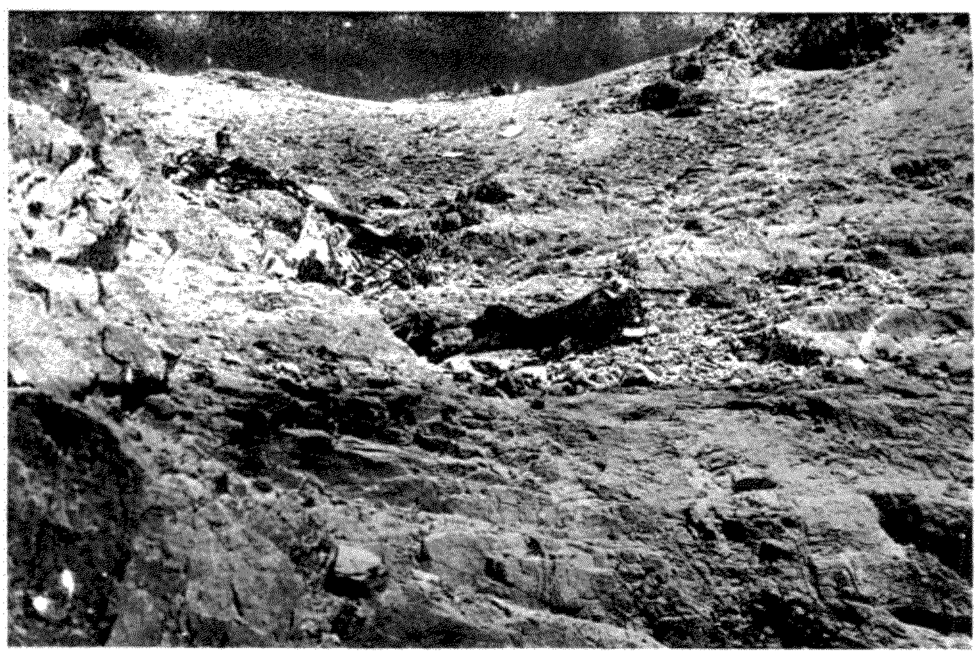

AIR ROUTE MILEAGE CHART
LOW FREQUENCY CORRIDOR SYSTEM
5th EDITION
ROUTES CURRENT AS OF
JULY 1, 1964
KABUL FIR
AIRCRAFT FL 140 OR ABOVE
REPORT TO KANDAHAR INFORMATION
KANDAHAR FIR
MAIMANA
HERAT
FARAH
KANDAHAR
KABUL
KUNDUZ
TO TASHKENT
Assumed Track out
Inbound Track
ACCIDENT TO DC-4, OD-AEB,
OF TRANS-MEDITERRANEAN
AIRWAYS, IN KOH-I-SAFID
MOUNTAINS, AFGHANISTAN,
12 DECEMBER 1963

FIGURE 7

ACCIDENT TO DC-4, OD-AEB, OF TRANS-MEDITERRANEAN AIRWAYS, IN KOH-I-SAFID MOUNTAINS, AFGHANISTAN. 12 DECEMBER 1963

Aircraft struck ridge at 13940 feet (4250 metres) above sea level and disintegrated.

FIGURE 8



Wreckage fell down steep slope on other side of ridge

FIGURE 9

No. 10

Aerolineas Argentinas, Caravelle SE-210-VI-N, LV-HGY, accident at Pajas Blancas Airport, Cordoba Province, Argentina on 3 July 1963. Accident Report No. 1905, published in Information Bulletin No. 11 (Aircraft Accidents), September 1965, by the National Directorate of Civil Aviation, Argentina.

1. Investigation

1.1 History of the flight

Flight AR-527/03 was a scheduled domestic flight from Mendoza to Buenos Aires Aeroparque, Argentina, via Pajas Blancas Airport in Cordoba Province. The flight plan for the trip was prepared in Mendoza by the airline's dispatcher and was approved by the chief of the Operations Office as well as by the Northwest Regional Control Area. The aircraft was cleared to fly at 8 700 m with reporting points along the airway at Chañar-Pampa Salinas and at the entrance to the Terminal Area. The aircraft took off from Mendoza at 1750 hours with 63 passengers and 7 crew members and made its first contact by radio with Pajas Blancas Airport control tower at 1840 hours. Six minutes later it was cleared for an instrument approach to runway 17. The approach was initiated at a height of 1 500 m which was contrary to the regulation height of 3 300 m prescribed for jet aircraft. A magnetic heading of 40° was flown on the outbound track and the aircraft was above the cloud layer at a height of 1 054 m above the ground. After the time prescribed in the airline's approach chart had elapsed, a left-hand turn was initiated, to intercept QDM 200°. During the turn the height was maintained with landing gear extended, flaps at 20° and an indicated airspeed of 140 kt. On completion of the turn a magnetic heading of 200° was flown towards the beacon, and the aircraft resumed its descent until intercepting VOR radial 168. At this point the pilot thought he was 250 m above the ground and, still flying on instruments, he intercepted the VOR and changed course to 170°. When he did not make visual contact with the runway at a height of 150 m he started a go-around, climbing on a magnetic heading of 105°. He then initiated a right-hand turn to intercept the radio beacon again and asked for another clearance from the tower to come in again.

He flew over the beacon at a height of 1 050 m, then followed a magnetic heading of 40° during about 2 min 30 sec and, while still descending, initiated a left-hand turn until he obtained QDM 200. The landing gear was extended and locked, flap setting 20°, and a normal descent at 500 ft/min. was maintained. He intercepted VOR radial 168, announced that he was at 160 m and then initiated a turn to align himself with runway 17. Shortly thereafter the aircraft's port wing struck some trees five meters high and the port landing gear came into contact with the ground. The pilot-in-command reduced power and pushed the control column forward. After having travelled during approximately 60 m on its port landing gear, the aircraft rolled on its whole undercarriage another 700 m.

At 390 m from initial impact the port wing struck some other trees, the fuel tanks bursted out and fire broke out. The aircraft then came into contact with the General Belgrano Railway tracks, broke its undercarriage, tearing away 25 m of railway rails and finally came to rest 280 m before the threshold of runway 17 (See Figure 10). The accident occurred at 1906 hours.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Non fatal			
None	7	63	

1.3 Damage to aircraft

The aircraft was destroyed by impact and subsequent fire.

1.4 Other damage

The aircraft struck two posts and the rails of the General Belgrano Railway, tearing them up over a distance of 25 m. Also, the rudder severed some telegraph wires and finally demolished some wire fencing.

1.5 Crew information

The pilot-in-command held a valid senior commercial pilot's licence and was satisfactorily certificated. His total flying experience amounted to 16 835 hours. He had flown a total of 15 139 hours with the subject airline including 5 109 hours at night and 1 313 hours on instruments. His experience on Caravelle aircraft amounted to 513 hours of which 70 hours were flown at night. During the 90 days prior to the accident he had flown 118 hours on the Caravelle - 11 hours during the preceding 30 days - and 3 hours on the day of the accident.

No information was included in the report regarding the other crew members on the subject flight.

1.6 Aircraft information

The aircraft's Certificate of Airworthiness was valid until 14 June. The aircraft had been satisfactorily maintained and operated within the specified limits.

No mention was made in the report of the aircraft's weight and centre of gravity.

JP. 1 fuel was being used on the subject flight.

1.7 Meteorological information

The forecast based on the 0900 hours weather chart was as follows:

Mendoza-La Rioja:

overcast; visibility 12 km; clouds: 6/8 to 8/8 Sc and St at 300-600 m, 7/8 Sc at 1200 m, 6/8 Ac and As at 2500 m; winds: 320°/40 kt at 7 000 m and 310°/50 kt at 9000 m.

This forecast which was nearly 9 hours old at the time of take-off, was approved by the dispatcher and the pilot-in-command. It was established that neither the dispatcher nor any of the flight crew member went to the meteorological office to discuss the weather situation and to request the latest information based on the 1500 hour chart. As the weather forecast for the Mendoza and Cordoba area remained the same until 2100 hours, it was concluded that this did not have any bearing on the accident, however it revealed negligence in the preparation of the flight. After the missed approach procedure was initiated the airline operations passed the following weather information to the aircraft: ceiling 150 m, visibility 12 km - decreasing and at 1855 the tower, on request, reported: estimated ceiling 300 m and estimated visibility 6 km. Finally at 1904 the aircraft was informed by the tower that the ceiling had lowered down to 150 m according to the MET office.

The accident occurred at night.

1.8 Aids to navigation

A radio beacon (CBA) and a VCR were available and functioning at Pajas Blancas Airport.

1.9 Communications

Communications were normal and were tape recorded by ATC.

1.10 Aerodrome and ground facilities

Runway 17-35 had electric lights on both sides and kerosene flares at both ends. All were in operation at the time of the accident as well as the aerodrome rotating beacon and identifier.

1.11 Flight recorders

The aircraft, at the time of the accident carried a Waste-King flight recorder, recording five parameters: time, height, speed, heading and acceleration. It had been inspected at the factory on 26 March 1962, was returned on 25 May and had then been installed in the subject aircraft on 12 June 1963.

For reasons which could not be established, headings were not being recorded. The cleaning of the tape by the airline to remove the effects of the fire made it impossible to obtain a clear interpretation of what had been recorded. It was sent to the Civil Aeronautics Board (U.S.A.) where despite varied laboratory treatment including x-ray, photographing and amplification by high-powered microscopes, the recording was impossible to decipher.

1.12 Wreckage

The accident site was approximately 280 m before the threshold of runway 17 and 450 m from the extended runway centre line.

1.13 Fire

About 390 m from the point of initial impact the port wing struck a clump of trees. This caused the fuel tanks to burst and, as the fuel escaped, fire broke out.

The type of fuel being used, JP. 1, and the fact that the fire was located some distance from the fuselage permitted all occupants to evacuate the aircraft. Minutes later it spread to the aircraft's fuselage. The airport had no fire fighting equipment and firemen from Cordoba City had to be summoned. However, it took them about half an hour to reach the site and, since they were inadequately equipped, they had to fight the fire with earth and water.

1.14 Survival aspects

Evacuation of the aircraft was by the front port door and the emergency exits on the starboard side. Neither the front nor the rear starboard doors could be opened. The safety lock of the rear one was jammed.

1.15 Tests and research

An analysis of the approach procedure was carried out on the radar simulator at the Centre for Regular, Advanced and Specialized Air Traffic Training. According to this analysis, the times ascertained from the control tower's tape recording and the height and speed data available, the pilot-in-command had executed an unauthorized procedure. Sketches of the flight path revealed the manner in which the pilot-in-command modified the approved procedure.

A flight was made in a Caravelle from Pajas Blancas Airport to execute the same approach procedure as that used on the day of the accident. It revealed that it is almost impossible to land on runway 17 and expect to intercept VOR radial 168, since a very sharp turn has to be made to align with the runway centre line, a manoeuvre which is not advisable for low-level night flying on instruments.

2. Analysis and conclusions

2.1 Analysis

Since ceilings were less than 400 m and steadily lowering, an instrument approach procedure to runway 17 had to be made.

Following the accident the co-pilot stated that when the aircraft intercepted the VOR radial during the first attempt, it was 200 m above the ground, and the pilot-in-command decided to go around on 105°. At that time the tower operator informed him that he could see the aircraft on track E and asked whether they were heading for the alternate. The co-pilot consulted the pilot-in-command and then replied that they would make another attempt. At this time there was a break in the clouds over the northern part of Cordoba City and some buildings and lights could be seen. The co-pilot stated that during the second attempt, just before intercepting the VOR radial, his altimeter showed a height of 135-140 m above the ground when he looked out, seeking a visual reference. He saw lights ahead and moments later the aircraft struck the ground.

On 1 April 1963 two instrument approach charts were issued by the aeronautical authorities for this runway: one for jet aircraft using the VOR facility and the other for jet aircraft using the Cordoba radio beacon. Either of the two procedures could be used for landing on runway 17, but no chart existed that combined the two. However, the pilot used an unrecognized combination of the radio beacon and VOR procedures.

The meteorological minima for each procedure, i.e. the critical height at which a missed approach procedure shall be initiated if visual contact with the ground is not established, was 160 m by night as well as by day. The airline had also published on 11 April 1963 an instrument landing chart (jet) for runway 17. Although this chart differed slightly from the one published by the aeronautical authorities and had not been submitted to their approval the procedure was in accordance with the officially established guidance and separation procedures and showed the same critical height of 160 m. The pilot did not observe this minimum. The recording of the air-ground communications revealed that during the first attempt to land he descended down to 150 m, and the accident proved that during the second attempt he descended even lower.

The critical height for Caravelle at Cordoba Airport was subsequently raised to 200 m by the airline. This was notified in a Circular dated 30 April 1963 and in a NOTAM dated 7 May 1963. Both the pilot-in-command and the co-pilot were unaware of that amendment.

The air-ground communication recording also indicated that the tower controller was unfamiliar with the instrument approach procedure. He should have warned the pilot-in-command that the prescribed height for initiating the procedure was 3 300 m. Also, when the pilot stated that his outbound track was 040°, the controller should have given him the correct track instead of indicating his approval. Finally when the pilot reported he had descended to 150 m without making visual contact and confirmed this a minute later, the controller did not check the meteorological situation. In the prevailing circumstances, he should have warned the pilot, that conditions at the airport were below the operational minima and cleared him down to the specified critical height.

During the final phase of the approach procedure, at 1904 hours, when the tower advised the aircraft that the ceiling had lowered down to 150 m, the pilot had sufficient time to increase thrust and execute a missed approach.

Material gathered during the investigation showed that weather reports at the airport differed considerably. The aircraft carried out the missed approach at 1854 because it could not make visual contact at 150 m. Yet shortly thereafter the tower gave ceiling as 300 m and estimated visibility 6 km, which reveals a significant deficiency in the flight advisory services.

2.2 Conclusions

Findings

The pilot-in-command was properly certificated and had considerable flying experience.

The aircraft had a valid Certificate of Airworthiness and had been satisfactorily maintained. The report contained no information regarding the aircraft's weight and centre of gravity at the time of the accident.

Although the weather forecast for the flight was prepared on the basis of the 0900 hour chart which was nearly 9 hours old at the time of take-off, this was not a factor contributing to the cause of the accident. It does, however, show negligence in the preparation for the flight since a new forecast could have been prepared.

Because of the low ceilings at Pajas Blancas Airport, an instrument approach had to be made to runway 17. Two procedures can be used for landing on this runway but no chart exists which combines them. However, the pilot used an unrecognized combination of the radio beacon and VOR procedures, and descended below the critical height of 160 m. Actually the critical height for Caravelle operations at the subject airport had been raised from 160 m to 200 m by the airline in April-May of 1963, however both the pilot and co-pilot were not aware of the amendment.

Although the aircraft carried a flight recorder, fire damage to the tape destroyed the evidence.

No fire fighting equipment was available at Pajas Blancas Airport. The fire fighting services which came from Cordoba City took approximately half an hour to reach the accident site and on their arrival they had to fight the fire with earth and water as they were not properly equipped.

The two starboard doors of the aircraft could not be used for evacuation purposes. The safety lock of the rear door was jammed.

Cause of
Probable cause(s)

Striking the ground during final approach, when the pilot failed to execute the approved instrument entry procedure.

3. Recommendations

No recommendations were contained in the report.

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ICAO Ref: AR/881

ACCIDENT TO CARAVELLE LV-HGY,
OF AEROLINEAS ARGENTINAS,
AT PAJAS BLANCAS, ARGENTINA.
3 July 196 3 JULY 1963

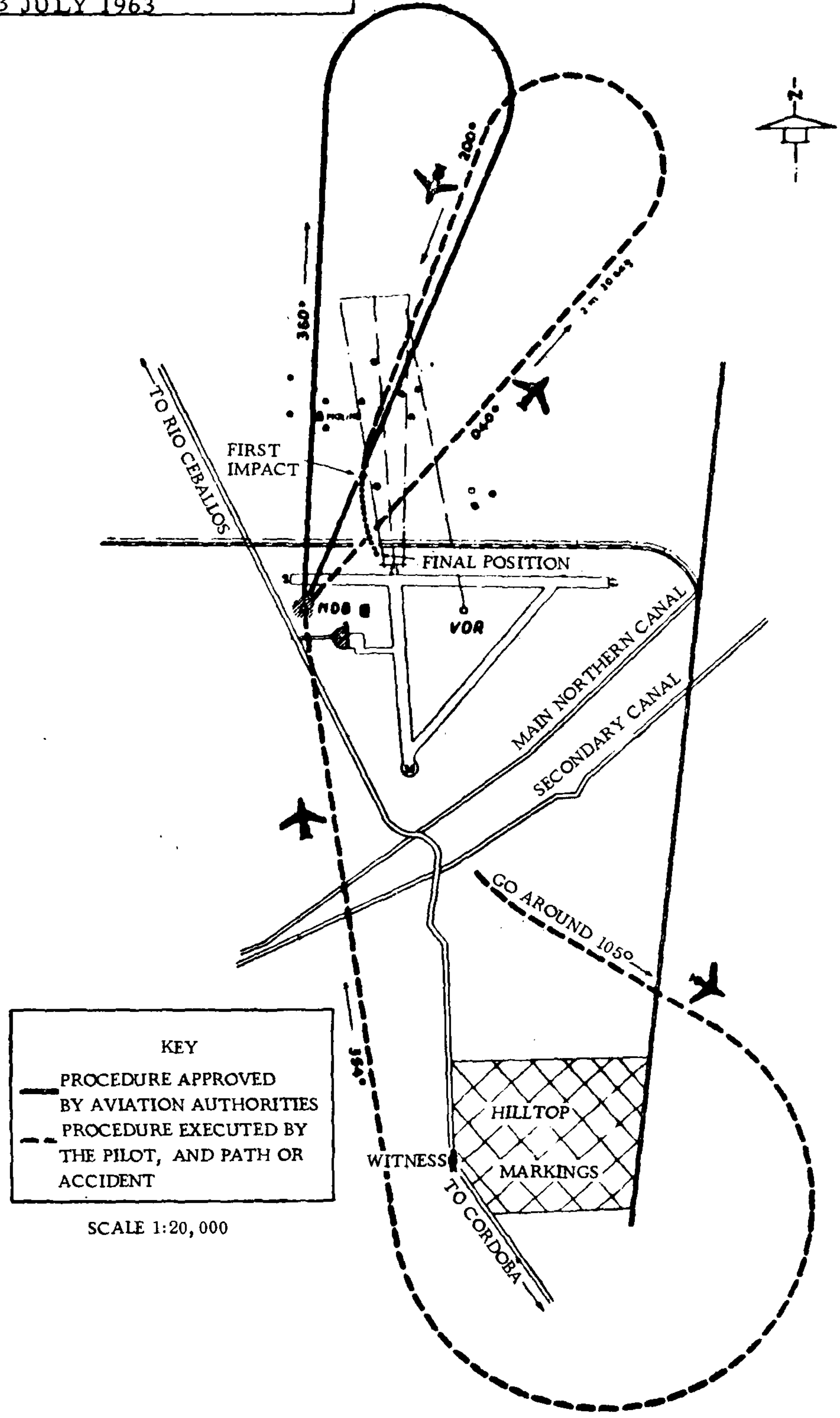

FIGURE 10

No. 11

Northwest Airlines, Inc., Boeing 720B, N 724US, accident near Miami, Florida, U.S.A. on 12 February 1963. Civil Aeronautics Board (U.S.A.), Aircraft Accident Report, File No. 1-0006, released 4 June 1965

1. Investigation

1.1 History of the flight

Flight 705 was a scheduled domestic flight from Miami to Portland with various intermediate stops. The aircraft had arrived in Miami, Florida, at 1240 hours eastern standard time having been flown by another crew from Chicago, Illinois, one of the intermediate stops, and a minor mechanical discrepancy was rectified during the "turnaround". The ground controller advised the crew that most flights were departing "either through a southwest climb or a southeast climb and then back over the top of it." The flight took off from Miami at 1335 hours on an IFR clearance. In accordance with the pilot's request for a southeast vector, a left turn was made following take-off from runway 27L and circuitous routing was utilized in conjunction with radar vectors from Miami Departure Control to avoid areas of anticipated turbulence associated with thunderstorm activity (See Figure 11). While maintaining 5 000 ft and a heading of 300°, the flight asked for clearance to climb to a higher altitude. At 1343 hours it was cleared to climb to flight level 250 and advised it would make a left turn of about 30° and climb. The climb-out heading was to be 270°. Turbulence in the area at that time was described as moderate to heavy. Radar service was terminated at 1345 hours, and control of the flight was transferred to Miami ARTCC (Air Route Traffic Control Centre). Departure Control instructed the flight to turn to a 360° heading, and this message was acknowledged. At 1347 hours, in response to a request for its position and altitude, the flight advised Miami ARTCC that it was just out of 17 500 ft and "to stand by on the DME one." This transmission which ended at 1348 hours, was the last known message from the co-pilot. It was subsequently determined that the aircraft entered a steep dive, during which the design limits were exceeded, and the aircraft disintegrated in flight. The aircraft crashed at about 1350 hours in an unpopulated area of the Everglades National Park, 37 miles west-southwest of Miami International Airport.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	8	35	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The pilot-in-command, age 47, held a valid airline transport pilot's certificate with ratings for various aircraft types including the Boeing 720. He had flown a total of 17 835 hours as pilot, including 150 hours on the Boeing 720B. His last flight proficiency check on 720B was carried out on 13 November 1962. During this check flight he obtained the lowest passing grade on 9 of the 22 items graded including Dutch Roll, jammed stabilizer, electrical emergency and engine fire. He had an FAA first-class medical certificate dated 21 November 1962, and was off duty from 13 January to 9 February 1963 inclusive. He was described as a person who had no problems flying instruments of the subject aircraft type. Also, he was very speed conscious in turbulence.

The co-pilot, age 38, also held a valid airline transport pilot's certificate with ratings for several aircraft types. He had flown a total of 11 799 hours as pilot including 1 093 hours on the Boeing 720B. His last flight proficiency check was carried out on 8 July 1962, and his medical certificate was valid at the time of the accident.

The second officer and the five stewardesses were all qualified on the Boeing 720B.

1.6 Aircraft information

The aircraft had flown a total time of 4 685 hours.

On arrival at Miami the pilot-in-command of the inbound flight reported that the outflow valves were a little sticky, and this made it slightly difficult to maintain the pressurization in a smooth manner. The valves were cleaned, and a leaking rivet at the No. 4 reserve fuel tank was plugged. No other maintenance was carried out at Miami.

The aircraft's maintenance records showed two occurences in which the aircraft had incurred significant structural damage. The first was a landing accident at Fort Lauderdale, Florida on 26 January 1962 when it landed short of the runway, and structural failure occurred when the right main landing gear separated. At that time the adjacent wing was damaged together with flap and fuselage areas and the No. 3 and No. 4 engine nacelles. The other was a bird strike on the right wing landing edge. However, it was airworthy at the time of the accident.

The computed take-off gross weight (175 784 lb) and the centre of gravity (25% MAC) were both well within the allowable limits.

The type of fuel being used and amount carried were not stated in the report.

1.7 Meteorological information

The weather in the Miami area at the time of the accident was characterized by a pre-frontal squall line approximately 250 miles in length, oriented on a northeast-southeast line immediately northwest of Miami. The U.S. Weather Bureau (USWB) radar observation at Miami at 1344 indicated a broken area of thunderstorms associated with this line, with cells two to twenty miles in diameter, and tops of detectable moisture at 30 000 ft. The line was moving southeast at eight knots, and moderate rain showers were occurring at the station. The 0600 and 1800 Miami radiosonde ascents showed the freezing level to have been at 11 100 and 12 400 ft msl, respectively.

SIGMET No. 3 prepared by the U.S. Weather Bureau at Miami, valid from 0900 to 1300 hours, forecast moderate to severe turbulence in thunderstorms, with a chance of extreme turbulence in heavier thunderstorms. This was brought to the attention of the crew by the operations agent at Miami, and was attached to their dispatch papers. SIGMET No. 4, valid from 1300 to 1700, was not received until about 1315, after the crew had left the operations office. It forecast moderate to severe turbulence, but deleted the reference to extreme turbulence indicated in SIGMET No. 3.

Northwest Airlines route forecast for Chicago south, valid at 1300, indicated a cold front at Fort Myers, Florida, moving eastward at 20 kt, with a line of thunderstorms 100 miles east of the front. The Macon to Miami portion of the en-route weather forecast indicated the tops of clouds would be 25 000 ft, with a few thunderstorms to 40 000 ft in the Miami area. There was no specific reference to turbulence. However, the company meteorologist, who prepared the route forecast for the flight, stated that turbulence was indicated in his forecast by the presence of convective clouds. The company Flight Operations Manual states that if cumulus clouds are forecast to exceed 10 000 ft, severe turbulence may be expected.

The pilot-in-command also obtained weather information from the pilot who arrived at Miami in the subject aircraft at 1240 hours. The pilot stated that the weather extended from LaBelle, about 70 miles northwest of Miami, to the Miami VORTAC and that he estimated the tops of the clouds to be from 27 to 30 000 ft.

1.8 Aids to navigation

A VORTAC was available at Miami.

1.9 Communications

The co-pilot carried out the communications during the flight, and no difficulties were reported. The last message from the aircraft to Miami Air Route Traffic Control Centre was at 1348 hours.

1.10 Aerodrome and ground facilities

Not pertinent to the accident.

1.11 Flight recorders

The aircraft was equipped with a Fairchild flight recorder recording pressure altitude, indicated airspeed, magnetic heading, and vertical acceleration as a function of time. The readout of the flight recorder tape (see Figure 12) indicated that following lift-off at 1335:22, a series of turns to headings of south, southwest, west, and northwest were accomplished while climbing to 5 000 ft in light turbulence. At 1342:46, as a climb was begun, heavier turbulence was encountered for about three minutes, until a left turn to 200° was accomplished just prior to the cessation of the large acceleration excursions. The indicated airspeed fluctuated from 320 kt to 210 kt, and the altitude increased from 5 000 ft to 15 000 ft. The aircraft continued climbing from 15 000 ft to 17 250 ft in a right turn which continued through 320° while the climb ceased and altitude remained constant for about 12 seconds. At 1347:25 the altitude began increasing again and the rate of climb gradually increased to about 9 000 ft/min at 1347:38. Following this, the rate of climb decreased through zero at 1347:47 when the altitude peaked momentarily at 19 285 ft. During this climb the airspeed decreased from 270 to 215 kt and as the peak altitude was approached the vertical accelerations changed rapidly from +1G to about -2G. In the next 7 seconds the negative acceleration continued to increase at a slower rate, with rapid fluctuations, to a mean value of about -2.8G, while altitude was lost at an increasing rate. As the descent continued with rapidly increasing airspeed, the acceleration trace went from the high negative peak to +1.5G, where it reversed again. In the last 9 seconds of the readout the altitude trace continued to decrease, the airspeed trace increased until the stylus hit the mechanical stop, the acceleration trace increased in a negative direction, and the heading remained fairly constant at 330°. The final manoeuvre from the onset of the climb at 1347:25 lasted about 45 seconds.

1.12 Wreckage

The main wreckage area was in a fairly open and flat section of the Everglades which had outcroppings of coral rock, marshy water areas, and groves or hummocks of cypress trees irregularly spaced at one-half to one mile intervals. Access to the accident area from the nearest road, 15 miles away, required over three hours by surface transportation or 15 minutes by helicopter. The wreckage distribution was aligned 080 to 260°, about 1-1/3 miles wide and 15 miles long, indicating in-flight breakup of the aircraft structure. About 90% of the wreckage, including all large segments, was found in the most westerly two miles. The remaining portions of wreckage found east of this concentration consisted mainly of light material which drifted to the east-northeast because of the prevailing winds aloft. The most westerly piece of wreckage was the upper part of the rudder, which was used by surveyors as a zero datum point. About 500 ft east of this point were engines No. 1, 2, 4 and 3 in that order oriented along a south to north line one-half mile long. Five hundred feet northeast of the No. 3 engine was the cockpit area. Next, about 1 500 ft east of the rudder fragment were the outboard portions of both wings. Two thousand and seven hundred feet east of the datum point were the main fuselage and wing centre sections which landed inverted on a heading of 060°. The tail section was 1 000 ft farther east. About 97% of the aircraft was recovered.

The main fuselage section was gutted by severe ground fire, the wings and all tail surfaces were separated and fragmented, and there were indications of severe in-flight breakup of the forward fuselage. An attempt was made to partially reconstruct the aircraft at the site, but as the work progressed it became apparent that a more sophisticated study of the wreckage was required, and arrangements were made to remove the wreckage to a U.S. Coast Guard hangar at Opa Locka Airport in Miami.

1.13 Fire

One witness heard the sound of an explosion which had no echo. When she looked in that direction she saw an orange ball of flame in the edge of a cloud, which dropped straight down, becoming a streak and disappeared behind trees.

There was a severe ground fire.

1.14 Survival aspects

The Civil Aeronautics Board was notified of a missing aircraft at 1400 hours, and a search was started immediately. The wreckage was discovered at 1859.

1.15 Tests and research

A mockup (See Figure 13) of the aircraft was completed on 1 April 1963, and the detailed study was resumed. The main failures in both wings and horizontal stabilizers were in a downward direction, and virtually symmetrical. The forward fuselage broke upward and the vertical stabilizer failed to the left. All four engines generally separated upward and outboard; however, certain peculiarities in the No. 3 engine separation generated considerable interest during the investigation. The reverser on this engine landed about 1 300 ft from the main engine section. The No. 3 engine also varied in that its final position was 150 ft on an azimuth of 015° relative to its initial impact point. The other engines bounced approximately 40-45 ft on azimuths of 055, 080 and 060° from their respective craters. Approximately 4 ft of the right wing, from the leading edge aft to the front spar, and inboard of the No. 3 nacelle, was broken away. Collision of the reverser with this leading edge section was indicated in the pattern of scratches found within the creases which resulted at ground impact. The main engine mount fractures were examined for fatigue, which might have resulted from damage sustained at the Fort Lauderdale accident, but none was found.

Selected samples of the aircraft wreckage were sent to the Federal Bureau of Investigation laboratory for examination. No explosive residues were found.

To more fully develop certain areas of its investigation the Board convened a public hearing during which experts from the aviation industry testified. Three basic areas were considered:

a) the weather and its potential;
b) the pilot and his ability to control the aircraft; and
c) the aircraft and its characteristics throughout a manoeuvre such as indicated on the flight recorder readout.

The Director of the National Severe Storms Project (NSSP)* testified that the turbulence encountered in a thunderstorm varies directly with the amount of rainfall and the diameter of the storm during its building or mature stage. During the deteriorating stage, the diameter of the storm is no longer indicative of the turbulence. The large updraughts occurring within thunderstorms are frequently 15 miles wide, and invariably contain smaller gusts which produce the turbulence. The strength of these smaller gusts generally varies directly with that of the draught in which they occur. The report submitted by NSSP in June 1963 concluded in part that it is not unreasonable to assume that severe turbulence exists at some point in any storm, and in a growing or large mature thunderstorm one may expect extreme turbulence.

Thunderstorm data of a more specific nature were developed by meteorologists of the U.S. Weather Bureau, who evaluated the nine indicators of turbulence which might have been present in the crash area at the time of the accident. They reported the most reliable of these indicators seems to be the rainfall rate, which indicates gusts values in the severe range; other fairly reliable indications such as buoyancy, hail, and surface gusts indicated somewhat higher gust values.

* ... a project of the U.S. Weather Bureau, with the participation of the Air Force, the FAA and NASA, to study the formation and life history of squall lines.

A representative of the Naval Medical Research Institute, and a pilot who performed as his subject during a series of tests on negative G manoeuvres conducted by the U.S. Navy, were called as witnesses at the hearing. They advised that from a physiological standpoint the acceleration evidenced by the flight recorder readout should not have physically incapacitated the crew members, assuming they were restrained in their seats. The Navy tests subjected the pilot to repeated loads of -3G for periods of up to 30 seconds and -5G for shorter intervals with no adverse physiological effects. These forces have been duplicated in flight as well as in centrifuge testing. However, they also advised that if one has never been exposed to high negative G forces, the experience could be frightening.

Boeing provided the Board with data from two studies which were conducted to determine:

1) the capability of the aircraft to perform the manoeuvre indicated by the flight recorder readout;

2) what control inputs would be required, and

3) what aircraft response would result from partial or complete loss of the horizontal tail.

Initially an analogue computer study was conducted. The data derived were then used in a more sophisticated IBM digital simulation of the flight path of the aircraft during its final manoeuvre. Both studies varied longitudinal control inputs to reproduce the vertical acceleration trace of the recorder. The results revealed that while the aircraft was capable of performing the manoeuvre, full aircraft nosedown deflection of both horizontal stabilizer and elevator was required to achieve the high negative load factors indicated. An intact and operable elevator would also have been required to produce the partial recovery following the initial pushover. In addition, partial or complete loss of the horizontal tail surfaces prior to the partial recovery would have resulted in a much higher rate of change of the pitch attitude and vertical acceleration. In the digital study, pitch attitudes varied from about 22° noseup during the steep climb to beyond the vertical in the nosedown direction during the dive. They estimated that negative stall buffet was encountered during a 6-second period of the final manoeuvre.

Following these studies which were carried out early in the investigation and because of the large control inputs indicated, a comparison was made between the known aircraft climb performance capabilities and the actual performance indicated in the flight recorder readout. For this study it was assumed that the power setting throughout the manoeuvre remained constant at maximum continuous power, which is normal for the climb. It was then possible to compare this normal performance with airspeed - altitude traces indicated on the flight recorder. Any variation from this normal aircraft capability, when comparing a loss in airspeed with a corresponding gain in altitude, represented the influence of an updraught. An opposite variation would be the result of a downdraught. The comparison revealed that draughts of high intensity were acting on the aircraft at the time of the high rate of climb and during the dive. The draughts were not of sufficient magnitude to damage the aircraft structure. However, the possibility that a pilot might be misled by the aircraft response to these draughts was considered. Entry into an updraught produces an initial aircraft response to "weathercock" nosedown into the relative wind. However, it was pointed out that the ultimate effect of the updraught is an altitude and noseup attitude increase. If the pilot attempted to overcome this initial "tuck" with noseup elevator, the rate and amount of change in attitude and altitude ultimately produced by the draught would be exaggerated. The converse would be true for downdraughts.

Boeing also conducted a study by simulating flights of a 720B through various draught histories. The various simulations included one flight with no control input from the pilot, another with sufficient control to maintain a constant horizontal attitude and also a resultant study which included a synthesized draught history. A comparison of the flights indicated that the acceleration forces were less without control inputs than for constant attitude flight. The pitch changes experienced during the stick-fixed flight were fairly large; however, the stability of the aircraft was sufficient to overcome the upsetting force in each instance.

Following the public hearing it was felt that two areas required further study. The first was the possibility of rain freezing in the balance bay area. Icing of the balance panel seals and the piano hinge, which connects the balance panel to the elevator, could restrict movement of the elevator, and consequently its effectiveness. There had been at least 13 occurrences of longitudinal control difficulty attributed to this icing problem. However, in these instances the difficulty was usually characterized by either a stiffness in the control column with poor aircraft response, or a cycling force in the column with a corresponding porpoising motion. In some cases more force was required to move the controls than the crew cared to exert, and the stabilizer trim was used to control the aircraft. In some cases descents to lower altitudes restored normal feel and response; in others greater than normal pilot forces alleviated the problem. In no case did the icing precipitate a loss of control.

Joint Northwest-Boeing flight tests were performed in climatic conditions similar to that experienced by Flight 705 and the temperatures within the balance bay were measured at four points. These tests showed that the measured temperature in all cases were equal to or warmer than the ram air temperature. When these data were correlated with the pertinent accident data, Boeing determined that the balance bay ambient temperature of the subject aircraft was about 40°F. In such case the balance bay cavity walls would have been at least 50°F and the piano hinge 60°F. Northwest also analyzed this data, and found that the pertinent temperatures in the balance bay area would have reached the freezing level shortly before the final manoeuvre.

The second area which needed further study resulted from calculations of NASA aerodynamicists. Their initial study of the 720B longitudinal control system indicated the possibility of control force lightening or even reversal at high down elevator deflections. However, a full scale wind tunnel test of the horizontal tail was required to resolve this possibility. NASA conducted the test in the fall of 1963 at their 40 x 80 ft wind tunnel at the Ames Research Centre, Moffett Field, California. Aerodynamic control tab hinge moments and elevator hinge moments were derived for a range of elevator angles and tail angles of attack. The data from the wind tunnel were then used to analyze the control forces which would be experienced in a pitching manoeuvre similar to Flight 705, at a series of elevator angles with the stabilizer at normal climb and full nosedown. Additionally, control forces were also calculated for +1G level flight at a series of stabilizer settings.

All computations were based on an equivalent airspeed of 250 kt, 15 000 ft altitude, 173 000 lb and a centre of gravity of 25% MAC, to closely approximate the parameters of Flight 705. The results indicated that for +1G level flight with varying stabilizer settings, the variation of control force with elevator angle was in the normal direction for all elevator angles. During pitching manoeuvres with constant stabilizer settings, the push force to maintain down elevator angles reached a maximum at about 10° down elevator, and then decreased as the down elevator angles increased. Positioning the stabilizer at full aircraft nosedown or normal climb settings did not appreciably alter the control forces. The push force to hold full down elevator during the pitching manoeuvres with either of these stabilizer settings was about 15 lb from aerodynamic loads and 15 lb from the elevator centring spring. The analysis also included data on the control force sensitivity for variations in balance panel cove gap clearances, and stabilizer actuated elevator (SAE) tab misrigging. The push force in the pitching manoeuvres studied was reduced 7.5 lb for each 0.05 inch reduction in the cove gap and 8 lb for each degree of misrigging of the SAE tab. A qualitative evaluation of aeroelastic effects indicated that these would be in a direction to reduce the push force required for the negative load factors developed in nosedown pitching manoeuvres.

2. Analysis and Conclusions

2.1 Analysis

There was no evidence of any control system failure or malfunction except those associated with in-flight breakup or ground impact. Nor was there any evidence of arcing, burning, or electrical overload on any of the generators. There were no signs of a lightning strike or hail damage.

Examination of the aircraft instruments revealed that the nosedown rotational pitch stops of both vertical gyros, which furnish pitch and roll displacement intelligence for the HZ-4 (a combined flight director and attitude indicator) and other devices, received severe impact damage as a result of a rapid rotation of the aircraft about its pitch axis. The compass instruments were indicating northeasterly headings at the time power was interrupted.

Because of the company's route forecast and information provided by the pilot of the aircraft on the incoming flight to Miami, who advised that he had descended after passing the squall line, the crew of Flight 705 should have been aware that some of the worst weather was still northwest of Miami. This would explain the decision to depart to the south and then reverse course when the continuing climb would "top" the weather. Since SIGMET No. 3 was not valid after 1300, and the crew did not receive SIGMET No. 4 regarding potentially hazardous weather, they might have assumed that the hazardous weather conditions were no longer anticipated.

Transmissions between the pilot and controller disclosed a misunderstanding of the intended departure route. The pilot, apparently basing his decision on a belief that the squall line was still northwest of Miami, was requesting an extended southerly climb before reversing course to overfly the weather. The controller, acutely conscious of arriving aircraft descending to the south for approaches to Miami, other conflicting traffic which restricted climb capability in that sector, and the proximity of Homstead AFB, envisioned a slight deviation to the south before vectoring the flight through the weather along a departure pattern similar to that which had been negotiated by a previous flight.

Regardless of other weather information available to the crew, if the airborne radar was operable and being utilized properly, it is difficult to reconcile the flight's progress to the southwest within the confines of the squall line. Apparently, the pilot-in-command believed that he was southeast of the line and intended to resist the inevitable turn to the north as long as possible, in order to gain more altitude.

The flight was airborne about 13 minutes from 1336 to 1349. Between 1336 and 1340 while climbing to 5 000 ft encountered light turbulence. From about 1342:30 to 1346, while climbing from 5 000 ft to 15 000 ft, the flight recorder G trace indicated moderate to severe turbulence. This was confirmed by transmissions from the crew. The airspeed variations during these turbulence encounters did not vary significantly from the recommended 230 to 280 kt penetration range in use. On several occasions, when turbulence was heavier, the heading trace showed a discontinuance of the turn then in progress, a good technique in rough air penetrations. However, at one point in the second encounter at about 1343, the heading trace broke sharply, the altitude dropped and the acceleration was at about +1G level, indicating some form of lateral upset.

According to the flight recorder, the aircraft passed out of the heavy turbulence area at about 1346 while climbing through 15 000 ft. From this point to the beginning of the final manoeuvre at about 1347:25, the recorder traces showed a mild oscillating motion of the aircraft as it climbed from 15 000 ft to 17 250 ft. The acceleration excursions were no greater then ±0.2G, and the altitude variations were small, but discernible during the oscillation. The half cycle time varied from about 16 seconds to 25 seconds.

The flight recorder traces indicated that the accident manoeuvre started some 12 minutes after lift-off at Miami and ended about 45 seconds later when disintegration of the airframe occurred in flight. During this interval the aircraft climbed steeply, reaching a climb rate about 3-1/2 times its normal rate, pitched nosedown, and dove toward the ground at high airspeed. At the start of the manoeuvre the aircraft was in a level turn at 17 250 ft and had been so for about 12 seconds. The airspeed had increased about 10 kt over the level-off airspeed of 260 kt, the heading was still changing toward the 360° clearance heading, and the vertical acceleration had returned to +1G after the slight decrease during level-off. About one minute earlier, while climbing through 15 000 ft, the aircraft had passed out of a heavy turbulence area into a light turbulence area through which it was still flying at about the start of the final manoeuvre. Several radio contacts with departure control were made by the flight in this one minute interval before the manoeuvre started, and two contacts were made with ARTCC in an approximate 10 second interval following the initiation of the final manoeuvre. None indicated concern, alarm or any mechanical difficulty with the aircraft.

Before the results of the flight recorder analyses and other studies were available, the extensive in-flight structural breakup was suggestive of a single catastrophic event such as:

1) an in-flight explosion;
2) a fatigue failure of a main component;
3) a control system failure or major malfunction;
4) an excessive gust loading;
5) flutter;
6) a "static-type" failure of a major component resulting from prior damage due to traversing the heavy turbulence area, an earlier incident or a combination of these prior damage possibilities. This last possibility received early consideration because of the distinctive manner in which the No. 3 engine separated and because portions of this engine's mounting structure had been repaired as a result of the Fort Lauderdale accident. Meticulous study of the aircraft wreckage mockup not only eliminated this causal area, but also disclosed no evidence to support the theories of in-flight explosion, fatigue failure, or control system malfunction.

NASA reviewed the methods and techniques used by Boeing in demonstrating substantiation for gust loads and flutter and found that they were in accordance with established procedures and in agreement with current design practices. Also the results of Boeing's analyses were considered to be reasonable. Flutter protection was provided in the design to speeds in excess of 120% of V_D (the dive speed), and no unusual dynamic response characteristics were found for either positive or negative gusts within the design limits. The analysis of the gust intensities in the accident area at the time, prepared by the U.S. Weather Bureau, demonstrated that the weather was severe but not unusual. Thus, except for the remote chance of an extreme gust encounter, the maximum gusts which the flight might have encountered were within the design limits. It was therefore concluded that the single event possibilities of excessive gust loading or flutter were not the direct cause of the final accident manoeuvre. Accordingly, the Board concluded that no single catastrophic event was the cause of the final manoeuvre. (This view was corroborated by the results of the wreckage trajectory studies and the flight recorder readout analyses.)

The trajectory study helped establish that the aircraft structure was essentially intact throughout most of the final manoeuvre and that the initial separations did not occur until the aircraft had descended below 10 000 ft.

The structural strength data review also tended to support a breakup at a lower altitude. Although the design regulations required that strength be provided for only a -1G limit load, the aircraft design incorporated strength in the negative direction considerably in excess of that value. The horizontal tail could withstand the high loads associated with manoeuvring to -3.2G in the early part of the noseover, and would not be expected to fail under this condition unless the elevator was deflected upward suddenly at an extremely high rate, well in excess of the rate indicated by the recorder readout analysis. However, the manner in which elevator and stabilizer did fail suggested that this type of loading did occur later in the dive. The forward fuselage could also withstand the initial high negative G loading and would not fail until the horizontal tail separated. The wing could be expected to exceed its design strength at either of the high negative G loadings, but would have been more critical at the lower altitude loading.

The early analogue and digital recorder readout studies by Boeing (See Figures 14 and 15) showed that the aircraft was intact during the initial steep climb, the noseover, and during at least most of the dive. The most significant and initially puzzling finding was that the final manoeuvre required -

(a) full nosedown stabilizer trim and full down elevator;
(b) full down elevator for about 8 seconds;
(c) a return to the full up elevator position about 9 seconds later.

This one finding was perhaps the most convincing of all the evidence indicating an essentially intact aircraft down to a lower altitude, even when the inherent limitations of the overall digital study were taken into account. For gusts to be considered as the major contributory generating source for the initial negative G portion of the manoeuvre, their velocities would have to have been inconceivably high because of the large gust gradient (rate of gust onset) required and the relatively long time interval (about 10 seconds) over which the negative G built up to its maximum value. Gust velocities inconceivably greater than the most severe gusts measured during the NSSP would be required. The results of the simulated gust computer studies provided still another indication that gusts and/or draughts alone, even of the type and magnitude believed to have been imposed on Flight 705, would not generate a G trace of the type shown on the flight recorder record.

The picture of the final manoeuvre that emerged from initial consideration of the evidence was that of an intact aircraft describing a path in space as a result of unusual longitudinal control displacements. Two of the three broad conclusions outlined in the summary of the December 1964 Northwest-Battelle study are in essential agreement with the Board's assessment of the evidence. They also conclude that the wreckage examination disclosed no physical evidence of a failure which caused the accident and that "analysis of flight recorder data has produced strong evidence that positioning of the elevator and horizontal stabilizer were directly responsible for the final manoeuvre from which the airplane did not recover." In arriving at their third conclusion that immobilization of the elevators due to freezing precipitated the pilot-in-command's control inputs, they chiefly relied on the previously reported incidents of balance bay freezing, and on their own calculations of the temperature environment in the balance bay area at the time of the accident. The Board, also, was aware of the significance of the previous incidents and early in the investigation had requested Boeing to provide test data bearing on the possibility of balance bay freezing. The balance bay temperature lapse-rate data collected in late 1963 during a joint Northwest-Boeing flight test programme clearly demonstrated that the pertinent temperatures were at least as high as the ram air temperature, and for certain components were appreciably higher. Since the ram air temperature determined from the U.S. Weather Bureau radiosonde data and the flight recorder airspeeds showed the ram air temperature would have been above 40°F for the entire flight, the Board believed it reasonable to conclude that balance bay freezing was not a factor in the accident. After detailed study of the Northwest-Battelle study report the Board found no sound justification for modifying this conclusion.

The Boeing Performance Analysis report was useful in forming an assessment of the events that transpired during the final manoeuvre.

The NASA wind tunnel tests and their subsequent longitudinal control force analysis provided clarification of the elevator and control tab hinge moment picture on the 720B. Although the control forces derived from the full scale tests were not appreciably different from the earlier predicted values, the elevator control force did show the same lightening effect at large down elevator angles but did not reverse within the range of negative lift coefficients used in the NASA analysis. The analysis did note that any change in the conditions of the analysis which would allow control to larger negative lift coefficients would further reduce the push force as a result of the associated aerodynamic characteristics. Moreover, in quantitatively establishing the control force sensitivity both to small variations in cove gap clearance and SAE tab rigging, and qualitatively to aeroelastic wing bending effects, the analysis indicates to the Board that control force lightening to within the system friction band or even mild force reversal is possible on service aircraft.

When questions arose regarding the possibility of making a successful recovery from a vertical dive below 20 000 ft, Boeing provided the Board in November 1964, with the results of a study they had made in this area. Their study showed that with application of full up elevator the aircraft was recoverable from a 95° dive at 14 200 ft and 320 kt with full aircraft nosedown trim. The level-off altitude would be about 5 000 ft. The airspeed at which the recovery is commenced is most important because zero dive angle must be reached before the speed in the dive exceeds 480 kt. Beyond this speed it is not possible to maintain 1G flight with full airplane nosedown stabilizer trim and full up elevator. At the start of the recovery at 14 200 ft, application of full up elevator would develop a +4G airplane load factor and require 185 lb of pull force on the control column. While maintaining full up elevator throughout the recovery, the developed airplane load factor would continuously decrease due to loss in elevator effectiveness with increasing airspeed until the maximum dive speed (472 kt) was reached. However, in this same interval the elevator control column load would increase to a maximum value of 320 lb shortly before level-off. The total time consumed in the recovery was found to be 31 seconds. The Board found these results extremely enlightening and indicative of the difficult problem confronting a pilot in such a recovery.

Some of the preliminary results of the extensive NASA rough air penetration studies shed considerable light on the overall turbulence flying problem and were of great assistance to the Board in its assessment of this accident. Of particular interest was NASA's finding that pilot workload, cockpit acceleration environment, aircraft characteristics, cockpit instrumentation displays, and piloting technique can all be factors in precipitating an upset in some cases. During extensive flight simulation tests in a specifically designed simulator, it was found that the simulator, without any pilot control inputs, can fly through the most severe NSSP gust/draught history without excessive G excursions, large airspeed variations or great altitude changes but with, in many cases, large changes in pitch attitude. The inherent or augmented stability of the simulated aircraft will in this type of trial provide the restoring forces required to maintain the trim condition. In most of the trials with a pilot "in the loop", the simulator could be flown successfully through the "storm" and the extent of the G, airspeed, and altitude excursions depended largely on how close the pilot tried to maintain the desired pitch attitude. Some of the trials revealed oscillations in the recorded parameters, sometimes quite large in amplitude, indicating pilot control input out-of-phasing with the simulator motions induced by the imposed gust/draught history. In a few trials the oscillations became divergent and an upset occurred. When the pilot was told to deliberately ignore the pitch attitude display, and to rely chiefly on controlling airspeed during the simulated penetration, large oscillations of all parameters invariably resulted. The preliminary results of the programme led the Board to conclude that, under certain conditions and circumstances, the unfavourable coupling of pilot control inputs and turbulence-induced aircraft motions can create a hazardous in-flight situation.

A paper presented by Captain Paul Soderlind (Manager, Flight Operations Research and Development Division, Northwest Airlines) in late 1963 re-emphasized the precautions to be taken in making rough air penetrations, especially at higher altitudes. Another paper presented in mid-1964 discussed potential pilot "miscues" from primary cockpit flight instruments and some pilot sensory cues which can be misleading under certain weather conditions. The importance of using the attitude indicator as the chief reference instrument in turbulence, and the need for still further improvements in attitude instrument design were amongst the significant conclusions reached by Captain Soderlind in this last paper.

Additional comprehensive rough air penetration computer simulation studies were conducted by Boeing to provide more information on the general problems associated with rough air penetrations. Severe turbulence history profiles from the NSSP data and from actual transport encounters were used in the simulations. The preliminary results of this study showed that providing the entry speed is not appreciably lower than the recommended values, the aircraft will do a pretty good job of flying itself through the "storm". Little is gained by trying to maintain rigid attitude control since this can produce excessive aircraft loadings without appreciably affecting the altitude and airspeed excursions that occur during severe encounters. Large pitch attitudes of 40° nose up can occur in severe turbulence but moderate counteracting elevator inputs will prevent excessive speed reductions that could result in a stall. The use of the autopilot on Manual Mode offers some advantages but considerable stabilizer trim activity can occur in some types of turbulence and could present a serious danger if the autopilot were disengaged either deliberately or inadvertently at a time when the trim varied appreciably from the in-trim setting. Simulations of rough air penetrations with an autopilot "modified" so as to deactivate the stabilizer trim showed that this type of autopilot configuration would do a very satisfactory job of flying through the rough air. It was found that the principal cues available during instrument flying in rough air can be confusing and contradictory and that the attitude indicator was the most consistently reliable reference instrument for rough air penetrations.

The Board found it difficult to agree in every detail with the suggested sequence in either the Boeing or Northwest-Battelle studies. From the evidence available a generalized picture was obtained of the events which took place during the aircraft's last 45 seconds of flight.

Shortly after 1347 the aircraft entered an area of severe turbulence. The climb that started at about this time was most probably initiated by the pilot and by air draughts. The rapidly decreasing airspeed, increasing rate of climb and the high nose attitude that soon developed would provide the necessary cues for any pilot to take drastic action to prevent what would appear to be an impending stall. It is therefore most probable that the pilot, who was at the time subjected to severe vibrating accelerations from the turbulence, used full down elevator and aircraft nosedown stabilizer trim to change the aircraft's flight path. Although the flight path analysis study indicated that the stabilizer trim was applied before the elevator, the Board found it difficult to believe that a pilot would use trim before using elevator in a situation of this type and was more inclined to believe that they were used in combination.

Although these large control displacements would have the effect of arresting the speed decrease and high climb rate and would return the nose high pitch attitude to a near level attitude, they would also develop extremely high negative G forces on the aircraft. The negative G forces shown on the flight recorder would result in a chaotic situation in the cockpit of any airliner with a crew totally unaccustomed to forces of this type and magnitude. Besides the distraction of warning lights and ringing bells which were probably actuated under the negative G conditions, loose items such as briefcases, charts, logbooks, etc., would be tossed around. The crew members, themselves, would be forced upward against their belts and the average airline pilot would probably have difficulty keeping his feet on the rudder pedals and his hands on the control wheel. For this reason the Board found it inconceivable to believe that the pilot continued to apply full down elevator during the initial high negative G period and believed that the elevator control forces lightened in the manner revealed by NASA's analysis of the wind tunnel results, but to a greater extent than was established in that analysis. Control force lightening to within the system friction band range or actual force reversal very likely did occur. With the control forces reduced to zero or reversed and the pilot's hands off the control wheel as a result of the high negative G effects, the control column would remain in full forward or nosedown position.

When the pilot managed to place his hands on the control wheel some 8 seconds later, the aircraft was in a vertical dive at about 16 000 ft, and the airspeed was building up rapidly. At this time the flight recorder G trace changes toward positive G, indicating a recovery attempt was initiated. However, the recorder flight path analysis indicated the elevator was returned initially to neutral, remained there for a few seconds, and then moved to the full up position. By this time the airspeed was at or beyong 470 kt, the altitude was nearing 10 000 ft, and the vertical acceleration was again moving in a negative direction, indicating that the excessive airspeed and air loads were precluding a successful recovery at this time. During the dive the pilot undoubtedly attempted to re-trim the stabilizer in the aircraft noseup direction, but these attempts were unsuccessful because the high down elevator loads had by that time stalled the stabilizer electric drive motor, preventing system operation by the pilot control column trim switches. Although the Boeing recovery calculations indicated that a successful recovery could be made from about 14 000 ft and an airspeed at or below 320 kt, it would be unreasonable to blame the crew for not being able to do so in view of the cockpit conditions existing at the time and the extremely high control forces required throughout such a recovery. Besides, it appears that the rapid upward elevator displacement required by the Boeing recovery calculation might only have precipitated an earlier elevator and horizontal tail failure.

Many factors were involved in this accident which is a classic illustration of the man-machine-environment causal triangle concept. Aircraft characteristics also played an important part. The cockpit acceleration environment induced by fuselage bending response in heavy turbulence, together with the acceleration amplification at the pilot's head as a result of pilot-seat belt-cushion response, probably caused blurring of the instruments and was annoying-to-alarming to the crew. In its extreme, this characteristic can have a significant effect on a pilot's actions and reactions during rough air penetrations. This unfavourable characteristic is present in all large, swept-wing transports. The lightening of elevator control forces at high down elevator angles in pitching manoeuvres is another undesirable characteristic. In the Board's opinion extensive control force lightening to at least within the system friction band provided the only reasonable explanation for the approximate 8 seconds of down elevator input and, accordingly, was an important contributing factor in this accident as the pilot was then faced with a hazardous problem. The powerful effect of the moveable horizontal stabilizer was another aircraft characteristic involved in the final manoeuvre. However, the moveable stabilizer feature is essential to the aircraft design, and other methods can be utilized to preclude serious out-of-trim conditions.

Flight on instruments in heavy turbulence can present a difficult problem to any pilot who departs too far from the recommended practice of using the attitude indicator as the main reference instrument for maintaining control. If the pilot places undue emphasis on any other flight instrument during his normal scan routine, a serious miscue with drastic consequences can occur. Similarly, attempts to maintain "perfect" attitude control can be equally hazardous, because of the high loadings induced, the danger of overcontrolling by the use of large control displacements, and the possibility of inducing an undesirable oscillatory motion of the aircraft. "Loose" attitude control, or moderate counteracting control inputs, appears to be the best method of counteracting the effects of heavy turbulence.

The HZ-4 attitude indicator installed in the subject aircraft provided an adequate attitude reference display for normal or near normal pitch attitudes. However, during high pitch angles, interpretation of the attitude is extremely difficult because the horizon reference line on the indicator recedes from the face of the instrument. This results from the sphere within the instrument rotating, and the line moving deeper into the instrument housing, away from the face. While this display peculiarity may not have been a factor in the initial climb portion of the manoeuvre, it almost certainly would have been a complicating factor during the noseover and recovery attempt.

Other factors, such as the limited experience of the pilot in this aircraft type, his recent return from an extended leave, and cockpit workload, occasioned in part by the large number of communications to and from ATC might also have had some influence on his flying technique. The pilot, who was believed to be flying the aircraft, had a wide experience in many aircraft types and in all types of weather. He was qualified and had average or better flying abilities. The Board was convinced that a clearer understanding of the "limits" of an "average" airline pilot must be found in order to ensure a safe matching of the man to the machine and the environment. Statistical methods may have to be applied in prescribing a realistic capability range for the "average" pilot in order to provide the aircraft designer with more meaningful data to use in achieving a safe design that provides for full consideration of all associated human factor elements.

2.2 Conclusions

Findings

The crew were qualified and had considerable flying experience.

The aircraft's computed take-off gross weight and centre of gravity were within the allowable limits.

While at Miami the outflow valves were cleaned and a leaking rivet at the No. 4 reserve fuel tank was plugged. No other maintenance was performed. At the time of the accident the aircraft was airworthy.

Because of the 1300 hour route forecast and other weather information provided, the crew of Flight 705 should have been aware that some of the worst weather was still northwest of Miami. Transmissions between the pilot and controller showed there was a misunderstanding of the intended departure route.

Every possible avenue of investigation that could be explored was considered during the Board's lengthy evaluation of this accident and it was found that more than one factor played a part in causing it. Severe turbulence was instrumental in producing a longitudinal upset and the aircraft's characteristics also had a significant bearing on the pilot's control displacements on the final noseover manoeuvre. The Board therefore concluded that the unfavourable interaction of high vertical air currents and large longitudinal control displacements resulted in the aircraft's entering a steep dive during which the design limits were exceeded and disintegration followed.

Since the Boeing recovery calculations indicated that a successful recovery might have been possible, the Board preferred to avoid stating that a successful recovery could not have been made although there were some reasons to believe this latter possibility is more nearly correct. In any event there is no intended implication that the pilot did not do everything possible to regain and maintain control under the most unusual conditions and circumstances.

Cause or
Probable cause(s)

The Board concluded that the probable cause of this accident was the unfavourable interaction of severe vertical air draughts and large longitudinal control displacements which resulted in a longitudinal "upset" from which a successful recovery was not made.

3. Recommendations

Regarding the problems associated with safe flight in turbulence, the Board recommended that a unified, cohesive federal programme be formulated, with a high level board or commission assigned the responsibility for integrating and co-ordinating the research efforts of all government agencies presently working in this field, and for providing appropriate liaison with all pertinent private groups and industry organizations.

The work currently underway within the Interdepartmental Committee for Meteorological Services could well form the nucleus for this broader programme which should include not only the meteorological aspects of the problem, but also the operational, human factors, and aircraft design characteristic aspects.

Pending the establishment of a federal turbulence programme, the Board believed that early FAA and industry attention should be directed to the following:

(1) Explore the possibility of increasing the horizontal stabilizer drive motor torque capacity so as to preclude motor stalling under anticipated conditions, taking proper care against structural damage in the case of a runaway of the more powerful motor.

(2) Consider modifying the elevator control force characteristics to eliminate any appreciable stick force lightening under all reasonable flight conditions inside and outside of the normal operational flight envelope.

(3) Evaluate the desirability of providing a "Turbulence Mode" feature on the autopilot wherein the stabilizer trim and Mach trim systems would be de-activated in this mode.

(4) Expedite the mandatory installation of improved attitude indicators which, by means of size, markings, lettering and/or colour coding methods, would provide greater assistance to the pilot in maintaining attitude control even at high pitch and roll angles.

(5) Develop improved flight simulators that can more realistically duplicate aircraft motions and rough air penetrations, and require their use in initial and recurrent flight training programmes.

(6) Seek further improvement in the utilization of airborne and surface radar to more safely navigate aircraft through areas of severe weather.

On 27 May 1964, shortly after the NASA longitudinal control force analysis report had been received and evaluated, the Board forwarded to the FAA a recommendation covering essentially the aforementioned area of elevator control force lightening. It was recommended that -

(a) a spot check of the Boeing 720 fleet be conducted to determine if the cove gap and SAE tab tolerances were within Boeing specifications;

(b) Boeing be requested to make a detailed evaluation of aeroelastic effects on elevator control forces in the down elevator range at high negative load factors; and

(c) Boeing be requested to assess the feasibility and advisability of modifying the SAE tab linkage as to preclude the lightening of control forces.

In a reply, dated 30 December 1964, FAA advised that after a thorough study and evaluation of all available information, it was their opinion that the data did not justify a requirement for modifying the longitudinal control system to preclude control force lightening during extreme conditions such as those experienced in this accident. The replies regarding a, b and c above were as follows:

(a) an assessment of operational information obtained from eight operators regarding their ability to maintain the pertinent cove gap and SAE tab tolerances indicated no discrepancies were found which would indicate "out of tolerance" settings were probable;

(b) Boeing was asked to provide information on the aeroelastic effects on control forces, and the information supplied showed the net aeroelastic effect would reduce the control force lightening; and

(c) they concurred with Boeing's conclusion that neither modification was justified because the SAE tab linkage would become too complex, and changing the cove gap to improve the down elevator characteristics would result in undesirable force characteristics for other important flight conditions.

FAA advised that current industry actions directed toward avoiding extreme regimes of flight beyond the aircraft design envelope will provide needed improvements in the level of safety for turbulence operation of this and other transport aircraft. Some of the current actions noted were improvements in attitude indicators and stabilizer trim setting displays, better turbulence penetration techniques, and flight and simulator studies of crew environment and airplane characteristics during turbulence penetration.

4. Action taken

Since this accident occurred the entire aviation community has devoted considerable attention and effort to the "upset" problem, and many real safety changes in today's operations have been brought about as a result of this concerted industry effort. Among the many programmes initiated by the FAA, their programme for educating the pilot to the potential hazards of turbulence has received, perhaps, the greatest attention. Many safety bulletins dealing with piloting technique and aircraft characteristics have been circulated to pilots and FAA inspectors have been instructed to ensure proper attention to the problem in airline training programmes. Plans underway to expedite the remoting of U.S. Weather Bureau weather radar displays on ATC radar scopes are expected to result in better weather information being relayed to flights. FAA's assistance to NASA in an intercentre rough air penetration programme has enabled NASA to proceed expeditiously with that programme. Finally, FAA has taken the initiative in stimulating the industry to develop improved attitude indicators. The broad, comprehensive NASA rough air penetration programme has already produced extremely significant data, and is being continued in an effort to provide more information on the involved fundamentals. The aircraft manufacturers have developed improved recommended rough air penetration techniques and have restricted aircraft nosedown electric stabilizer trim limits so as to reduce the likelihood of serious out-of-trim conditions. The U.S. Weather Bureau is actively engaged in many turbulence research programmes, all aimed at developing a greater understanding of the basic problem: Airlines have devoted increased attention to turbulence in their training programmes with the result that pilots today are more aware of the hazard and the proper techniques for save penetrations.

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ICAO Ref: AR/871

ACCIDENT TO BOEING 720-B, N724US, OF NORTHWEST AIRLINES, INC., AT MIAMI, FLORIDA, U.S.A.
12 February 1963

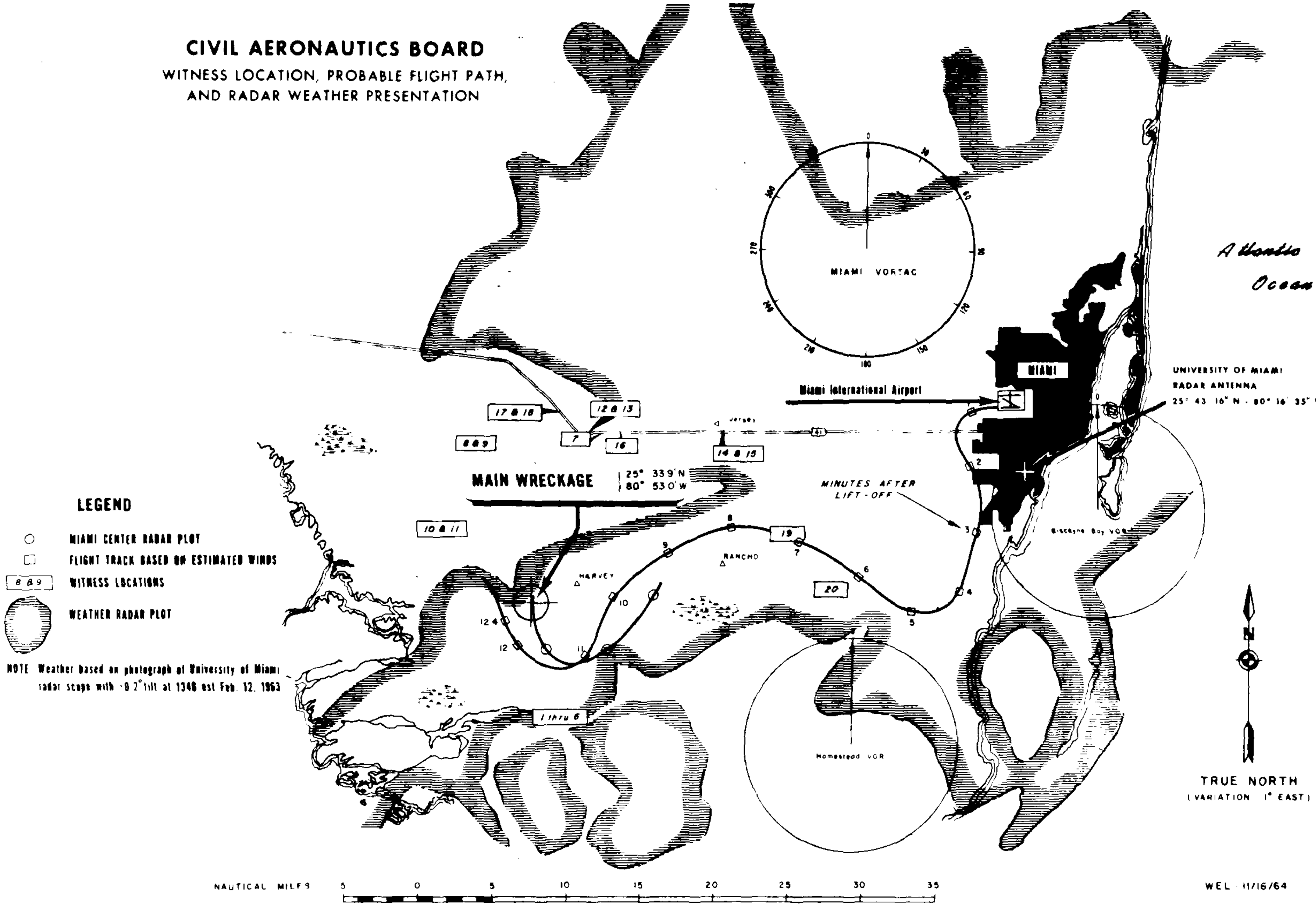


FIGURE 11

ACCIDENT TO BOEING 720-B, N724US, OF NORTHWEST AIRLINES, INC., AT MIAMI, FLORIDA, U.S.A.
12 February 1963

CIVIL AERONAUTICS BOARD
FLIGHT RECORDER DATA

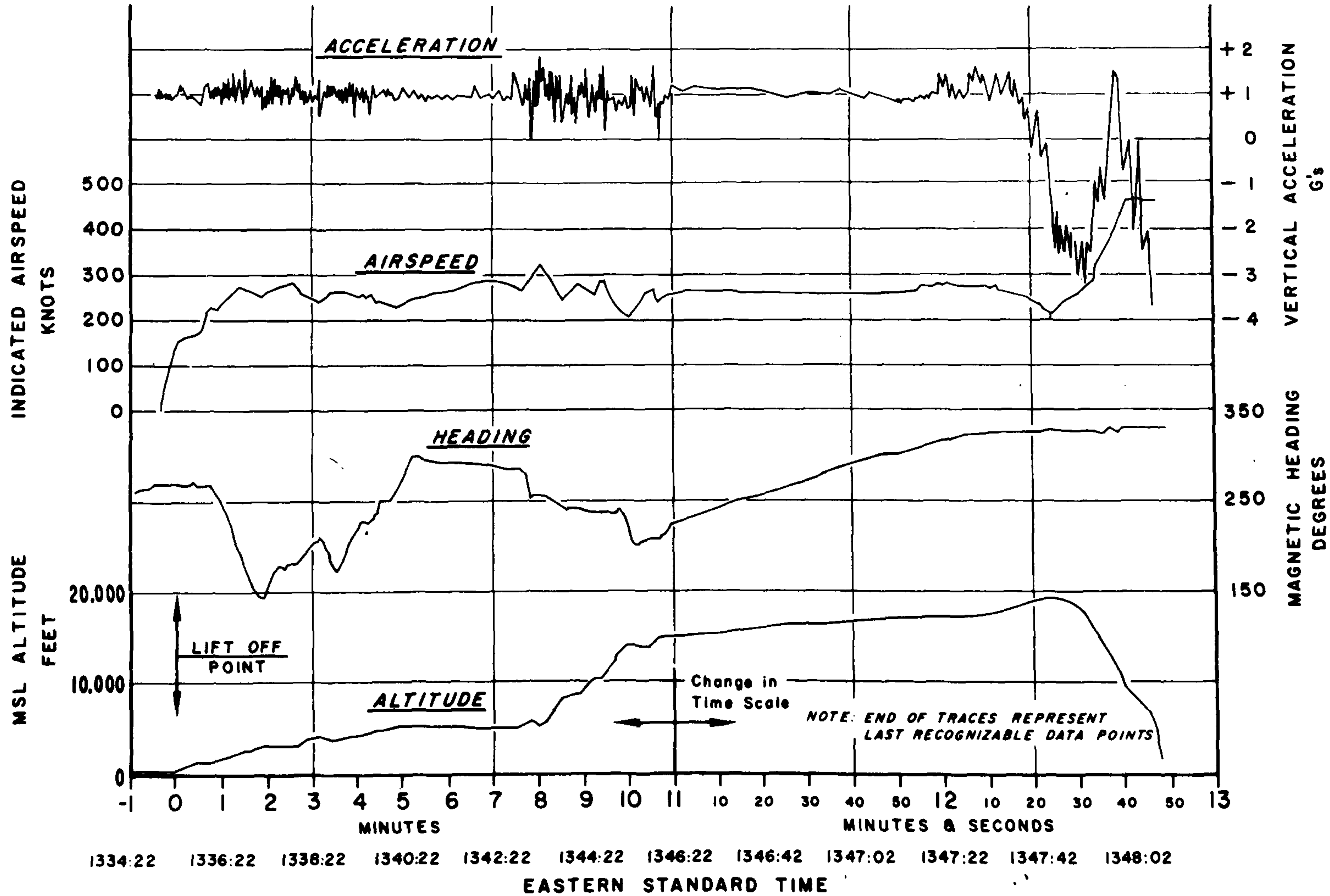


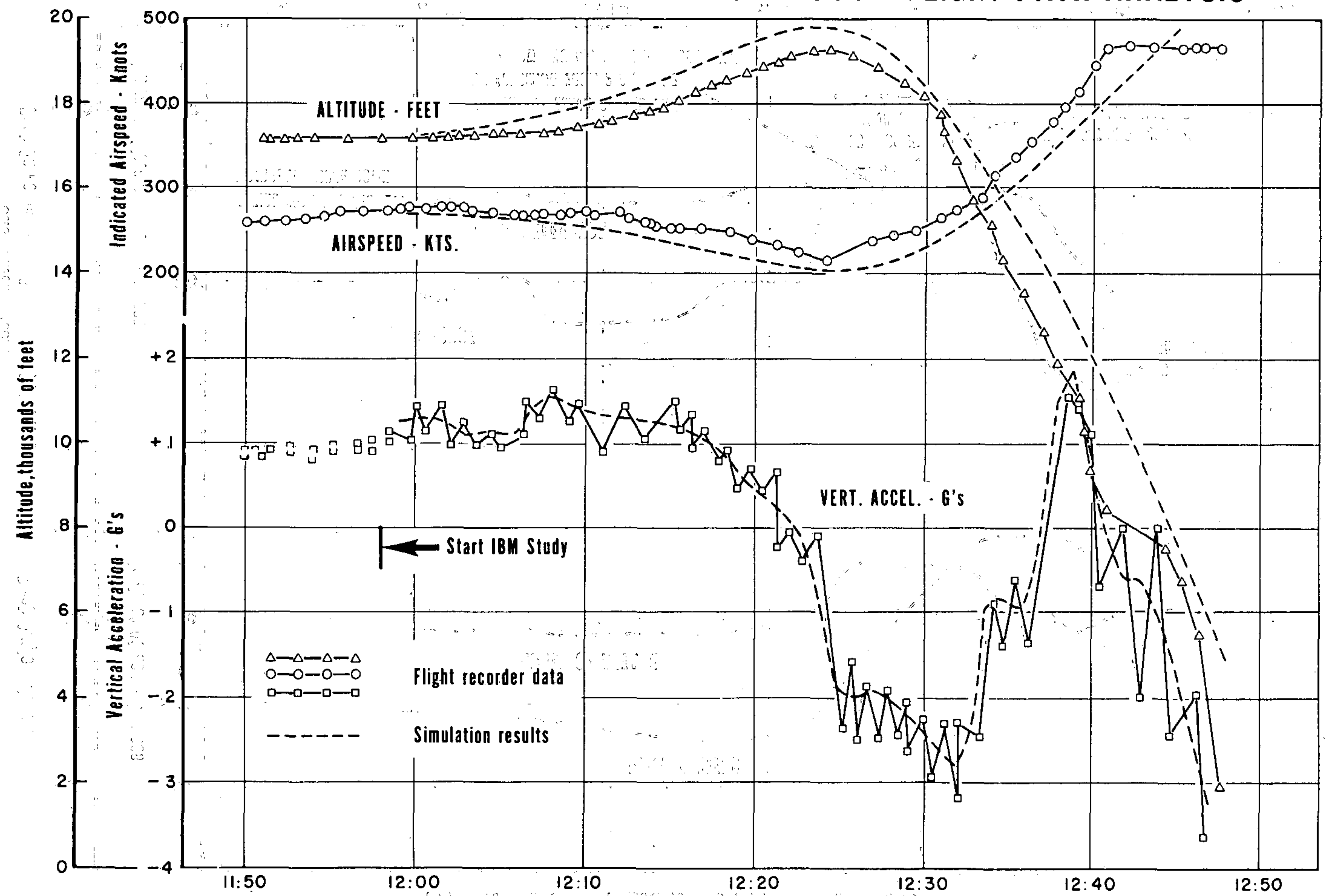
FIGURE 12

ACCIDENT TO BOEING 720-B, N724US, OF NORTHWEST AIRLINES, INC., AT MIAMI, FLORIDA, U.S.A.
12 February 1963

CIVIL AERONAUTICS BOARD
WRECKAGE MOCKUP

FIGURE 13

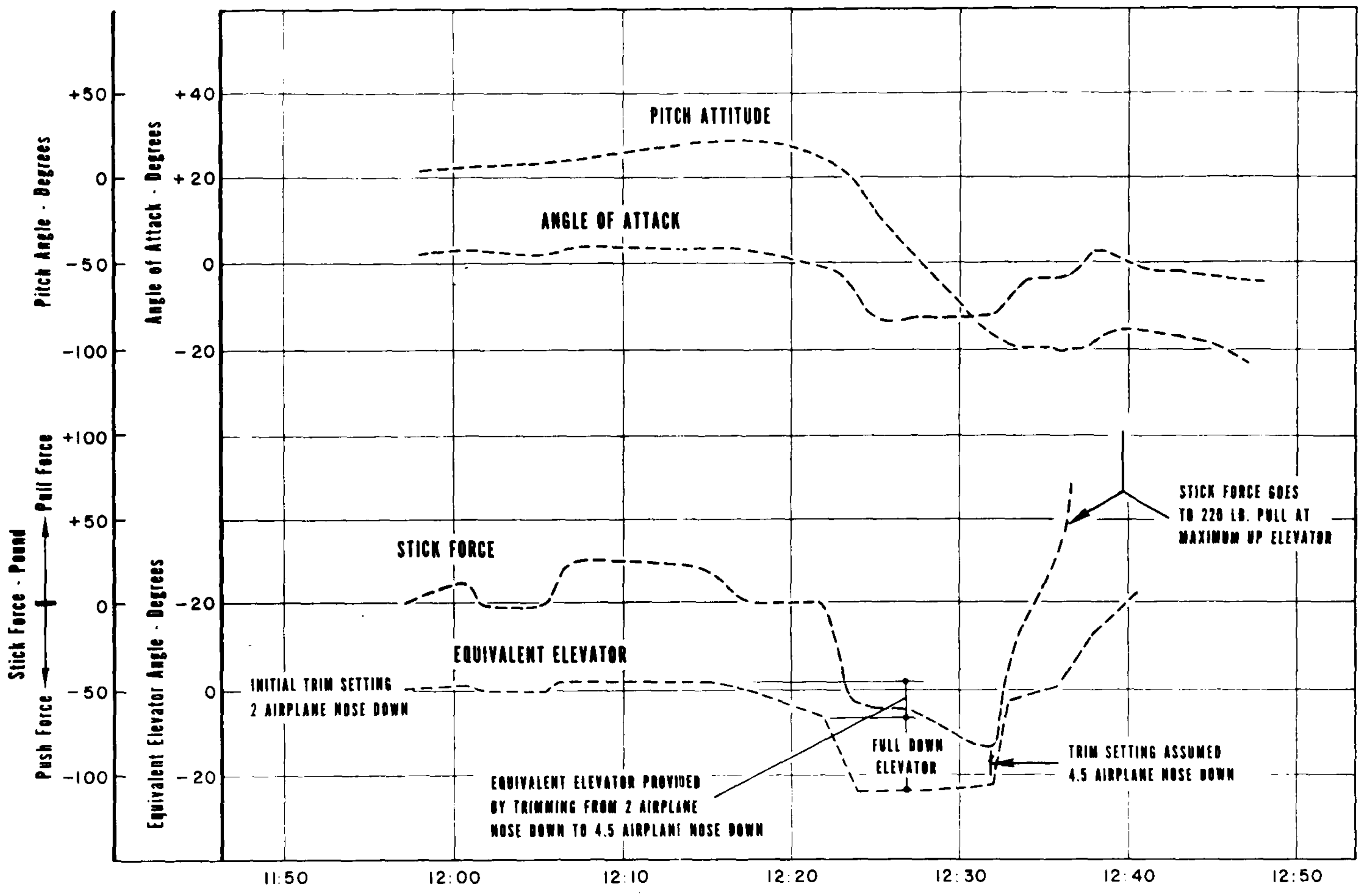
COMPARISON OF TRACES FROM FLIGHT RECORDER AND FLIGHT PATH ANALYSIS



From: Boeing Document D6-6135

FIGURE 14

DATA FROM FLIGHT PATH ANALYSIS



From: Boeing Document D6-6135

FIGURE 15

No. 12

Pan American World Airways, Inc., Boeing 707-121, N 709PA, accident near Elkton, Maryland, U.S.A. on 8 December 1963. Civil Aeronautics Board (U.S.A.) Aircraft Accident Report, File No. 1-0015, released 3 March 1965.

1. Investigation

1.1 History of the flight

Flight 214 was a scheduled domestic flight from San Juan, Puerto Rico, to Philadelphia, Pennsylvania with an intermediate stop at Baltimore, Maryland. Before departing San Juan the pilot was briefed, on the weather along his intended route and a SIGMET indicating possible thunderstorm and turbulence was brought to his attention. The aircraft took off from San Juan at 1610 hours eastern standard time and arrived at Baltimore at 1935 where it was refuelled and a visual inspection performed. While at Baltimore a Pan American operations representative provided the pilot-in-command with the 1900-hour east coast weather sequence reports and advised that a front would be in Philadelphia at approximately 2025 hours. The aircraft departed Baltimore at 2024 hours with an IFR clearance to the Port Herman Intersection via Victor 44 and Victor 433, at 4 000 ft. Further clearance after Port Herman via Victor 433 to the New Castle VOR thence direct to Philadelphia was to be expected. The Baltimore radar which monitored the flight until 2031 hours revealed neither unusual flight progress nor significant weather. Communication was then established with New Castle Approach Control. At 2042 hours the flight reported over the New Castle VOR at 5 000 ft, and control was then transferred to Philadelphia Approach Control which then provided the latest Philadelphia weather. Having been advised that five aircraft were awaiting on holding patterns because of extreme winds the crew also elected to wait and were instructed to hold west of the New Castle VOR on the 270 radial and to expect an approach clearance time of 2110. Permission was granted to use two-minute legs in the holding pattern and at 2050:45 hours the crew advised ATC that they were ready to start an approach. Eight minutes later Philadelphia Approach Control heard the crew sending a "MAYDAY" and stating that the aircraft was out of control. Seconds later a message was received from Flight 16 which was in the same holding pattern 1 000 ft higher, stating that Flight 214 was going down in flames. A large portion of the left wing separated in flight and the aircraft crashed in flames at 2059 in open country 2 miles east of Elkton, Maryland. At the time of the accident it was cloudy, light rain was falling, and there was lightning in clouds.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	8	73	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed by explosion, impact and fire.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The pilot-in-command, age 45, held a valid air transport pilot's certificate with type ratings for various aircraft including the Boeing 707. He also held a navigator's rating. His total flying experience amounted to 17 049 hours of which 2 890 hours were on this aircraft type. He was physically fit.

The co-pilot, age 48, also held a valid air transport pilot's certificate, with a type rating for the Boeing 707, and a navigation rating. His flying experience totalled 13 963 hours including 2 681 hours on the Boeing 707.

The second officer, age 42, was also satisfactorily certificated and had flown 10 008 hours of which 2 808 hours were on the Boeing 707.

The flight engineer held an aircraft and power plant mechanic's certificate and a flight engineer's certificate. He had flown approximately 6 000 hours which included 76 hours on the Boeing 707.

Also aboard the flight were 4 cabin attendants who were properly trained and qualified for their respective positions.

1.6 Aircraft information

The subject aircraft had flown a total of 14 609 hours. The last major inspection was performed on 25 March 1963, and the last layover transit inspection was on 7 December 1963. It had been maintained in accordance with FAA and approved Pan American directives and procedures. The records revealed no history of fuel leaks, lightning strikes or static discharges. The lightning protection requirements of the FAA had been satisfied.

No mention was made in the report of the aircraft's gross weight and centre of gravity at the time of the accident.

On arrival at Baltimore, during a visual inspection, the aircraft was examined for fuel leaks and was then refuelled. Twenty-seven thousand four hundred pounds of Type A fuel were added, which resulted in the following quantities and mixtures: Nos. 1 and 4 reserve tanks - an estimated 1.81 gal of residual fuel, about 69% Type B; Nos. 1 and 4 main tanks - 12 000 lb of fuel each, 31% Type B; centre tank, estimated 15.05 gal residual fuel, 100% Type B. Fuel temperatures were estimated to by 42°F in the reserve tanks and 46°F in the main ones.

Type A is a kerosene type turbine fuel with a flashpoint of 110° - 150°F. Type B is a wide-cut gasoline type turbine fuel with an unspecified flashpoint and a maximum Reid vapour pressure of 3 psi. The flammability limits of a mixture of these two kinds of fuel fall somewhere between the limits of either fuel examined separately. The limits vary according to the temperature and pressure. Flammability is also affected by misting or foaming of the fuel.

Expert testimony at the hearing indicated that the fuel vapours at the time of the accident were well within the flammable range.

1.7 Meteorological information

Before leaving San Juan the pilot-in-command was briefed on the weather conditions to be expected along the route to Philadelphia, and the briefing included discussion of SIGMET No. 3, which mentioned possible thunderstorm activity and turbulence. The times of frontal passage at certain east coast cities, including Baltimore and Philadelphia, were also discussed. The pilot was also provided with a flight folder which contained the required weather documents.

The trip to Baltimore was uneventful. While there, the pilot-in-command was provided with copies of the 1900-hour east coast weather sequence reports and was advised that the front would be at Philadelphia at about 2025 hours. Departure from Baltimore was at 2024 hours.

Shortly after the flight reported over the New Castle VOR at 2042 hours at 5 000 ft, control was transferred to Philadelphia Approach Control, who supplied the following weather information:

> "... Philadelphia weather, now, seven hundred scattered, measured eight hundred broken, one thousand overcast, six miles (visibility) with rain shower, altimeter two nine four five, the surface wind is two hundred and eighty degrees at twenty (knots) with gusts to thirty (knots)..."

Turbulence, thunderstorms and icing were included in all routime forecasts as well as SIGMETS for the area surrounding the accident site during the period the flight was operating in that region.

Nine miles east of the accident site the weather at 2100 hours (i.e. one minute after the accident) was reported as:

> "900 scattered, measured 4 400 overcast, visibility 8 miles, thunderstorms, light rain, temperature 44, dew point 43, wind west-southwest 10 kt, thunderstorm began at 2054, thunderstorm west, movement unknown, lightning in cloud, cloud to ground west-northwest-northwest."

The crew of another aircraft (National Airlines' DC-8 - Flight 16) observed a lightning strike on their own aircraft while in the same holding pattern 1 000 ft higher than Flight 214.

One hundred and forty ground witnesses were interviewed. Ninety-nine reported sighting an aircraft or flaming object in the sky. Seventy-two saw lightning, and seven stated that they saw the lightning strike the aircraft. Three other persons saw a ball of fire appear at the fork or one end of the lightning stroke. Seventy-two witnessess indicated that the ball of fire appeared concurrent with or immediately following the lightning stroke.

(See also paragraph 1.16 for further discussion on Lightning.)

1.8 Aids to navigation

Not pertinent to the accident.

1.9 Communications

Communications were normal between Philadelphia Approach Control and the aircraft from shortly after 2042 hours up until about 2058:56 when a "MAYDAY" message was heard on frequency 124.6.

1.10 Aerodrome and ground facilities

No information was contained in the report.

1.11 Flight recorders

The flight recorder tape was torn and crumpled but had little fire damage. About 95% of the tape was reassembled and read out. It showed an elapsed time of about 32 min 50 sec from lift-off at Baltimore until ground impact. The record of the first 32 minutes indicated no severe turbulence. The abnormal excursions appeared 32:15 minutes after take-off. The tape showed that the aircraft stayed at 5 000 ft for about 15 seconds after the beginning of the unusual excursions and then descended rapidly to ground level with little change in heading. The flight recorder tape of National's Flight 16 showed no major differences between its traces and those of Flight 214 insofar as evidence of turbulence was concerned.

1.12 Wreckage

The accident site was about 10 NM southwest of the New Castle, Delaware VOR.

Nearly 600 pieces of wreckage were strewn outside the main impact crater in an area approximately 4 miles long and 1 mile wide. The long axis of this area was on a bearing of 255° true from the easterly end through the impact crater near the westerly end. However, there were two distinct wreckage paths and three concentrations in this area.

Examination of the wreckage in conjunction with consideration of the wreckage distribution disclosed multiple indications of lightning damage, fire and disintegration in flight.

The complete left wind tip, with portions of the left outer aileron and spar webs still attached, was found approximately 1.8 miles east-northeast of the main impact area.

1.13 Fire

Following a lightning strike the aircraft caught fire, and an in-flight explosion then occurred. Witnesses also mentioned that an explosion took place at impact.

1.14 Survival aspects

No information of this type was contained in the report.

1.15 Tests and research

Toxological examination of the flight crew showed no evidence of alcohol or elevated carbon monoxide levels. Carbon monoxide tests of passengers also indicated no elevated levels.

Fuel samples were taken from the supply sources at Idlewild, Baltimore and San Juan for analysis. However, no discrepancies were noted.

The aircraft's left outer wing and other parts were examined and analysed by the National Bureau of Standards in an effort to detect ignition points and confirm lightning damage. Special attention was given to the left wing tip and parts of the No. 1 reserve tank; the left fuel vent surge tank; the HF antenna probe cover; a piece of top skin from the right side of the centre fuel tank with float valve attached; and the float valve from the right wing reserve tank.

Metallographic examination of several areas of lightning damage showed characteristic deposits of porous fused metal on the damaged surfaces and a distinct boundary between the affected and unaffected metal.

Metal splatters on the leading edge of the horizontal stabilizer were identified by spectrographic analysis as being formed from two different aluminium alloys. These alloys could not be identified since the chemical composition of the deposites dit not conform to any alloy used in the aircraft.

Pan American World Airways conducted a flight test in a Boeing 707 to determine if fuel would discharge through the tank vent system ram air inlet, in flight conditions simulating moderate to rough air turbulence with skidding two minutes turns. There was no visible discharge of fuel at any time during the test. There was evidence that fuel entered the vent system, collected in the surge tanks, and returned to the proper fuel tanks (See Figure 16).

1.16 Lightning

A U.S. Weather Bureau witness was called to testify in this connexion at the hearing, and various technical reports were reviewed.

A lightning stroke begins when the air's resistance to the passage of electricity breaks down. At that time a faintly luminous stepped leader advances toward an area of opposite potential, the earth in the case of cloud to ground lightning. The difference in electrical potential between a cloud and the ground may be in the order of ten to one hundred million volts and discharge currents may exceed 100 000 amperes with 10 000 amperes per micro-second rate of current rise.

The stepped leader advances toward the ground in a series of discrete branching movements, forming an ionized path down from the cloud. As a branch of the stepped leader is approaching the ground, the intensified electric field causes an upward moving streamer to form at a ground projection and advance toward the stepped leader. As the oppositely charged leaders meet, completing the ionized channel, an avalanche of electron flow follows, discharging the cloud to the ground. This entire sequence is accomplished in approximately one millisecond. Additional charge cells in the cloud may then successively discharge through this main ionized channel as a single flickering flash which may last as long as one second. The electron flow suddenly heats the ionized channel to about 15 000°C, expanding the air supersonically outward with a thunderclap. The discharge can also occur between oppositely charged regions within a cloud, or in different clouds.

If the stepped leader of a stroke approaches a flying aircraft, the intense electric field induces streamers from the extremeties of the aircraft out toward the approaching stroke. The stepped leader contacts one of these aircraft streamers, completing the ionized channel to the aircraft and raising the potential of the aircraft to the order of 100 megavolts. This high potential produces streamers from all the extremities and high gradient points of the aircraft. These streamers can have sufficient energy to ignite fuel vapours. Meanwhile, the stroke leader continues on from the aircraft to another cloud or to the ground to complete the ionized channel for the electron avalanche.

Lightning discharges can be hazardous to aircraft fuel systems by possibly igniting the fuel vapour within the tanks. Direct strokes may penetrate the wall of the tank or cause internal sparking, either form the high resistive and/or inductive voltage developed across internal discontinuities, or from possible high voltages induced in the fuel probe wiring. In addition, flame can propagate through the vent system, from fuel vapours ignited at the vent outlet by direct strokes, streamering, or blast pressure waves, spark showers, and possible plasma penetration from direct strokes. Accelerated studies have recently been completed into these hazards to provide technical data on their probable occurrence and control. These studies have also indicated the structural damage that would be caused by the different causes of ignition. Neither blast wave compression nor induced streamer ignition would leave visible evidence of the cause of ignition. The various types of sparking could also cause ignition without leaving identifiable evidence but might leave such evidence if the sparking energy is sufficiently high to produce visible pitting or fusion of metal surfaces.

The majority of lightning strikes to aircraft occur at ambient temperatures near the freezing level. This correlates with thunderstorm electrification theories that charge separation occurs about the freezing level. The subject aircraft was at or near the freezing level just prior to the accident.

Immediately following the accident the Federal Aviation Agency (FAA) sponsored research to improve protection from ignition of fuel by lightning strikes to aircraft. The circumstances and facts of the accident were applied to the planning of the research programme. Its scope and intent were to provide information that could be applied industry wide. Only that portion of the programme which is relevant to the subject accident is discussed hereafter.

The Coordinating Research Council reviewed all available data concerning the relative safety of Type A and Type B jet fuels and mixture thereof. It concluded that while there are differences, the adoption of a single type of aviation turbine fuel by the entire industry would not significantly improve the overall excellent safety record of commercial aviation. Also, additional research into the nature and effect of lightning strikes and electro-static discharges is warranted and more information is desirable regarding the phenomena of fuel spray, misting, and localized vapour-air mixtures in tanks under actual flight conditions. The Federal Aviation Agency implemented research and test programmes to accomplish, in the main, the Coordinating Research Council's recommendations.

It was demonstrated that direct lightning strikes to over wing filler caps and access plates of the type used on the ill fated aircraft can produce sparks inside the fuel tank. However, no evidence of a direct strike on these parts was found on the aircraft. Practical means whereby these potential hazards can be eliminated, as demonstrated within the limits of the testing facility, were developed and, in the case of acesss plates, have already been applied to aircraft in service. Testing failed to demonstrate any hazard from induced voltages in the fuel quantity measuring system. A complete wing section essentially identical to that of the ill fated aircraft was tested for internal sparking in the reserve tank. Simulation of lightning strikes to the extent of the testing facility capability dit not produce any recorded evidence of sparking within the tank.

2. Analysis and conclusions

2.1 Analysis

Examination of the wreckage disclosed multiple indications of lightning damage, fire and disintegration in flight.

There was evidence that the four engines separated from the aircraft in flight due to excessive load factors, but no evidence of engine failure or malfunction prior to separation were found.

No evidence of pre-impact failure was found in the hydraulic or electrical systems. The fuel dump valves were found to be in the closed position.

Multiple lightning strike marks were found on the left wing tip. There was an area of extensive damage on the top surface of the tip along the end rib, in and adjacent to the joint where the wing tip cap and the top wing skin were attached to the end rib. The damaged area extended from the trailing edge of the wing to a point about 3 ft 8 in from the leading edge, measured along the end rib. Within this area there were numerous spots where the metal surface and rivet heads showed indications of melting, and associated dendritic patterns were visible on the wing surface. The largest single indication of lightning damage was an irregular shaped hole about 1-1/2 inches in diameter. There was evidence of high heat in this area and fused metal was found around the hole.

The surge tank was intact except for a 2.2 inch opening along the top extending from spar to spar. The interior of this tank was heavily sooted of all sides and the sealant was burned inside. The exterior of the wing fuel tank ram vent was moderately sooted inboard of the recess in the bottom skin. The heaviest concentration of soot was below and aft of the tank vent screen.

There was evidence of in-flight fire particularly on the left wing aft of the rear spar, the ailerons and spoilers on both sides (with the exception of the outer half of the left outboard aileron), the left horizontal stabilizer and the left side of the vertical empennage. In view of this, the possibility of a fuel leak in the trailing edge of the left inboard wing was explored. It was determined that such fuel leak was not sufficient to explain the observed in-flight fire damage prior to failure of the wing and that explosions did occur in the left, reserve, centre and right reserve fuel tanks. The initial explosion occurred in the left reserve tank and no fire damaged part separated from the aircraft prior to the explosion. The exact sequence and timing of the subsequent explosions and in-flight fires was not determined.

Fires were observed on both wings of the aircraft before impact. It was concluded that main tanks which contained fuel and were adjacent to the reserve and centre tanks were structurally disrupted when some or all of the aforementioned tanks exploded; fuel was spilled and ignited. Such spillage from the opened outer end of the No. 1 main tank and fire damage to parts aft thereof, including the still attached inner ends of the outer panel rear spar and outboard aileron, were quite apparent. Early separation of the outboard engines in the sequence of events may have contributed, at least in part, to the large fires that were observed on the wings.

The evidence failed to disclose the precise mechanism of ignition which triggered the explosion in the left reserve fuel tank. Witnesses, including some who were particularly well qualified, observed a cloud to earth lightning discharge, described as being of exceptionally great magnitude, in the immediate location from which, moments later, the burning aircraft emerged. Before observing the aircraft, a glow or light was observed near the location of the lightning discharge. There was, therefore, a direct correlation in time and location between the lightning discharge and start of events which culminated in the accident.

None of the lightning damage (believed to be of recent origin) in the left wing tip area was on wing skin that encompassed fuel tank or vent system space of the aircraft. Consequently, a direct correlation of any of this damage with the tank explosion was not possible.

Extensive efforts were made to try and find evidence of an electrical discharge that may have ignited the flammable mixture in the left reserve tank with negative results.

Physical evidence of the means by which ignition occurred was not found. However, certain phenomena associated with lightning discharges, which leave no physical evidence can ignite flammable mixtures. One of the most significant is the development of streamers from extremities and/or surface discontinuities as a lightning stroke develops in the step leader stage. These streamers have been found to be in the duration and energy range required to ignite flammable mixtures. Other phenomena, of which less is known because of generation and measuring difficulties, that are considered potential ignition sources are plasma, shock waves and sparking due to induced voltage from extremely high current rise rates that occur. Although much has been learned about lightning and its effects through research and study, many questions are still unanswered and the upper limits of voltage, current and total energy that may be associated with lightning are not conclusively defined. In view of the known facts of this accident, there was no logical explanation for ignition of the flammable vapours other than some effect stemming directly from the lightning strike. As the vent system interconnects all fuel tanks and the vent outlets through passages capable of transmitting flame when filled with flammable mixtures, the initial ignition could have occurred inside the left reserve tank itself or inside the left surge tank, or at the left vent outlet.

2.2 Conclusions

Findings

The crew were properly certificated and qualified for the flight. There was no evidence of crew incapacitation.

The aircraft had been properly maintained, and there was no history of fuel leaks, lightning streaks or static discharges. No fuel leaks were noted during the visual inspection at Baltimore.

On the subject flight a mixture of Type A and Type B fuel was being used. The fuel vapours were well within the flammable range.

The weather service provided at San Juan was satisfactory but was not complete at Baltimore. However, all the weather data available indicated that the cold front would be past Philadelphia, and the weather would be improving upon their arrival. At the time and place of the accident a thunderstorm was present and lightning was observed. Turbulence in the area was not of the strength normally associated with a loss of control or structural failure. Even though the aircraft was operating in precipitation at or near the freezing level, icing was not considered to have been a factor contributing to the accident.

It was determined that explosions occurred in the left reserve, centre and right reserve fuel tanks. The precise mechanism which triggered the initial explosion in the left reserve fuel tank could not be determined from the physical evidence available. There was no logical explanation for ignition of the flammable vapours other than some effect stemming directly from the lightning strike. Initial ignition could have occurred inside the left reserve tank, inside the left surge tank, or at the left vent outlet.

Following these explosions fuel was spilled and caught fire, the complete left wing tips, with portions of the left outer aileron separated from the aircraft which fell down in flame.

Cause or
Probable cause(s)

The probable cause of this accident was lightning-induced ignition of the fuel/air mixture in the No. 1 reserve fuel tank with resultant explosive disintegration of the left outer wing and loss of control.

3. Recommendations

In a letter dated 17 December 1963 the Civil Aviation Board submitted the following recommendations to the Federal Aviation Agency for consideration:

1. Install static discharge wicks on those turbine powered aircraft not so equipped.

2. Re-evaluate problems associated with incorporation of flame arrestors in fuel tank vent outlets... it is believed that positive protection against fuel tank explosion from static discharge ignited fuel/air mixtures at fuel tank vent outlets can be provided by flame arrestors having sufficient depth.

3. A possible alternate to No. 2 that may be considered is to render the mixture emitting from the vent outlet non-ignitable by the introduction of air into the vent tube.

4. It is believed that the surge tanks located just outboard of the reserve tanks, by virtue of their location near the wing tip, are vulnerable with respect to lightning strikes. Burn marks on the skin in the tip area of the subject aircraft (N 709PA) substantiates this belief. This being the case, it is believed a measure of protection will be attained if the wing skin is not utilized as part of the surge tank walls. This could be accomplished by providing an inner wall with an air gap between it and the wing skin to form the surge tank. It is recommended that this concept be considered. Another alternate appears to provide sufficient thickness of the skin in this area to prevent burning through by lightning strikes.

5. Suggested for consideration is the requirement that only Jet A fuel be used commercially. Vapour flammability temperature limits charts provided by Esso show that much less of the operations would occur with the vapour in the flammability range while using Jet A fuel as compared with Jet B fuel.

6. Every effort should be expanded to arrive at a practical means by which flammable air/vapour mixtures are eliminated from the fuel tanks. There appear to be at least two approaches to accomplish this aim -

   a) the possibility of inerting the spaces above the fuel by introduction of an inert gas;

   b) introduce sufficient air circulation into the tanks to maintain a fuel/air ratio too lean for combustion. Other approaches to attain this goal should be explored. It is felt that the resolution of this problem is attainable at a cost commensurate with the benefits. It is recommended that FAA/CAB solicit the aid of the aviation and petroleum industry as well as government and defence agencies to provide a solution to this problem that is applicable to aircraft in service as well as new aircraft.

4. Action taken

On 12 March 1964 the Federal Aviation Agency advised the CAB that the foregoing recommendations and suggestions had been carefully considered along with other ideas for achieving improved protection against lightning strikes. It also advised that the FAA was engaged in a programme of studies, tests and investigations to provide information essential to the development and application of superior protective measures and applied the following precautionary measures:

1. On 13 December 1963 a NOTAM was issued which alerted pilots and traffic controllers to lightning hazards, the need for thunderstorm avoidance, and encouraged the use of PIREPS (pilots' reports);

2. On 18 December 1963 a telegram was sent to air carriers and aircraft operators recommending the installation of static dischargers on all aircraft using turbine fuels;

3. On 4 February 1964 an Airworthiness Directive was issued requiring modification of fuel tank access door bonding on Boeing 707, 720 and 727;

4. On 21 February 1964 an Airworthiness Directive was issued requiring overlay on surge tank skin on Boeing 707 and 720 aircraft for improved protection against penetration.

On 25 February 1964 information on all aspects of the FAA programme was given to the Board of Inquiry at Philadelphia. Briefly, the programme status at that time was as follows:

Technical Committee

A Technical Committee on lightning protection for aircraft fuel systems had been formed, composed of representation from the FAA, CAB, National Aeronautics and Space Administration, U.S. Weather Bureau, U.S. Air Force and U.S. Navy. It met regularly and provided guidance and assistance in planning and carrying out specific actions.

Installation of static dischargers

Response to the telegram sent on 18 December 1964 was completely favourable. Installations were made as parts became available. Reports (around March 1964) showed that about 24 air carrier airplanes had yet to have dischargers installed. Availability of parts was the main factor in completing the remainder.

Collection and analysis of data

Lightning strike data was being received from all available sources and was being consolidated and analysed with the assistance of the Technical Committee.

Contract with Atlantic Research Corporation (30 January 1964)

This work was to include the evaluation of flame arrester design for effectiveness, and studies and tests on other ways of protecting the vent system - such as explosion suppression and ventilation of vent outlet. Equipment calibration tests were also conducted.

Contract with Lightning and Transients Research Institute (4 February 1964)

The possibility of internal arcing on typical wing tank construction was being investigated to evaluate means of eliminating any arcs found to exist. Proof tests of promising flame arrester designs were to be conducted subsequently. The test article was in place and initial discharges were being fired to check out the equipment.

Planning for comprehensive research and development projects

A more comprehensive programme of research and development was required to refine design criteria, make advanced studies of protection concepts - in general covering areas of investigation not possible in the short range contracts with Atlantic Research Corporation and the Lightning and Transients Research Institute. The Technical Committee considered suggestions for the scope and nature of the projects.

Fuel study

The question raised concerning the relative safety of JP-4, kerosene, and mixes of the two were studied. The FAA asked the Coordinating Research Council (CRC) to undertake a review of all available data on the subject. The CRC proceeded with this work which served to define the "state of the art", identified areas where research may be needed and recommended how to accomplish any needed research. FAA also issued Advisory Circular No. AC 20-20, which furnished some general information on the subject.

Re-evaluation of aircraft in service

Based on information on hand, which was later supplemented by information derived from the contract work and the accident investigation, the FAA proceeded with a re-examination of the basis for approval of lightning protective features of all turbine-engined aircraft.

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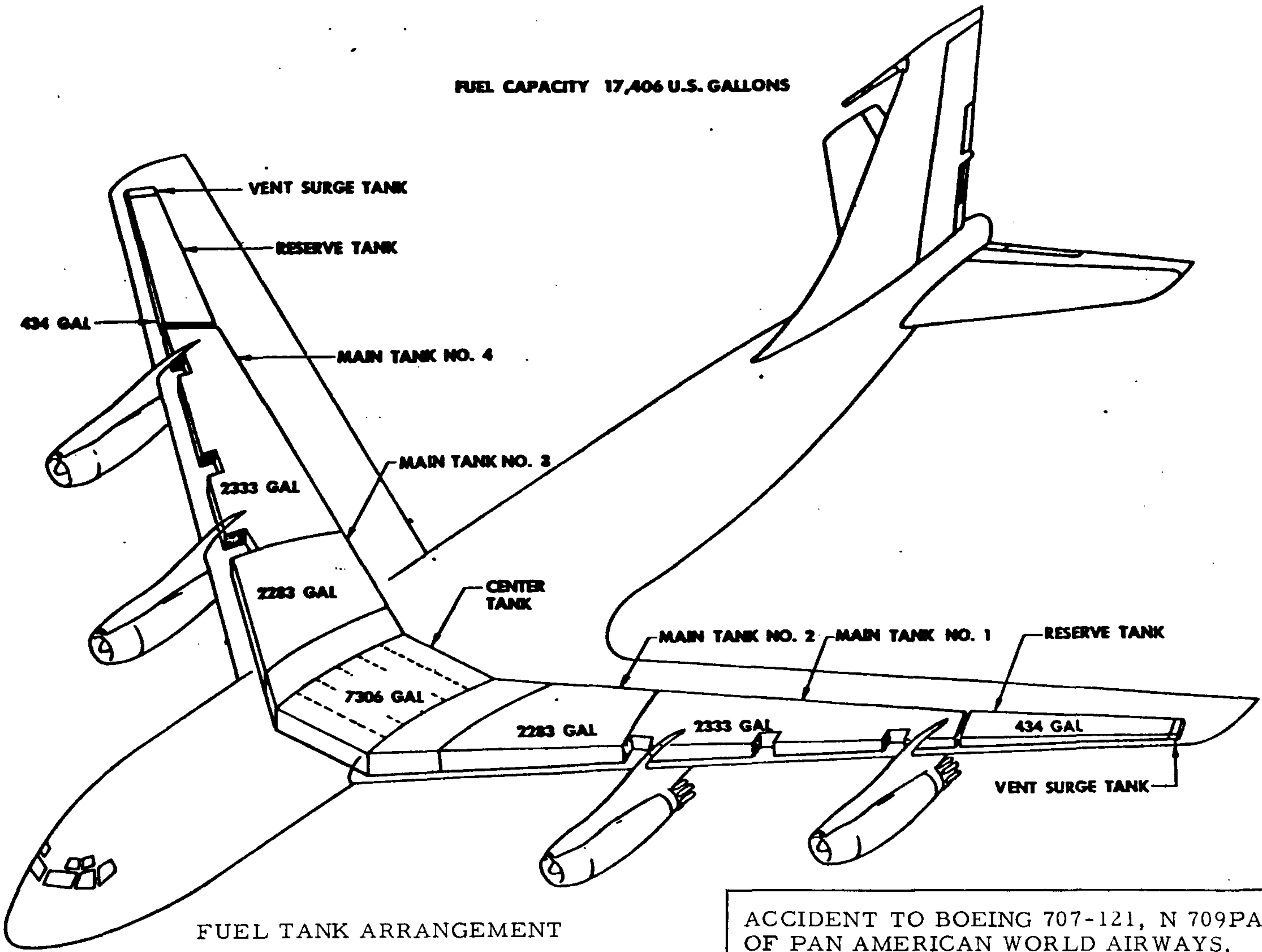
ICAO Ref: AR/872



FUEL TANK ARRANGEMENT

ACCIDENT TO BOEING 707-121, N 709PA, OF PAN AMERICAN WORLD AIRWAYS, INC., AT ELKTON, MARYLAND, U.S.A. 8 DECEMBER 1963

FIGURE 16

No. 13

Norseman V, CF-BHW (Skiplane), accident 73 miles northwest of Pickle Lake, Ontario, Canada, on 22 January 1963. Accident Report No. 1902, released by the Department of Transport, Canada.

1. Investigation

1.1 History of the flight

The aircraft took off from Pickle Lake, Ontario on a flight to Round Lake, Bear Skin Lake, Trout Lake and Big Beaver House. The type of flight and time of departure were not stated in the report. The aircraft did not arrive at any of the intermediate points nor at its destination. Nothing further was heard or seen of it until it was found on 30 May 1963 approximately 73 miles northwest of Pickle Lake (52°24'N - 90°54'W).

The investigation showed that break up of the left wing had occurred in flight prior to impact. The time of the accident was calculated to be 1215 hours central standard time.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	1		
Non fatal			
None			

The pilot, the sole occupant of the aircraft, was killed on impact.

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The pilot held a Senior Commercial Pilot's Licence and had flown a total of 2 886 hours, including 1 277 hours on the subject aircraft type, of which 130 hours were flown during the 90 days before the accident.

1.6 Aircraft information

A Certificate of Airworthiness had been issued for the aircraft.

1.7 Meteorological information

The weather conditions existing at the time of the accident were:

ceiling: unlimited, visibility: 1 to 6 miles in ice crystals, temperature: colder than -25°F, dew point: lower than -30°F, wind: from the northwest at 22 mph.

1.8 Aids to navigation

No information in this regard was contained in the report.

1.9 Communications

Not mentioned in the report.

1.10 Aerodrome and ground facilities

Not relevant to the accident.

1.11 Flight recorders

Not mentioned in the report.

1.12 Wreckage

Pieces of the left wing were found along the wreckage trail, which extended for about 3/8 of a mile on a track of 150°M.

The aircraft was inverted and buried deeply in muskeg at the main point of impact. The engine and propeller were buried deeply in the muskeg and were not recovered.

1.13 Fire

Fire burned the aft portion of the cabin, fuselage and part of the tail section. It had destroyed the right wing except for metal parts and heavy spar timber.

1.14 Survival aspects

In spite of an extensive search, the aircraft was not located until 30 May 1963 (i.e. approximately 4 months after the accident occurred).

1.15 Tests and research

The top portions of the lift struts and the associated wing fittings and the inboard wing fittings were removed from the aircraft for laboratory examination. A Department of Mines and Technical Surveys Report (IR63-71) indicated that the failure of the upper forward eyebolt of the left wing strut was primarily due to fatigue and that the crack initiated in a thread root. It then propagated through about one-third of the cross section, at which stage a brittle fracture of the remaining cross section occurred. A significant feature of the fracture was that initiation and propagation were parallel to the axis of the cross head bolt along the longitudinal axis of the aircraft. (A similar failure occurred in 1958, and the cracks in both cases had initiated in a thread root and extended through the same area of cross section.)

Further tests and examination of a number of sample eyebolts were carried out and revealed substantial dimensional and material differences in the part. However, it was considered unlikely that the fatigue properties of any eyebolt in service would be significantly lower because of these factors. It was suggested by the laboratory that some additional loading in excess of normal flight loads must have been superimposed. The appearance of the fractures was consistent with the imposition of cyclic plane bending loads, which could have been caused by an unobserved structural defect, excessive clearance in the main root fixtures or by transverse flexure of the wing. It was not possible to establish that any of these factors prevailed during the operation of this aicraft.

2. Analysis and conclusions

2.1 Analysis

Examination of the left wing wreckage eliminated the possibility that the aircraft may have been struck by a foreign object. Both left and right flap operating jacks were in the fully retracted position. All aileron hinges and control cables appeared to be airworthy prior to separation of the left wing. Examination of the left wing strut revealed that the upper forward eyebolt had failed from fatigue, and the fatigue failure area had extended about 30% across the break prior to failure. Failure of this eyebolt was followed by separation of the wing in an upward motion towards the rear of the aircraft.

2.2 Conclusions

Findings

The pilot's licence was valid at the time of the accident, and he had flown approximately 1 277 hours on this type of aircraft.

A Certificate of Airworthiness had been issued for the aircraft, and there was no evidence of any fault in the engine or controls prior to the accident. While en route a fatigue failure of the upper forward eyebolt of the left wing resulted in break up of the left wing while in flight, and the aircraft crashed.

Cause or Probable cause(s)

The accident was attributed to fatigue failure of the front eyebolt on the left wing strut.

3. Recommendations

It was not possible at the time this report was released to determine conclusively the primary cause of this failure. However, further laboratory work was being carried out and in the event of any significant findings, this report was to be revised.

Pending the receipt of any additional information relating to this failure, compliance with Airworthiness Directive 63-66, dated July 1963, should serve as an adequate safeguard against repetition of this type of failure.

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ICAO Ref: AR/884

No. 14

National Airways Corporation DC-3C, ZK-AYZ, accident in the Kaimai Range, New Zealand on 3 July 1963. Report No. 25/3/1338, dated 28 November 1963, released by the Minister in Charge of Civil Aviation, New Zealand.

1. Investigation

1.1 History of the flight

Flight 441 was a scheduled domestic flight from Whenuapai Airport, Auckland to Tauranga. The aircraft took off at 0821 hours local time from Whenuapai Airport and reported over the Browns Bay locator at 0826. At 0835 it reported at its cruising altitude of 5 500 ft and gave its ETA at Tauranga as 0914 hours.* The aircraft's heading at this time was estimated as 116°. At 0904 hours the crew called Tauranga and amended its ETA to 0908 hours. This was confirmed at 0906 when the flight requested permission to descent to 4 100 ft, the minimum safe altitude for the route Auckland to Tauranga. The request was granted by Tauranga Control. The wind velocity over the first 30 to 35 miles of the trip was assessed as 070°/30 to 35 kt. This would give a ground speed at cruising altitude of about 130 kt and a drift of 10° starboard, compared with the flight plan ground speed of 123 kt and drift of 13° starboard. It was believed that the aircraft initially drifted to port of its intended track and, when the stronger winds started to take effect, drifted back to be approximately on track when it crossed the southern coastline of the Firth of Thames, at 0849 hours with a ground speed of 137 kt. (A calculation at this point, based on a ground speed of 137 kt, would have resulted in an ETA Tauranga of 0908 hours.) The weather forecast could have led the crew to believe that the wind would decrease in strength over the remainder of the trip. However, from the Firth of Thames, the wind, though retaining roughly the same direction, became progressively stronger, reaching a maximum of between 70 and 80 kt, and the aircraft drifted starboard, while the ground speed diminished. At 0857 the aircraft was about 3 NM abeam Paeroa and was seen by ground witness within 3 miles of that position. The crew, at that time, would have expected to see Waihi. At 0904 the aircraft reported to Tauranga that it was at 5 500 ft and estimating Tauranga four minutes later. It was given the Tauranga weather picture and the altimeter setting (1 011 mb). (The setting of this pressure datum on the altimeter caused it to overread by at least 150 ft.) At 0906 hours the flight reported it was two minutes out and requested descent clearance to 4 100 ft. The aircraft was cleared to descend and the crew acknowledged the message. Shortly thereafter, the descent was commenced. Approaching 0908 a descending turn onto 056° was

* The flight plan time of 48 minutes for the trip appears to have been added to the set heading time of 0826 hours from the Browns Bay locator to give the ETA of 0914. The two-minute discrepancy is due to the following:

1) No allowance was made for the portion of the climb achieved at Browns Bay locator.
2) The distance from Browns Bay locator to Tauranga is 90 miles compared with 93 miles from Whenuapai to Tauranga.

initiated so as to track over the beacon and commence the let-down procedure. The turn was completed, and the aircraft probably encountered a severe down draught of the order of 2 000 ft/min, which caused a rapid and unavoidable descent. It was then subjected to severe turbulence. The aircraft was seen and heard by several witnesses as it tracked along the western side of the Kaimai Range until two witnesses (in the Gordon area) heard the noise of the engines cease abruptly. At approximately 0909 hours it crashed into a face of rock on the Kaimai Range 660 yds from the summit of Mount Ngatamahinerua and came to rest in a cleft at an altitude of 2 460 ft amsl at a point about 16 NM west of Tauranga Airfield.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3	20	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed by the impact and subsequent fire.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The pilot-in-command, age 35, held a valid airline transport pilot's licence and instrument rating. He had flown a total of 6 639 hours including 3 244 hours in command practice and as pilot-in-command. His DC 3 experience amounted to 5 687 hours, including 146 hours during the three months preceding the accident. This figure was well within the flight time limitations imposed by regulation. His last routine DC-3 training check was carried out on 26 February 1963 and a routine 180-day route check was completed on 19 March 1963. He was rated as satisfactory on both. At the time of his last medical examination in March 1963 he was physically fit.

Theco-pilot, age 38, held a valid commercial pilot's licence and instrument rating at the time of the accident. He had flown a total of 10 014 hours including 6 694 hours as co-pilot on DC-3 aircraft. On 17 April 1963 he satisfactorily completed a 180-day route check. On 2 July 1963 (the day before the accident) he successfully completed a routine DC-3 training check. At the time of his last medical examination in August 1962 he was physically fit.

The air hostess had been with the Hostess Section since 4 April 1963.

1.6 Aircraft information

The aircraft had flown a total of 18 629 hours which included 17 604 flown since it was in service with the airline (December 1953). Its last major overhaul was carried out on 29 March 1963 concurrently with the modification to "Skyliner" specifications. From that time it had been in continuous service and had flown 465 hours.

The aircraft's engines were well within their approved engine life at the time of the accident.

The aircraft was equipped with one magnetic compass, two altimeters, two radio compasses and distance measuring equipment (DME). Prior to the departure of the flight the co-pilot of the standby crew checked the radio compasses and distance measuring equipment (DME). However, maintenance records of the subject aircraft showed a disturbing number of unserviceability reports of the DME. Between 1 April 1963 and 2 July 1963 this aircraft carried out 96 flights. On 24 of these a defect report on the DME was made by the pilots. It is possible, therefore, that on the day of the accident the DME equipment was not operating satisfactorily.

The gross weight of the aircraft was 26 819 lb, slightly under the maximum authorized weight of 26 900 lb. The centre of gravity was not mentioned in the report.

The type of fuel being used on the subject flight was not stated in the report. It was estimated that the fuel tanks contained about 300 gal of fuel at the time of the accident.

1.7 Meteorological information

The area and zone forecasts for the period 0700 to 1400 hours were completed at 0540 by the duty forecaster at the Auckland meteorological office and were then transmitted by teletype to Whenuapai Aerodrome. The pilot-in-command and co-pilot of the duty standby crew arrived at the aerodrome at 0655 hours, checked the weather, obtained the flight forecast and prepared the flight plan for Flight 441, which was approved by the pilot-in-command of flight 441 when he arrived at 0735 hours. The salient features of the forecast for the zone, which included the route Whenuapai to Tauranga, were:

winds	3 000 ft	070°/35 kt
	5 000 ft	070°/40 kt
	7 000 ft	060°/40 kt
	10 000 ft	060°/35 kt

The height of the cloud base was forecast at 1 000 to 3 000 ft with patches down to 600 ft. The amount of cloud was estimated to be between 5/8 and 8/8.

Freezing level - estimated at 7 000 ft

Patches of light rain

Terminal forecast for Tauranga:

wind 090°/15 to 25 kt with gusts to 30 kt, intermittent light rain, visibility: 3 to 10 miles; cloud base: 1 000 to 2 000 ft.

The actual weather conditions existing over the route from 0800 to 1000 hours on 3 July were, briefly:

rain - continuous and moderate to heavy in and/near the ranges

cloud and visibility - cloudy to overcast over the whole route. In the area of moderate to heavy rain the cloud base was 500 to 1 000 ft, and the visibility on the ground was 1 to 2 miles. The top of the low cloud layers may have been higher than 6 000 to 7 000 ft over the Kaimai Range. Over all there was a higher layer of cloud, probably between 12 000 and 15 000 ft.

surface wind - from east to southeast about 15 to 20 kt except where this flow was considerably distorted by local topography.

upper winds - the average wind over the whole route was probably 050° to 070°/55 to 60 kt. The winds at 5 000 ft (cruising altitude of the flight) could well have been about 070°/30 to 35 kt over as much as the first 30 to 35 miles of the route from Whenuapai to Tauranga. If this were so, the average wind over the whole route at the time of the subject flight was probably 060 to 080°/55 kt. However, over the latter half of the flight the wind at 5 000 ft increased to about 75 kt, or possibly more.

icing - Freezing level at noon was about 10 000 ft over Auckland and airframe icing at 5 000 ft was considered improbable.

down draughts - the conditions existing on 3 July suggest a maximum down draught of the order of 2 000 ft/min, about 1 000 to 2 000 ft above the crest of the ridge and some distance, possibly about a mile, downstream from it. The zone in which a down draught of this magnitude would occur appears to be quite limited in extent, and the magnitude of the down draught would drop off quite rapidly away from this zone. Evidence of local residents lent support to the existence of these conditions in the vicinity of the crash on the morning of 3 July.

turbulence - it did not seem likely that there would have been significant turbulence at 5 500 ft or even at 4 000 ft. Nearer to the level of the crest of the range, and particularly just in the lee of it, turbulence could have been severe.

1.8 Aids to navigation

There was a beacon at Whenuapai, 3 miles southwest of the airfield, one at Tauranga and a locator beacon at Browns Bay, which is 6 miles northeast of the field. The track between Whenuapai beacon and Tauranga beacon is 123°. Between Browns Bay locator and Tauranga it is 129°.

No DME equipment was available at Tauranga at the time of the accident.

1.9 Communications

The aircraft radio equipment was tested prior to take-off from Whanuapai and was functioning satisfactorily. The aircraft was in contact with Tauranga up until approximately 0906 hours and no difficulties were reported.

1.10 Aerodrome and ground facilities

Not relevant to the accident.

1.11 Flight recorders

No flight recorder was carried out.

1.12 Wreckage

The wreckage was contained within a narrow and nearly vertical U-shaped cleft about 30 ft wide at its entrance and extending inward for a distance of 50 ft. The side and rear walls of this cleft were precipitous and composed of rock and compacted earth.

Impact marks at the entrance to the cleft were compatible with the port and starboard mainplanes having been at relatively the same level. Moreover, the indentations in the port mainplane and tailplane appeared to be vertical. The conclusion, therefore, was that the aircraft was laterally level at impact.

The entry of the aircraft into the narrow opening had resulted in both mainplanes being forced simultaneously rearward, as the fuselage moved forward until it was brought to rest by impact with the rock face at the innermost extremity of the cleft. The entire wreckage, with the exception of the starboard engine, was resting within the cleft on a heading of 054°. A clearly-defined swathe in the undergrowth indicated that the missing engine had rolled down 200 yds away from the wreckage after impact. There was no discernible tree damage on the adjoining ridges, indicating that the aircraft had flown up the valley on a heading approximating that on which the wreckage lay.

1.13 Fire

The aircraft caught fire on impact, and it was apparent that the fuel tanks had ruptured and that fuel had been thrown onto the surrounding rock face. An intense fire resulted which was concentrated mainly in the cabin area and almost completely destroyed all cabin fittings and passenger seats.

1.14 Survival aspects

The wreckage was sighted from the air about midday on 4 July 1963 and was reached by a ground party on the morning of 5 July.

1.15 Tests and research

A post-mortem examination of the co-pilot revealed a severe degree of coronary disease, however, there was no evidence that this condition contributed in any way to the accident.

The magnetic compass was tested by the Dominion Physical Laboratory and was found to be serviceable.

1.16 Air flow over mountains - (Mountain waves)

Mountain waves are well known to pilots as phenomena to be avoided by aeroplanes; however, the magnitude of the disturbances they cause may not be so widely appreciated. The Court was concerned at the somewhat general lack of knowledge in aviation circles of the very real dangers of the dynamic effects which can be produced by the air flow over high ground and therefore extracts from the considerable amount of literature on this subject placed before the Court, are given hereunder.

In unstable air, vertical air currents associated with convection are liable to be more intense over mountains than over level terrain, especially in strong transverse air streams, but in these cases the distribution of vertical currents is irregular. In stable air conditions, however, the disturbance of a transverse air flow by a mountain range can set up an organized flow pattern comprising waves and/or large-scale eddies in which strong vertical currents and turbulence can occur. These effects are sometimes manifest to a considerable height above the level of the crest, and the train of waves may extend for many miles downwind. Thus, whether the air be stable or unstable, mountains and ridges of hills may rise to strong vertical air currents.

With transverse winds of about 20 kt, down currents of 800 ft/min have been experienced on the lee side of mountains rising only 1 500 ft above the surrounding terrain. Stronger winds can give rise to higher vertical velocities, especially over higher ground with a steep lee slope. Indeed, vertical currents of 2 000 ft/min have been recorded on rare occasions in the lee of mountains only 3 000 ft in height, whilst in the Sierra Nevada region of California (U.S.A.) velocities have been known to exceed 5 000 ft/min.

When lee waves are operating, the strongest surface winds are commonly found sweeping down the lee slope. These winds may carry the cap cloud down the lee slope during the process of dispersal by adiabatic warming, so that the cloud resembles a waterfall known as the "cloud fall" or "fohn wall".

If the waves are of large amplitude the flow may contain rotors in the crests of the waves at about the level of maximum amplitude. Because of the large vertical wind shear in the region, the characteristic rotor or roll cloud which may form commonly has the appearance of rotating about a horizontal axis. The low-level winds beneath rotors are much lighter than elsewhere and may indeed even be reversed. Violent turbulence is liable to be encountered in the vicinity of rotor clouds.

If a ridge of substantial high ground has to be crossed when transverse winds are strong and waves are likely, much greater hazard is likely to be encountered when doing so against the wind than for downwind flights. There are two reasons for this:

1) when flying into wind the aircraft's ground speed is reduced, and it will, therefore, remain in the down currents longer;

2) where no attempt is made to counteract height changes, the aircraft's height variations when flying into wind are out of phase with any airstream waves, so that the aircraft is liable to be at its lowest height when actually over the highest ground.

Above the friction layer, which may extend to a considerable height above the crest of the high ground, flight through mountain waves is likely to be very smooth.

Within the friction layer, however, and particularly in the rotor or roll cloud zone, the turbulence encountered may be more violent than that occurring in the most violent thunderstorms. Thus, a region of severe turbulence may be suddenly encountered when height clearance above the terrain has become marginal. If there are reasons to expect strong effects, e.g. from the forecast, appearance of the clouds, or from the pilot's experience, the cruising flight level should be at least one and a half times the height of the mountains above surrounding terrain, and preferably higher.

From the point of view of navigation, the largest tracking (and timing) errors are likely to occur when an aircraft is flying parallel to a long ridge lying across the general wind. When mountain waves are operating the pilot must expect marked departures to occur, both from the forecast winds and from those recently measured in flight. In mountainous regions, therefore, where the available navigational aids do not provide constant and accurate track and ground speed checks, the cruising height selected must allow for maximum deviations from the intended track.

In determining safety heights for each sector of a route, account should be taken of the configuration of the terrain, the alignment of any high ground relative to the intended track, the maximum wind velocity normal to the high ground, and the cruising speed and climb performance of the aircraft. Where the route forecast or the pilot's past experience of the route indicate a possibility of lee waves operating over high ground, an adequate safety margin should be added to the normally accepted terrain clearance heights to ensure that any height fluctuations caused by wave phenomena will not bring the aircraft dangerously close to the high ground.

2. Analysis and conclusions

2.1 Analysis

Examination of the wreckage indicated that no structural or engine malfunction or failure occurred prior to impact of the aircraft within the cleft. Both hydraulic flap-jacks and hydraulic landing gear jacks were found in the fully retracted position and although the starboard flap and landing gear were too badly damaged to ascertain their respective position, it was considered that both flaps and landing gears were retracted at the time of impact. Evidences were found indicating that the aircraft was sinking at a high rate of descent and that the attitude of the aircraft was 7° nose up at the time of initial impact.

Forecasts, although designated by routes, apply to a zone or area, and the wind velocities given are the averages for that area. It was established that the predicted average velocity of winds for an area can be quite misleading as to a particular locality within that zone.

Based on the material available to him, it was believed that the conclusions reached by the Whenuapai forecaster regarding the weather situation were as accurate as could reasonably be expected, however it was considered that the forecast issued at Whenuapai could have given more information for the zone covering the flight of the subject aircraft. No warning was given of the possibility of turbulence and down draughts in the Kaimai area, although a storm commenced to rage during the night of 2 July, and power supplies were cut off in the early hours of 3 July due to poles being blown down in the vicinity of Gordon.

According to Regulation 38 (4) of the Civil Aviation Regulations (1953): regarding minimum terrain clearance altitudes -

> "No aircraft, unless landing or taking-off, shall be flown in accordance with instrument flight rules at a lower height than 1 000 ft above the highest obstacle located within 5 NM of the estimated position of the aircraft in flight:
>
> "Provided that in areas of mountainous terrain a clearance of at least 2 000 ft shall be maintained."

To determine the minimum safe altitude for the route from the Browns Bay locator to Tauranga beacon, Mount Te Aroha, which is 3 126 ft, was used as a basis for calculation. Following consideration as to whether the route terrain clearance area contained terrain which should be classified as mountainous, it was the unanimous opinion of the Operations Planning Section, Civil Aviation Administration, that mountainous terrain clearance was not required, and the minimum safe altitude for the route was fixed at 4 100 ft, i.e. 3 126 + 1 000 ft, rounded off to the nearest 100 ft.

It appeared that the aircraft was flying in accordance with this regulation.

It was considered that when the subject flight was over the Thames coastline, the crew probably obtained an accurate position by visual reference to the ground. Failing such a ground sighting, a DME reading from Whenuapai would have made possible a ground speed calculation, and a back bearing on the radio compass on Browns Bay locator would have given a track check. Having considered many combinations of wind strength, headings, tracks, and ground speeds, the Court concluded that at the halfway point in the flight the aircraft was probably on track and ahead of time. Judging from the weather forecast provided, the crew might have expected the wind would decrease in strength over the last part of the trip, since the wind velocity south of Tauranga at 5 000 ft was given as 060°/25 kt compared with 070°/40 kt from Whenuapai to Tauranga. However, the wind actually increased up to a maximum of 70 to 80 kt, resulting in a drift to starboard and in a reduced ground speed. Based on the evidence of 29 witnesses, who heard or saw the aircraft between Kerepehi and Gordon, together with a knowledge of the wind velocity, it was possible to plot the track of the aircraft with reasonable accuracy. Evidence of the weather in the area, combined with the testimony of experienced pilots, led the Court to conclude that for the greater portion of the last 15 minutes of flight the radio compasses were affected by terrain and precipitation static, and were not giving adequate tracking guidance. At 0904 the flight reported that it would be reaching Tauranga four minutes later. Although the changed ETA had probably been calculated 15 minutes earlier, it was felt that Tauranga was not advised of the amendment, because the crew believed that satisfactory communications were unlikely until the flight had passed to the east of the Kaimai Range. Also, they may have been waiting for another position check. If the radio compass was operating satisfactorily it probably started to settle down around 0904 hours, and this would have indicated to the crew that the aircraft was approaching Tauranga on the starboard side of the beacon. The crew unaware of the displacement of the aircraft to the west, would have believed they were close to the Tauranga beacon and in a good position to turn onto 056°, the bearing of the outbound leg of the let-down procedure. Shortly thereafter the aircraft made its descending turn, encountered the severe down draught and turbulence then crashed. As there was evidence that additional power was applied during the last few seconds of flight, it was believed that an abortive attempt had been made to regain height at that time.

2.2 Conclusions

Findings

Both pilots were satisfactorily certificated and had considerable experience on DC-3 aircraft. During their latest medical examination they were found to be physically fit. Although a post-mortem examination revealed that the co-pilot had a severe degree of coronary disease, there was no evidence that it contributed in any way to the accident.

The aircraft was airworthy and no failure or deficiency of the engines contributed to the accident. Its gross weight was within the authorized limits. The centre of gravity was not mentioned in the report. The aircraft was equipped with various aids to navigation, including distance-measuring equipment (DME). Maintenance records indicated a number of unserviceability reports of the DME and this equipment might not have been operating satisfactorily on the day of the accident. Furthermore at that time Tauranga Airfield was not equipped with DME. Also the aircraft radio compasses were probably affected by terrain and precipitation static during the last 15 minutes of the flight.

The area weather forecast induced the crew to believe that the wind strength would diminish during the last part of the flight whereas it actually increased considerably. This resulted in a drift to starboard and in a reduced ground speed of which the crew was unaware. Believing they were close to the Tauranga beacon and in good position to start the let down procedure, a descending turn to 065 was initiated. The aircraft then encountered turbulence and a severe down-draught of the order of 2 000 ft/min and crashed in a cleft of the Kaimai Range, 327 ft below the summit of Mount Ngatamahinerua

Cause or Probable cause(s)

The main cause of the accident was a strong downward current in the lee of the Kaimai Range close to the Gordon quarry. This downward current carried the aircraft below the level of the crests of the range where, under the conditions prevailing at the time, the aircraft encountered an area of extreme turbulence in which it was impossible for the pilot to regain effective control and recover height.

Contributory causes of the accident were:

a) The pilot-in-command of the aircraft was unaware of his true position and initiated a premature descent. However, it must be appreciated that he decided to descent only to the level officially designated as the minimum safe altitude in the area of his descent.

b) The decision of the Civil Aviation authorities to classify the Kaimai Range as non-mountainous terrain for the purpose of determining the safe altitude for the route.

c) The misleading forecast of the upper winds between Whenuapai and Tauranga.

3. Recommendations

Following this accident the Court recommended that:

- the installation of DME at aerodromes used by air transport operators be accorded priority and that reliable airborne DME equipment be provided on passenger aircraft operating on scheduled flights;

- a critical examination be made of existing minimum safe altitudes for air routes in New Zealand, and that such an examination be made in conjunction with meteorological experts and those who have made a specialized study of vertical air currents (such as the gliding fraternity);

- where the forecast wind velocity is 30 kt or greater at planned cruising level, the minimum safe altitude for DC-3 aircraft on any route be increased by 1 000 ft and where the forecast wind velocity is 55 kt or greater DC-3 flights be cancelled;

- a climbout procedure be initiated for instrument flight rules departures from Tauranga so that aircraft set heading at the Tauranga beacon at not less than 3 000 ft;

- when DME equipment is not available, or is suspect for any reason, aircraft flying under instrument flight rules, arriving at Tauranga, remain at the en route cruising altitude until overhead the beacon. Other routes which involve high terrain and lack of positive fixing should also be examined with this precaution in mind;

- ballpoint pens be used by air traffic control officers and no superimposed alterations to figures be permitted;

- a forecaster be made available at Whenuapai Airport to brief and de-brief crews;

- where possible and practicable, specific winds be furnished rather than an average for the route and forecasters be encouraged to comment on any suspected unusual weather phenomena along the route;

- an investigation be carried out into the feasibility and cost of fitting a crash-proof radio beacon to aircraft which would operate on impact and be available to guide searching aircraft to the accident site;

- the possibility of installing flight recorders on turboprop and jet aircraft should be promptly and carefully investigated particularly in the light of recent practice and compulsory requirements in certain other countries. (The Court was not disposed to recommend the fitting of flight recorders to DC-3 aircraft because it doubted the expense was justified.)

4. Action taken

Following the accident, the complementary ground equipment required for the use of DME was installed at Tauranga Field.

On 8 July 1963 (i.e. 5 days after the accident) the minimum safe altitude of the Whenuapai/Browns Bay - Tauranga route was raised to 5 126 ft, an addition of 1 026 ft, as a precautionary measure, due to the possibility of excessive down draughts around the Kaimai Range.

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ICAO Ref: AR/883

No. 15

Western Air Lines, Inc., DC-6B, N 93131, accident at Los Angeles International Airport, Los Angeles, California, U.S.A. on 17 December 1963. Civil Aeronautics Board (U.S.A.) Aircraft Accident Report, File No. 1-0016, released 14 April 1965.

1. Investigation

1.1 History of the flight

Flight 221 was a scheduled domestic flight from San Francisco to Los Angeles International Airport. It had been dispatched as combination Flights 220/221, Los Angeles - San Francisco - Los Angeles. When at San Francisco the pilot-in-command checked the latest weather information for the return flight to Los Angeles. The aircraft took off from San Francisco at 2206 hrs Pacific Standard time, on an IFR clearance with the same crew and 40 passengers. At 2315, in the vicinity of Bakersfield, California, the crew received the 2300 Los Angeles surface weather observation broadcast.

After the flight had arrived in the Los Angeles terminal area the approach controller informed the crew of the weather conditions at the airport, provided normal vectoring services and cleared the flight for an Instrument Landing System (ILS) approach to runway 25L. At 2337 the flight reported over the outer marker inbound and was given Precision Approach Radar (PAR) advisories after having intercepted the ILS glide slope. The aircraft was on course and on the glide slope 4 miles and 2 1/2 miles from touchdown; at 1 1/2 miles and 1 mile it was still on the glide slope but 100 ft left of course; at 3/4 a mile from touchdown it was 200 ft left of course and the crew was told to execute a missed approach if they did not have visual contact with the runway.

The crew advised the tower that they then had visual contact with the runway. The aircraft's radar target was observed by the PAR controller to correct back to the course centreline prior to reaching the touchdown zone. The pilot-in-command called for full flaps. At this point the aircraft was slightly to the left of centreline, but a correction was made, and the approach was continued on course. The pilot-in-command also stated that there was at least 1/2 mile visibility on the approach end and about 6 to 10 runway lights were visible. The approach was continued with visual reference to the runway. The landing gear was down, the landing lights extended and on, the flaps fully extended (50°) and all propellers were set at 2 300 rpm. The flareout was normal and the touchdown, described by the crew as a little harder than usual, was made 1 000 ft down the runway. Immediately after landing the aircraft entered a fog condition, which reduced visibility to zero. The pilot hesitated to apply power because sight of the runway lights was momentarily regained. However, almost immediately the aircraft again entered dense fog and the pilot-in-command stated that he then called for full power, 20° flaps, and initiated a go-around procedure. He rotated the aircraft at V_2 (100 kt), and it became airborne. Shortly after the check pilot warned the pilot-in-command that the aircraft was sinking and to pull up. The pilot at this time was preoccupied with trying to maintain V_2 climbout speed (100 kt) and the heading and attitude of the aircraft. A noise was heard and the aircraft was not performing at all, however, it was still airborne and started to climb out on full power until it reached the top of the fog at about

350 to 400 ft amsl. The pilot-in-command stated that he then accelerated the aircraft to 120 kt and called for gear up, METO power and flaps up at about 500 ft. However the copilot stated that the command for "gear up, flaps up" was given subsequent to the noise and that he then raised the landing gear handle to the up position and the flaps handle from the 20° detent to the full up position. The airspeed increased to 135 kt. During the climbout the check pilot noted the No. 2 engine oil pressure warning light coming on, and the No. 2 engine tachometer indicating less than 1 000 rpm. He ordered to feather propeller No. 2, and the second officer engaged the No. 2 feathering switch. The aircraft obtained a clearance to Lockheed Air Terminal at Burbank and proceeded there where it was vectored to the ILS final approach course for runway 7. While en route to Burbank a visual inspection of the aircraft revealed that No. 2 propeller was missing and that No. 2 engine nacelle was drooped. Following a landing gear check by the Burbank tower the aircraft landed at 0005 hrs (18 December) without further incident.

The accident at Los Angeles occurred at 2341 hrs.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal			
Non fatal			
None	6	40	

1.3 Damage to aircraft

The aircraft was substantially damaged.

No. 2 engine nose case and propeller assembly separated from the engine at the forward section of the front power case and was heavily damaged by impact. Four of the six engine attach mounts had separated from the mounting, and the forward section of the engine nacelle drooped at an angle of about 7°. No. 1 engine cowling and propeller dome spinner were damaged by propeller fragments and the blades of No. 1 propeller were bent and 1/2 inch of the tips was grounded off.

1.4 Other damage

No damage was sustained by objects other than the aircraft.

1.5 Crew information

The pilot-in-command, age 40, held a valid FAA airline transport pilot's certificate with type ratings for the DC-6B and DC-7. He had flown a total of 15 200 hrs including 5 000 on the DC-6B. He was requalified as pilot-in-command on DC-6B aircraft on 21 November 1963 and it was his first flight as pilot-in-command since June 1960. Five days before the accident occurred he underwent a first-class FAA physical examination which he passed satisfactorily.

The co-pilot, age 32, held a valid FAA commercial pilot's certificate with aircraft single and multiengine land, and instrument ratings. His last proficiency check on the subject aircraft type was on 1 October 1962, and his last line check on DC-6B was on 20 September 1963. He had flown a total of 2 200 hrs including 750 hrs on DC-6B. His medical certificate was also valid at the time of the accident.

The second officer, age 26, held a valid FAA flight engineer's certificate and a commercial certificate with single and multiengine land aircraft and instrument ratings. His last line check on the DC-6B was on 9 October 1963. He had flown a total of 360 hrs as flight engineer including 344 hrs on the DC-6B. On 3 May 1963 he successfully passed a second-class FAA flight physical.

Also aboard the aircraft, in the jump seat, was a company check pilot, age 43, who had flown in this capacity from 1 July 1950 to 1 October 1959 and from 1 February 1960 until the subject accident. He was assigned to the flight to requalify the assigned pilot-in-command for the route involved. He held a valid airline transport pilot's certificate with numerous type ratings including DC-6Bs. His last line check on DC-6B was on 14 March 1963, and his last proficiency check on the same aircraft type as on 27 March 1963. His flying experience amounted to 14 600 hrs including 8 000 hrs on the DC-6B.

Both stewardesses had completed recurrent training in emergency procedures on all equipment in November 1963.

1.6 Aircraft information

The aircraft had flown a total of 13 743 hrs. Since last overhaul, engines No. 1, 2, 3 and 4 had flown 841, 103, 189 and 324 hrs respectively.

No maintenance was required or performed at San Francisco.

The aircraft's computed landing gross weight (74 993 lb) at Los Angeles and its centre of gravity (21.9% MAC) were within the operating limitations.

The type of fuel being used and amount carried on the aircraft were not mentioned in the report.

1.7 Meteorological information

The Company dispatcher at Los Angeles responsible for Flight 200/221 discussed the weather forecast for Los Angeles with the pilot-in-command during the briefing at 1915 hrs. He advised the pilot to expect fog conditions with low visibility on his return to Los Angeles rather than the clear skies called for, after 1900 hrs, in the U.S. Weather Bureau forecast issued at 1445 hrs and valid from 1500 on 17 December to 0300 on 18 December.

At San Francisco the pilot-in-command and check pilot checked the latest weather information for Los Angeles and points en route in preparation for Flight 221 which was planned to arrive at Los Angeles at 2336. The latest weather reported for Los Angeles at that time was the 2100 hour U.S. Weather Bureau sequence report, giving: partial obscuration, 16 000 ft scattered, visibility 2 miles, haze, smoke temperature 55°F, dewpoint 52°F, wind ENE/3 kt, altimeter setting 30.11 in RVR runway 07 - 1/2 mile, runway 24 - 1/4 mile, runway 06 - less than 3/16 mile, visibility west 1 mile. Also, the terminal forecast for Los Angeles issued by the U.S. Weather Bureau at 2045 was available and was valid for 12 hours beginning at 2100. At 2315 hrs when the flight was near Bakersfield, California, it received the regularly scheduled weather broadcast on the Bakersfield low frequency radio range. This included the 2300 Los Angeles surface weather observation which was as follows:

> partial obscuration, visibility 1/2 mile, ground fog, smoke, temperature 51°F, dewpoint 49°F, wind southwest 3 kt, altimeter 30.10 inches, runway visual range (25L) 6 000 ft plus, runway 07 runway visibility 3/4 mile, runway 24 runway visibility 1/2 mile, runway 06 runway visibility less than 3/16 mile, fog obscuring 3/10 of the sky, surface visibility 7/8 mile.

The published approach minima for runway 25L were 200 ft ceiling and 1/2 mile visibility or 2 400 ft Runway Visual Range (RVR).

After the flight arrived in the Los Angeles terminal area the following weather observation for the Los Angeles International Airport was transmitted by approach control:

> "sky partially obscured; visibility: 1/2 mile, ground fog and smoke"

At 2340 hrs at about the time the flight was inbound from the outer marker, the U.S. Weather Bureau at Los Angeles recorded the following local weather observation:

> sky partially obscured; surface visibility 3/4 mile, tower visibility 1/2 mile, ground fog and smoke; temperature 47°F, wind south-southwest 4 kt, altimeter setting 30.11 inches. Further remarks were: runway 25L visual range 5 000 ft, runway 07 runway visibility less than 3/16 of a mile, runway 06 runway visibility less than 3/16 of a mile, fog obscuring 4/10 of the sky, surface visibility 3/4 of a mile.

The U.S. Weather Bureau's transmissometer record indicated that the RVR for runway 25L went below 6 000 ft at about 2338 hours and varied between 5 000 and 6 000 ft from 2340 to 2345. At 2347, i.e. six minutes after the accident, it dropped to less than 1 000 ft.

Following the accident the pilot-in-command stated that after he had made visual contact with the runway there was at least 1/2 mile visibility on the approach end of runway 25L with about 6 to 10 runway lights visible and that immediately after landing the aircraft had entered a fog condition which reduced visibility to zero.

1.8 Aids to navigation

ILS and Precision Approach Radar (PAR) were available at Los Angeles International Airport.

1.9 Communications

The flight was in contact with the Precision Approach Radar controller during the instrument approach. No communications difficulties were experienced.

1.10 Aerodrome and ground facilities

Runway 25L at Los Angeles International Airport is 12 000 ft long and 200 ft wide, and its threshold is displaced 650 ft to the west to provide proper approach clearance for aircraft above ground obstacles located near the approach end of the runway. The ground elevation at the approach end of the runway is 91.4 ft, and the effective runway gradient is +0.27%.

A standard configuration "A" approach lighting system with sequenced flashing (strobe) lights is installed for this runway. High intensity, directional, runway lights parallel both sides of the runway, 10 ft outboard of the runway edge and spaced 200 ft apart.

All components of the approach and runway lighting systems were on and operating at their highest intensity setting at the time of the accident. The runway lights were positioned to the east.

1.11 Flight recorders

No information in the report.

1.12 Wreckage

Not pertinent to the accident.

1.13 Fire

There was no fire.

1.14 Survival aspects

Not applicable.

1.15 Tests and research

No information of this type was contained in the report.

2. Analysis and conclusions

2.1 Analysis

It was determined that the subject flight was properly dispatched in accordance with company procedures.

There was no evidence of malfunction or failure of the aircraft or any of its components prior to impact.

Initial propeller slash marks from the No. 2 engine were found on the runway starting at a point 5 489 ft beyond the displaced threshold and approximately 59 ft beyond the initial tire marks left by the left main landing gear. These slash marks continued for a distance of 48 1/2 ft. The impact point of the No. 2 engine propeller and nose case was approximately 11 ft beyond the last slash mark made by this propeller. These components were found on the runway 850 ft beyond this point.

Propeller slash marks from the No. 1 engine started from a point 5 522 ft beyond the displaced threshold and continued for approximately 114 1/2 ft.

There was no evidence that any part of the aircraft other than the Nos. 1 and 2 propellers and both main landing gears made contact with the runway.

Based on the observations of the tower and the U.S. Weather Bureau personnel, the airport remained above published minima throughout the approach. However, it is considered that the prevailing visibility of 1/2 mile, which was reported to the flight, and the RVR value of 5 000 ft, were not truly representative of the RVR for runway 25L. Although the RVR for this runway remained above 5 000 ft throughout the approach of the flight, it must be noted that this value was only representative of the transmissivity of the atmosphere over the 750 ft baseline of the instrumentation, which is at the approach end of that runway. It was not representative of the fog-induced non-homogeneous conditions which existed beyond the approach end of the runway. Similarly, the area of thick patchy fog was beyond the visual range (1/2 mile) of the observer in the tower and was therefore, not detectible from his location.

During the approach to runway 25L the crew sighted the runway lights when the aircraft was near the middle marker. The dense fog condition which existed beyond the pilot's forward visibility range would not have been discernible at this point, nor would it have been discernible to the crew subsequently during the flare and landing transition. In the light of the existing conditions, the crew's visual acuity would have been enhanced had the landing lights been extinguished at touchdown, thereby eliminating the resultant glare.

According to crew, touchdown was effected about 1 000 ft beyond the runway threshold. However, computations based on applicable performance data gave an average acceleration of 2.2 kt/sec and elapsed time of 11.8 sec, from lift-off (100 kt) to initial impact (126 kt), and resulted in a lift-off point about 3 250 ft beyond the runway threshold. Thus, based on this lift-off point and on crew testimony regarding elapsed time between touchdown and the initiation of go-around procedures it appeared that the aircraft actually touched down between 2 000 and 2 400 ft beyond the runway threshold.

The DC-6B performance curves showed that, at a gross weight of 80 000 lb, the aircraft in landing configuration can climb at the rate of 725 ft/min at sea level, on a standard day, when full power on the four engines is used and an indicated airspeed of 100 kt maintained. To establish a climb from a level attitude on the runway, with take-off power applied for a go-around, and flaps extended 50°, a 5° nose up rotation of the aircraft is required. As the flaps are retracted from the 50° to the 20° position, an additional 3° rotation, or about 8° noseup attitude is required to maintain climb.

The evidence showed no tail skid contact with the runway which proved that the longitudinal attitude of the aircraft was less than 5° nose up at impact. It was therefore concluded that the aircraft was not rotated a sufficient amount to maintain a positive rate of climb during or after the transition of the flaps to the 2° position.

Following the accident the crew stated that the landing gear handle was not placed in the "up" position until after impact had occurred. However contact of the propeller with the ground is impossible with the landing gear extended and locked without prior damage to the gear. Therefore, the Board concluded that the landing gear handle was placed in the "up" position shortly after initial lift-off for the go-around by either the co-pilot or the second officer and that the landing gear was retracting at the time the aircraft settled onto the runway with its Nos. 1 and 2 propellers. Had the gear been in the down and locked position, the aircraft would most probably have bounced off the runway, continued the climbout and little or no damage would have resulted.

At the time of the accident the procedures in effect to be followed for a go-around from a normal approach (gear down, flaps 50°, all engines operating), were set forth in two Company manuals as follows:

DC-6B Airplane Manual 20 July 1954 -

a) Apply full necessary power and attain best climbing speed ...
b) Raise the landing gears.
c) Retract the wing flaps to the 20° take-off position.

Pilots Manual - March 1963 -

1. Apply necessary power and attain best climbing speed ...
2. Retract the wing flaps to the 20° take-off flap position.
3. Raise the landing gear as quickly as possible after obtaining a positive rate of climb.

These company procedures were conflicting regarding the sequence of landing gear and flap retraction.

On 14 November 1963 the Company issued a Flight Operations Memorandum (No. 63-27) to all flight personnel, which changed the duties of the first officer (co-pilot) and the second officer with respect to throttle handling during take-off and gear retraction and extension for take-off and landing. The memorandum read, in part.

"4. Throttle Handling During Take-off

In application of power during take-off, the second officer instead of the first officer will follow up on the right-hand set of throttles (or left-hand throttles if the airplane is being flown from the right) and will make the final adjustment and setting in accordance with the command received ...

5. Gear Retraction and Extension

Hereafter, the retraction and extension of the landing gear will be handled by the first officer instead of the second officer ...

Note: Until the flight crews become accustomed to the changes in procedure in items Nos. 4 and 5, the captain should brief his crew prior to take-off that -

a) the second officer on command will set power; and

b) the first officer on command will retract and extend gear."

Although this memorandum was quite recent and the crew was operating together for the first time the pilot-in-command dit not brief his crew regarding these changes.

A lack of crew co-ordination and understanding concerning the procedures had probably occurred as shown by the fact that the co-pilot assumed the duties of the second officer during the go-around by placing the rpm control forward prior to retracting the flaps to 20°.

2. 2 Conclusions

Findings

The crew were well qualified and experienced. A check pilot was abroad to requalify the pilot-in-command for the route as it was the latter's first trip as pilot-in-command since June 1960.

The aircraft was airworthy and its gross weight and centre of gravity were within the permissible limits at the time of the accident.

The crew were well briefed regarding the weather conditions to be expected at Los Angeles. However, the visibility (1/2 mile) and the RVR value (5 000 ft), which were transmitted to the flight were not actually the conditions that the aircraft encountered when landing. Beyond the approach ent of the runway there existed fog-induced non-homogeneous conditions. The pilot's actual visual range probably varied from 5 000 ft, to near zero in patches of fog. However, the weather conditions warranted continuation of the approach to touchdown and permitted the landing. According to the crew, touch-down took place about 1 000 ft beyond the runway threshold. Calculations made following the accident showed that the actual touchdown was made between 2 000 and 2 400 ft beyond the threshold.

It was determined that at impact the longitudinal attitude of the aicraft was less than 5° nose up and that the aircraft was not rotated sufficiently to maintain a positive rate of climb during or after the transition of the flaps to the 20° position. According to the crew landing gear retraction was not called for, and the landing gear handle was not put in the up position until after impact. Since propeller contact with the ground could not be possible with the landing gear extended and locked without prior damage to the gear, it was concluded that the landing gear handle was, in fact, placed in the retracted position shortly after initial lift-off for the go-around by either the co-pilot or second officer.

At the time of the accident there were in effect conflicting Company procedures regarding the sequence of landing gear and flap retraction during go-around. A lack of crew co-ordination and understanding may have existed concerning these procedures. Although the crew members were flying together for the first time and some of the respective duties of the co-pilot and the second officer were recently interchanged, the pilot-in-command failed to brief them prior to the subject flight regarding their duties.

Cause or
Probable cause(s)

The probable cause of this accident was the failure of the pilot to maintain a positive rate of climb and the premature retraction of the landing gear during a go-around in fog conditions.

3. Recommendations

Following the Eastern Air Lines DC-7B, N 815D, accident at Idlewild International Airport, New York, U.S.A. on 30 November 1962*, it was recommended that:

1. The Air Traffic Control procedures require the transmission of all operationally significant weather information in terminal areas to approaching aircraft. The FAA by letter dated January 8, 1963, stated that the necessary procedural changes were being prepared.

2. An alternative method be developed to determine runway visibility when the RVR is inoperative. This was to be accomplished by utilizing runway observers certificated by the Weather Bureau. The Weather Bureau indicated concurrence with the recommendation on January 8, 1963. On January 14, 1963, the FAA stated that this procedure would be implemented on a trial basis in New York, Chicago, and Los Angeles.

3. The Weather Bureau amend their methods of observing and reporting prevailing weather where "partial obscurations" are present. The Weather Bureau indicated concurrence with this recommendation on January 8, 1963.

4. The "Remarks" portion of weather reports be broadcast to aircraft. The FAA informed the Board that a priority project had been initiated to standardize the transmission of weather information from ATC facilities to airmen in flight.

5. The RVR instrumentation in the recently commissioned IFR room of the Idlewild Tower was inadequate. Also, the Board requested a study of the physical arrangement in all towers where PAR is installed. On January 11 1963, the FAA stated that corrective action was being taken and that a new programme would permit installation of five RVR indicators in a tower facility.

Both the Board and the Administrator are aware of the possible detriments to take-off and landing caused by unreported weather phenomena such as the thick patches of fog encountered by WAL Flight 221 after touchdown. It is recognized that non-homogeneous fog conditions when existing beyond an RVR installation or outside of the sphere of visual observation points used for determining prevailing visibility can, under the present methods of measuring visibility, remain unreported. However, as outlined in the FAA Advisory Circular ACC 00-13A, effective February 24, 1964, plans are now in effect to improve the "state of the art" in these areas. It is anticipated that in the future one or more additional transmissometers may be located on other portions of the runway for the purpose of providing more representative reports.

*Note by ICAO Secretariat: See ICAO Circular 71-AN/63 Aircraft Accident Digest No. 14, Summary 23, pages 85 to 90 inclusive.

Moreover, on airports equipped with one or more RVR installations, a ten-minute mean of RVR values of all runways reporting RVR is contained in the hourly weather sequence reports. This is shown on the sequence report as a Visual Range and is given in feet. This value does not pertain to, nor control operations on any individual runway but is given as an information item to assist in the overall appraisal of airport conditions. It is anticipated that the highest and the lowest one-minute value recorded during this period will also be given, together with the ten minute average.

Also, it is planned that RVR equipment will serve all runways equipped with an instrument landing system, and take-off runways where deemed necessary. All presently installed Runway Visibility Systems will be converted to Runway Visual Range Systems as soon as computers and digital readout equipment become available.

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ICAO Ref: AR/813

No. 16

Philippines Air Lines DC-3C, PI-C489, accident at Mt. Boca, Sitio Kiniledan, Philippines, on 2 March 1963. Report released by the Philippine Aircraft Accident Investigation Board on 7 July 1966.

1. Investigation

1.1 History of the flight

Flight 984 was on a scheduled domestic flight from Zamboanga to Davao, with an intermediate stop at Cotabato. It departed Cotabato at 0940 hours, with a crew of three and twenty-four passengers, estimating Davao at 1025 hours. At 1002 hours the flight reported to the Company radio station at Cotabato that it was halfway to Davao, at Flight level 60, descending. Later on, it contacted the Company radio station at Davao and requested the Davao weather. After having received weather information the flight advised that its arrival would be delayed on account of bad weather. No aircraft difficulty was reported and this was the last message from the flight. When the aircraft failed to arrive, 30 minutes after its ETA a search was started. The aircraft was subsequently found on Mt. Boca, approximately 50 miles SE of Davao Airport, where it had crashed at an altitude of 3 000 ft around 1130 hours.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	3	24	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

None reported.

1.5 Crew information

The pilot-in-command held a valid Airline Transport Pilot's Licence rated for the DC-3C; his last proficiency check took place on 22 February 1962. His medical certificate, Class 1, was current without waivers. He had flown a total of 10 320 hours, including 6 500 on DC-3C. He had been flying on the same route for almost nine years, five of which were as DC-3C and Otter pilot-in-command; and was very familiar with the route and with the prevailing weather conditions.

The co-pilot held a Commercial Pilot's Licence with a DC-3C rating, and had a total flight time of 870 hours. His medical certificate was current with no waivers

1.6 Aircraft information

The past history and records of the aircraft disclosed nothing of an unusual nature. No malfunction was reported by the pilot at Cotabato. It was testified that at the time of take-off from Cotabato the aircraft was airworthy and that its gross weight and center of gravity were within the prescribed limits. The type of fuel used was not mentioned in the report.

1.7 Weather information

Weather en-route was not furnished to the pilot, since this was the first flight of the day on the Cotabato-Davao segment and that the only source of information on en-route weather in that area was weather reports by pilots.

The Company radio operator at Davao testified that the prevailing weather over the area was:

500 to 1 000 ft overcast, visibility 1 to 2 miles, wind 5 to 8 kt, altimeter setting 29.94 in Hg.

1.8 Aids to navigation

Not mentioned in the report.

1.9 Communications

Communications with the Company radio stations were normal until just prior to the time of the accident.

1.10 Aerodrome and ground facilities

Not of significance.

1.11 Flight recorders

No mention of flight recorders was made in the report.

1.12 Wreckage

See 2.1.

1.13 Fire

No fire took place.

1.14 Survival aspects

All aboard were fatally injured at impact.

1.15 Tests and research

No information in this respect was contained in the report.

1.16 NIL

2. Analysis and Conclusions

2.1 Analysis

The aircraft was on a heading of 030° approaching the shoreline of Digos when it hit tree tops, both wings separated and finally the aircraft crashed in an upside down attitude after hitting a tree, three feet in diameter. The landing gear was down and locked at the time of impact and engines were developing power. The Board believed that the pilot was not flying at normal cruising power on account of the bad weather.

The probable flight path of the flight was reconstructed. It was believed that the aircraft had drifted inland due to the easterly 8 - 12 kt wind. When the pilot asked for Davao weather, he probably believed that he was over Digos shoreline, however, he was 3-miles off the route in poor visibility and approximately 5-miles inland of Digos when he started his descent. The Board believed that the pilot having flown that route for almost nine years was too confident of his position without necessarily taking into account the existing crosswind.

2.2 Conclusions

Findings

The aircraft and flight crews were properly certificated.

There was no evidence that the aircraft was not in an airworthy condition prior to the accident.

The pilot did not report any operational difficulty en-route, except the weather.

The Manifest showed that the aircraft's weight and balance were within the approved limits.

The visibility over the area was one mile, with easterly wind at 8 - 12 kt, overcast.

The flight crew and passengers died instantaneously.

The aircraft was destroyed.

Cause or
Probable cause(s)

The probable cause of the accident was due to navigational error, en-route and during let-down. Contributory factors were the limited visibility and the crosswind, all existing on the final phase of the flight.

3. Recommendations

The Board recommended that an Air Traffic Control Service be established in Davao Airport; and that in the interim, all airline pilots be enjoined to strictly adhere with the established let-down procedure when the weather is IMC.

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ICAO Ref: AR/906

No. 17

ITAVIA Airline Company, Douglas DC-3, I-TAVI, crashed into mountainous terrain south of Rome, Italy on 30 March 1963. Report released by the Directorate of Civil Aviation, Italy (undated)

1. Investigation

1.1 History of the flight

Flight IT 703 was a scheduled domestic flight from Pescara Airport to Rome/Ciampino. The aircraft which had departed Rome at 1526 hours GMT, took off from Pescara with the same crew at 1736 hours on an IFR plan and climbed to flight level 100, its cruising altitude. At 1739 hours the pilot requested radar guidance from the Pescara defence radar "FIONDA", which is not normally available for flight information service to civil aircraft. The first part of the flight was intentionally carried out south of the direct route to avoid heavy cloud formations.

At 1750 hours the Pescara defence radar picked up the flight in the Ortona area and at approximately 1803 hours it passed to the flight "QDM Ciampino 265°, distance 80 NM". At 1805 hours the pilot reported this position to the Rome ACC/FIC. After having directed the flight around some cumulo-nimbus the Pescara defence radar lost the aircraft at 1812 hours.

At 1816 hours the pilot enquired whether the aircraft had been picked up by the Rome surveillance radar. Two minutes later he reported to Rome ACC/FIC that he was crossing the eastern edge of airway A 14 and requested a clearance to Rome NDB "LJ".

At 1822 hours he reported having Rome in sight and requested authorization to descend from flight level 100. Two minutes later, upon confirmation that Rome was in sight, the flight was cleared to proceed to Rome NDB and to descend to 6 000 ft. At 1828 hours the pilot reconfirmed that he had Rome in sight and requested clearance to descend further. The flight was then given instruction to contact Ciampino tower, but was unable to establish communication either on the tower frequency or on 120.1 or 124.1 Mc/s and therefore came back on the Rome ACC/FIC frequency. At 1830 hours the pilot reported that he was unable to tune on Rome NDB and had to keep out of the clouds since his radio compass was not working properly. At that time the Rome 2 defence radar which had first picked up the flight around 1802 hours, lost its trace in the Arpino area. Around 1832 hours, on a request from Rome ACC/FIC, the pilot reported that he was in the vicinity of Mount Cavo, of which he could see the antennae. One minute later the flight lost visual contact with the ground and, since the pilot believed that his radio compass was out of order, he requested clearance to proceed on Ostia VOR. At 1835 hours he was cleared to Ostia VOR at 6 000 ft, but reported that his VOR was not giving reliable information and that he would fly on a heading of 270° and break over the sea. This was the last message of the aircraft.

The aircraft was subsequently found on a very steep slope on the southeast side of Mount Serra Alta at an elevation of 1 630 m.

The accident occurred around 1837 hours.

1.2 Injury to persons

Injuries	Crew	Passengers	Others
Fatal	3	5	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was completely destroyed.

1.4 Other damage

None reported.

1.5 Crew information

The crew consisted of a pilot-in-command, a co-pilot and a trainee steward.

The pilot-in-command held a valid airline transport pilot licence with numerous type rating including one for DC-3 and instruments and night flying qualifications. His last medical examination took place on 4 January 1963. He had a total of 10 731 flying hours, 2 296 of these being on DC-3 aircraft. He had flown a total of 85 hours during the 30 days prior to the accident and of 17 hours during the 7 days prior to the accident.

The co-pilot held a valid airline transport pilot licence with a rating for DC-3, and his last medical examination took place on 5 February 1963. His total flying time was 832 hours, including 134 hours during the last three months, all of them on DC-3 aircraft.

1.6 Aircraft information

The aircraft had a certificate of airworthiness valid until 2 August 1963. It had flown a total of 13 941 hours, including 244 hours since its last overhaul. The engine total times were 8 734 and 4 414 hours, including 244 and 942 hours respectively since their last overhaul.

The aircraft was equipped with an ADF receiver and indicator, a VHF/VOR-ILS receiver and indicator, and a VOR radial selector (OBS). Within 10 days prior to the accident the OBS and the ADF receiver were replaced and the ADF timing scale had been aligned.

At the time of the accident, the computed weight and centre of gravity position were within specified limits.

The type of fuel used was not indicated in the report.

1.7 Meteorological information

The weather situation over Italy at 1800 hours Z on 30 March 1963 was:

a) At ground level:

A large depression extended from Southern England to Central Europe and Italy with two main lows over the Gulf of Genova and the Venetian region. Masses of cold air moving in from the Rhone Valley and the Gulf of Lyons had invaded the Italian peninsula. The main cold front which constituted the front edge of this cold air invasion extended at 1800 hours GMT from Venice along the Adriatic to Lecce and was moving from the west toward the east. The frontal cold mass was very unstable with extensive masses of heavy cumulus and cumulo-nimbus accompanied by rain storms and snowfall on high ground above 5 000 ft. At 1800 hours GMT a secondary cold front was taking shape from the upper Tyrrhenian to the Eastern Coast of Sardinia and Tunisia, which was also moving in an easterly direction.

b) Situation at 5 000 and 10 000 ft levels:

Vast regular depression with low point over Lombardy. Currents from NW over Gulf of Lyons, Genova, Corsica, 30 - 40 kts.
Westerly winds 30 - 40 kts over Sardinia, the middle and lower Tyrrhenian.
SW currents 30 - 40 kts over middle and lower Adriatic.

The weather forecast for the Rome - Pescara route as supplied to the pilot-in-command before take-off from Rome was:

- Sky very cloudy, locally overcast:

  Low clouds: 3/8 to 5/8 stratocumulus: base 1 500 - 2 000 ft, top 5 000 - 7 000 ft; 2/8 to 4/8 cumulus: base 1 500 - 2 000 ft, top 12 000 - 14 000 ft

  Middle clouds: 3/8 to 5/8 altocumulus and altostratus: base 10 000 ft, top 14 000 - 16 000 ft; isolated cumulonimbus, top 21 000 ft

- Moderate turbulence and icing conditions along entire route; strong turbulence and heavy icing conditions in heap clouds

- Freezing level: 5 000 ft

- Surface visibility: 10 km

- Upper winds: 5 000 ft 220°/25 kt
  10 000 ft 240°/40 kt

Weather conditions at the time and site of accident were:

Cloud cover: 6/8 stratocumulus and cumulus: base about 3 000 ft, top estimated at 8 000 - 9 000 ft

Light steady rain in area towards west with possibility of local thunderstorms

Surface wind	200°/10 - 15 kt
Wind at 3 000 ft:	260°/25 kt
Wind at 6 000 ft:	260°/35 - 40 kt
Wind at 10 000 ft:	260°/40 kt

Temperature and dew point:

3 000 ft	4°C	1°C
6 000 ft	-3°C	-6°C
10 000 ft	-9°C	-16°C

Surface visibility: 10 km

Upper air visibility, outside of cloud: good

Risk of turbulence due to terrain features and thunderstorms in the area

General risk of light icing conditions within cloud from 5 000 ft to 10 000 ft

No information regarding the weather was requested at Pescara, however, the pilot-in-command was aware of the weather conditions along the route because he had flown the route Rome - Pescara a few hours before and had exchanged information with the pilot of another flight en-route from Pescara to Fongia.

1.8 Aids to navigation

The radio aids to navigation along the Pescara - Rome route included four VOR's (Ostia, Bolsena, Teano and Ancona), seven NDB's (Bolsena, Teano, Frosinone, Rome, Bracciano, Ciampino and Guidonia), Rome surveillance radar, Rome defence radar, Brindisi defence radar, and VDF's at Mounts Silvano and Guarcino. Ciampino Airport instrument approach aids are ILS, GCA, VDF/APP and an NDB at Pratica di Mare for missed approaches. From the time of departure to the time of accident, no report of unsatisfactory performance was received for those aids.

1.9 Communications

The radio communications between the aircraft and the ground stations were satisfactory except that contacts with FIC Rome were made on the military control frequency 122.1 Mc/s instead of on frequencies 120.1 and 124.1 specified for traffic entering the Rome Terminal Area, because of communication difficulties on the appropriate frequencies as reported by the pilot.

1.10 Aerodrome and ground facilities

Not pertinent to the accident.

1.11 Flight recorders

Not mentioned in the report.

1.12 Wreckage

The accident site was located at 70 m from the mountain crest, which at this point reached an altitude of 1 670 m. The wreckage was lying on the snow in a limited area with the axis of the fuselage oriented 282° and the nose of the aircraft pointing towards the mountain crest (See Figure 17).

The forward and central part of the fuselage was destroyed together with the left wing. The aft part of the fuselage and the tail assembly appeared to be intact.

1.13 Fire

The left fuel tank was smashed on impact and the escaping fuel caught fire. The fire completely destroyed the central part of the fuselage.

1.14 Survival aspects

Due to adverse weather conditions and terrain difficulties the accident site was reached three days after the accident.

1.15 Tests and research

Tests were made of the altimeter, the elapsed time clock, and the VOR Omni-Bearing Selector in the aircraft. The altimeter was set at 1 013.2 mb, the clock indicated 1 hour 4 minutes and the magnetic heading was between 269° and 270°.

2. Analysis and conclusions

2.1 Analysis

Evidence at the accident site indicated that the aircraft was flying at a heading of approximately 300° in a nearly straight and level altitude and that it was converging with the slope of the mountain at an angle of approximately 60°. The left wing and propeller struck first some trees; the propeller became detached, the wing was bent backward and its tip together with the aileron broke off and was found 15 m to the left of the main wreckage. This swung the aircraft anticlockwise, the fuselage struck some trees, came into contact with the ground and was deflected upward by the slope to finally come to a halt on a large stump. The right side burst open and the bodies of the passengers were thrown outside.

At the same time the right wing was stopped by a large tree.

No evidence of damage or failure of the aircraft or its engine prior to impact were found.

The autopsy did not reveal any evidence of incapacitation of the crew.

Negligence in the preparation of the flight was found: no weather information was requested at Pescara before departure and the flight plan did not take into account the winds and the minimum safety altitudes requested for obstacle clearance along the planned route. However, the pilot-in-command was aware of the weather along the route because he had flown the route Rome - Pescara a few hours before and also had exchanged weather information with the pilot of another flight.

The Board considered that the following psychological factors might have played a role in the decision of the pilot to carry out this flight in spite of the very bad weather conditions and the late hour:

- overconfidence in his abilities supported by the fact that he was very familiar with this route
- the fact that he was chief pilot-instructor of the airline
- the fact that the Vice-President of the airline was a passenger.

After take-off, the pilot intentionally departed from the flight plan and flew south of the approved direct route Pescara - Rome (See Figure 18). He, however, failed to report this change to the appropriate ATC units. During the first part of the flight, he received radar assistance from Pescara defence radar and was therefore able to circumnavigate cumulo-nimbus which were numerous at the time. At 1803 Pescara radar gave him a fix, and he reported accordingly to Rome ACC/FIC. This was the only accurate position report, all subsequent position reports and estimated time of arrival to reporting points were either incomplete or erroneous. The fact that the pilot enquired at 1816 hours if Rome had radar contact with him and reported at 1818 hours that he was crossing airway A 14 indicated that he believed being far more to the north-west than he really was. Furthermore, if he had been aware of his exact position he would never have requested, four minutes later, clearance to descend, as there were several peaks above 6 600 ft in the area.

An examination of the flight positions recorded by Rome 2 defence radar led to the conclusion that when the pilot reported seeing the lights of Rome and shortly after the Mount Cavo antennae, he actually was in the Arpino-Frosinone-Sora area and probably mistook the lights of Sora, or Frosinone, for those of Rome and the Mount Favone antennae for those of Mount Cavo. This erroneous estimate of his position made him believe that his radio compass was out of order, when he was unable to tune on Rome NDB "LJ". In fact, he was probably out of range to receive the radio beacon signals, especially with the presence of cumulo-nimbus in the area. The Rome surveillance radar was not able to pick up the aircraft that far away because of the weather conditions and the terrain. The unreliable indication given by the Ostia VOR, as reported by the pilot, might be explained by the fact that the aircraft was flying at low altitude over mountainous terrain. Furthermore, as the pilot reported that his instruments were only partly efficient due to flight conditions, it was concluded that after having lost the assistance of Pescara radar he ran into clouds and heavy turbulence and had difficulties in maintaining the aircraft altitude and route. No reasons were found to explain why the crew failed to request the assistance of the VDF stations available at Mounts Silvano and Guarcino and of Rome 2 defence radar. Whether the crew deliberately neglected such assistance or were unable to do so could not be determined. Fatigue was also considered as a possible contributing factor in this accident.

2.2 Conclusions

Findings

Both pilots were properly certificated and qualified for the route. The pilot-in-command had a large experience of the route.

The aircraft had a valid certificate of airworthiness and at the time of the accident its gross weight and centre of gravity were within the specified limits.

The weather along the route was particularly bad with strong head winds and numerous cumulo-nimbus clouds. No weather information was requested at Pescara, however, the pilot-in-command was well aware of the situation as he had flown the route Rome-Pescara a few hours before and had discussed the weather with the pilot of another flight.

No evidence of damage or failure of the aircraft or its engines prior to impact were found.

After take-off the flight intentionally departed from the flight plan and flew south of the approved direct route Pescara-Rome without reporting so to ATC.

During the first portion of the route, the flight, which was receiving assistance from Pescara defence radar, was able to circum navigate heavy cumulo-nimbus and was given a fix at 1803 hours QDM Ciampino 265°, distance 80 NM. This was the only accurate position report passed by the flight to Rome ACC/FIC.

When Pescara defence radar lost the aircraft at 1812 hours the aircraft probably ran into clouds and heavy turbulence and the pilot had difficulties in flying the aircraft and navigating. Estimating his position far more north-west than he actually was, he started to descend in a region of high peaks and crashed on the south-east side of Mount Serra Alta at an altitude of 1 630 m.

Assistance of two VDFs and of Rome 2 defence radar available along the route were not requested.

Cause or Probable cause(s)

1. Significant errors by the pilot in estimating his own position with consequent presumed identification of lights in the Rome area and of the Mount Cavo antennae, which led him to:

   a) misjudge the effectiveness of the aircraft radio and navigational equipment;

   b) request clearance to descend to 6 000 ft and subsequently below the specified level in order to maintain at all costs visual contact with the ground, with the result that he crashed into the mountain because of inability to achieve the desired visual contact.

2. Particularly adverse weather conditions over the last segment of the route flown at night.

3. Failure to report to the various ATC units the departures from the flight route indicated in the PLN submitted prior to departure and in the subsequent PLN transmitted by the pilot after departure.

4. Added to the above, the unfortunate concurrence of a series of facts and circumstances that all played against the pilot.

3. Recommendations

1. As regards the ITAVIA Airline Company:

   a) pending completion of the replacement programme of DC-3's with other aircraft, DC-3's and aircraft of similar type should be used on the Rome - Pescara route with some caution in view of the terrain features along this route and the violent thunderstorms frequently encountered;

   b) every effort should be made to modernize and improve the efficiency of their flight operations organization, flight planning, study of routes and efficiency of station operations at various stopping points;

   c) the attention of their pilots should be drawn to the need for:

      i) early reporting of any change in the current flight plan to the ATC units concerned,

      ii) utilization of all available aids, regardless of weather conditions.

2. While recognizing that radar information service (recently established on a trial basis and proved to be very useful) is strictly limited to providing information to pilots who request assistance, and therefore is quite separate from ATC services, nevertheless it would be highly desirable to expedite studies to achieve optimum co-ordination between the radar units selected to provide this information service and the ATC units, and to establish the necessary procedures for rapid communications between these services.

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ICAO Ref: AR/891

ACCIDENT TO DC-3, I-TAVI, OF ITAVIA AIRLINE COMPANY, SOUTH OF ROME, ITALY. 30 MARCH 1963

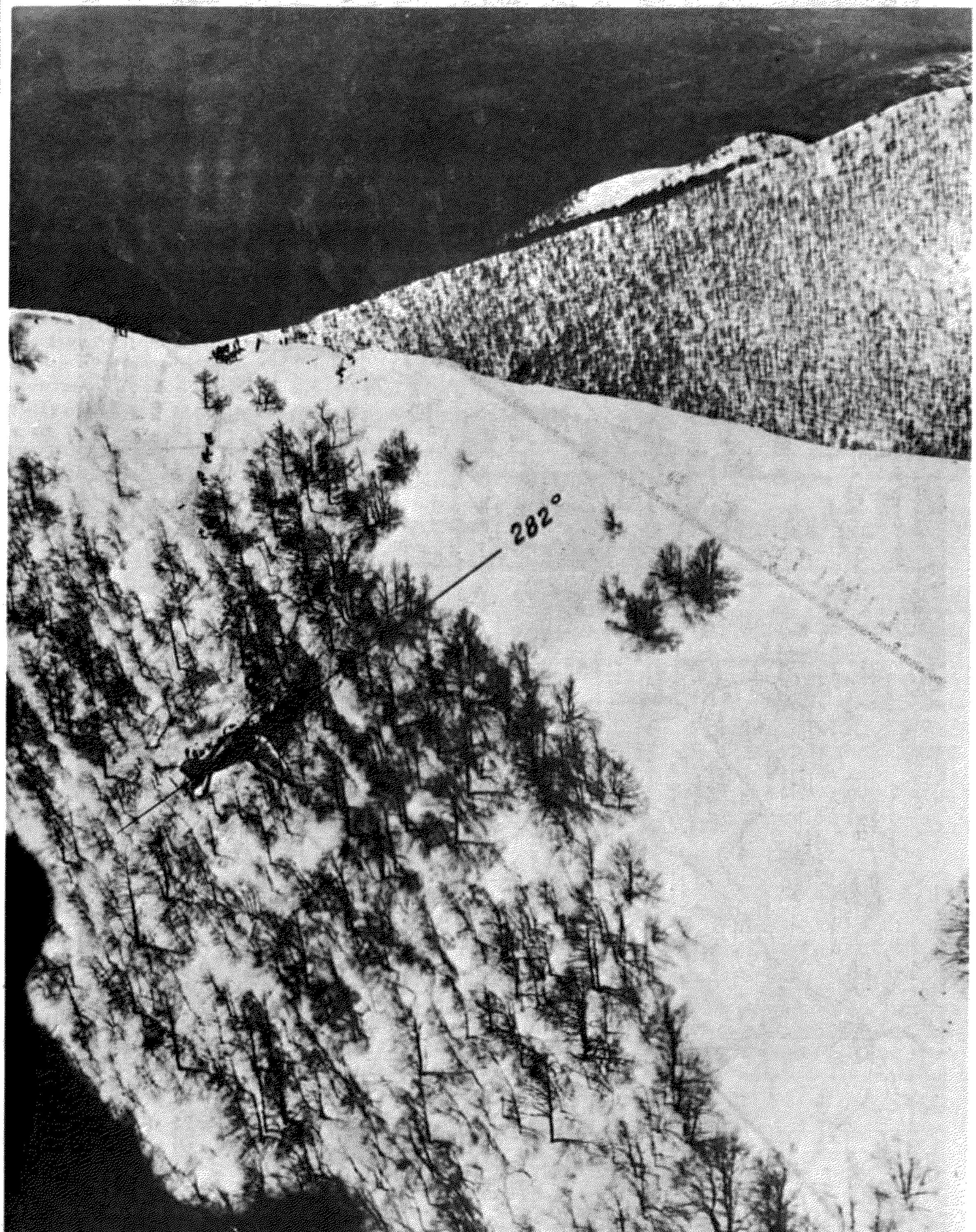

FIGURE 17

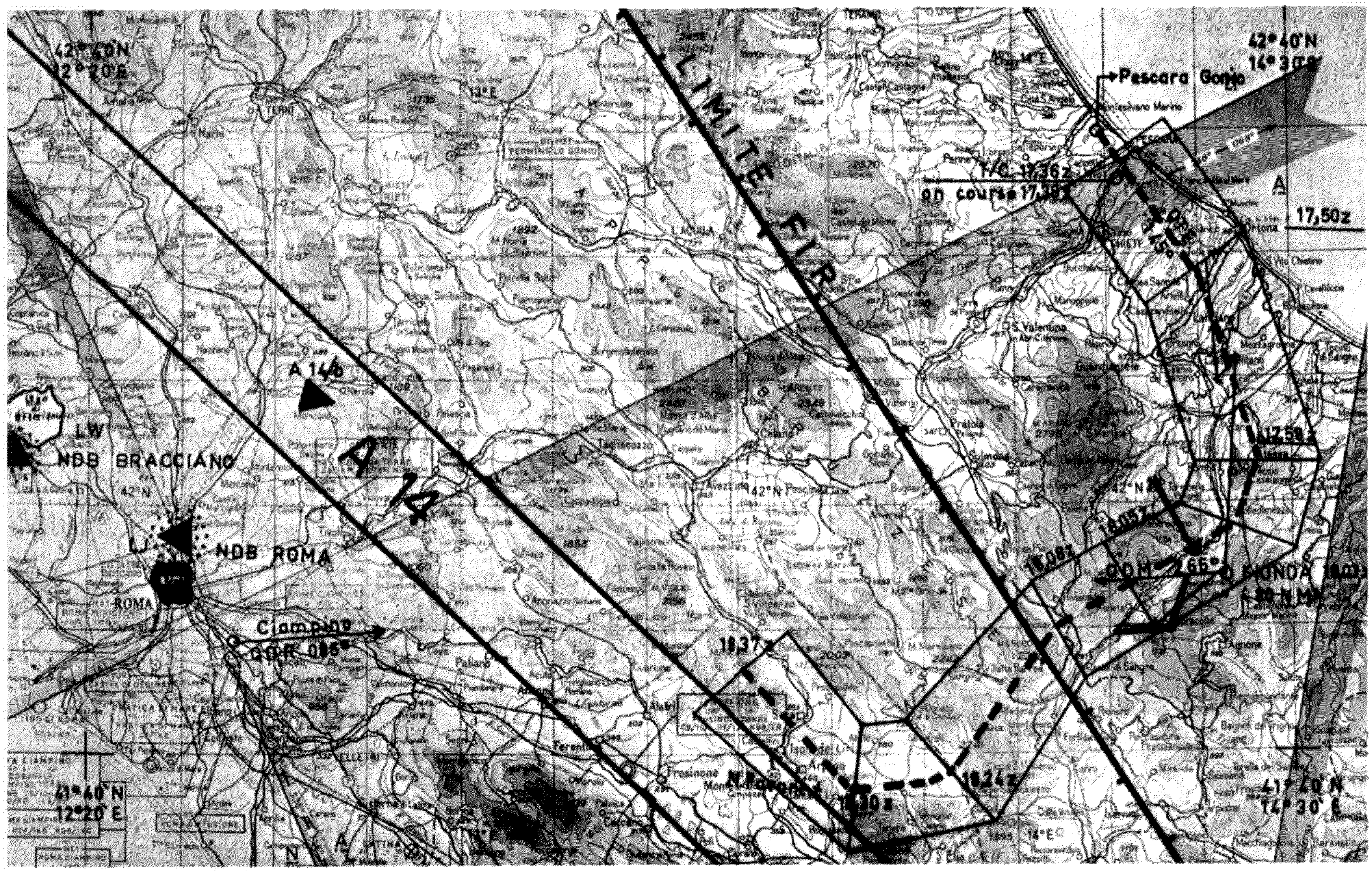
42°40'N
12°20'E
42°40'N
14°30'E
41°40'N
12°20'E
41°40'N
14°30'E
Pescara Gonio
T/O 17,36z
on course 17,38z
17,50z
17,58z
18,05z
18,08z
18,37z
18,24z
LIMITE FIR
A 14
A 14b
NDB BRACCIANO
NDB ROMA
ROMA
Ciampino QDR 085°
QDM 265°
RIONDA
30 NM
TERNI
L'AQUILA
CHIETI
Ortona
Guardiagrele
Pratola
Sulmona
Celano
Avezzano
Frosinone
VELLETRI
LATINA
Tivoli
Tagliacozzo
S.Valentino

FIGURE 18

No. 18

Indian Airlines Corporation, Hiper DC-3, VT-AUL, accident near Pathankot, India, on 3 June 1963. Report released by the Indian Ministry of Civil Aviation on 30 September 1964.

1. Investigation

1.1 History of the flight

The aircraft was on a scheduled domestic flight from Amritsar to Srinagar. It took off at 1115 hours (local time) with 29 persons on board and 7 minutes later it reported its position, 25 miles from Amritsar. No further communication was received from the aircraft. Shortly after 1200 hours a report was received by telephone at Amritsar, stating that the aircraft had crashed in a field near the Sarna railway station, about five miles from Pathankot. The crash took place at a point where the aircraft had to make a left turn of 70° to proceed on its normal course to Srinagar. Eyewitness evidence indicates that the aircraft made a left turn, went out of control and lost height rapidly. It then attained a climbing attitude, broke up and crashed to the ground, catching fire on impact.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	25	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

None reported.

1.5 Crew information

The pilot-in-command and the co-pilot each had considerable experience, the first had flown 2 700 hours as pilot-in-command on DC-3's and the second 4 000 hours as co-pilot on DC-3's. However, neither had had much experience with the Hiper DC-3; during the past six months the pilot-in-command had flown Hiper DC-3's for less than 16 hours, and the co-pilot for 51 hours. Both pilots had flown the subject aircraft on 1, 2 and 3 June.

Although impact and fire had totally destroyed and consumed the bodies so that positive identification was impossible, there was evidence to indicate that the co-pilot was flying the aircraft from the left seat.

Note: Other information on the crew was contained in an Appendix to the report, but the Appendices were not received by ICAO.

1.6 Aircraft information

VT-AUL originally was a C-47 manufactured in 1944. In 1956 it was converted into a Hiper Dakota, the main changes being the installation of more powerful engines (Pratt & Whitney R-2000-D 5), of a geared rudder trim tab (servo trim tab), and bungee springs to the rudder controls. The purpose of the geared rudder trim tab was to reduce the rudder forces to be applied at minimum control speed on one engine. This increased the tendency to rudder force reversal or rudder lock, which was already existing on normal DC-3. To correct this the conversion also included installation of bungee springs to the rudder controls. There was evidence that these bungee springs were neither installed assymetrically as specified in the drawings provided for the conversion nor rigged strictly in accordance with specifications and that this was not corrected during subsequent overhauls. The auto-pilot was a Jack & Heintz A-3A type. There was a placard on the instrument panel prohibiting the use of the auto-pilot and a second placard, affixed in December 1961, stated:

> "Possible sudden force reversal and/or sudden lock may be experienced in this aircraft if sudden application is not co-ordinated with lateral control. Avoid yawed flight."

The aircraft had a Certificate of Airworthiness valid until 21 January 1964. The last 200-hour check took place on 18 May 1963.

The all-up weight of the aircraft was within the permissible limit. No information about the centre of gravity position was available.

The type of fuel used was not mentioned in the report.

1.7 Meteorological information

There was no turbulence. Windspeeds were low - 3 to 4 kt at lower levels, 10 to 15 kt between 5 000 - 10 000 feet altitudes. Visibility was good and there was no cloud.

1.8 Aids to navigation

Not pertinent.

1.9 Communications

Communications were normal until 1123 hours, the time of the last message from the aircraft.

1.10 Aerodrome and ground facilities

Not pertinent.

1.11 Flight records

Not mentioned in the report.

1.12 Wreckage

Fire destroyed the aircraft completely. However, indication of break-up in the air was given by the finding of components of the aircraft lying in a small area north east from the main wreckage. This confirmed that the aircraft was in a left turn before it crashed.

1.13 Fire

Fire occurred after impact, and could not be checked.

1.14 Survival aspects

None.

1.15 Tests and research

None mentioned in the report.

1.16 Auto-pilot

In view of the placard prohibiting the use of the Jack & Heintz auto-pilot enquiries were made regarding the suitability of this auto-pilot on Hiper DC-3. It was confirmed that this type of auto-pilot was considered satisfactory but that each aircraft so fitted should be flight tested after conversion to ensure that the follow-up ratio adjustment of the rudder was correct, otherwise oscillations in yaw might occur. It appeared that this was not done by the operator and therefore the placard was not removed. However, there was evidence that during their conversion to Hiper DC-3, pilots were told that they could use the auto-pilot between 125 and 180 mph and that some pilots did in fact use it although the auto-pilot control was supposed to be wire locked. Several instances of loss of control were reported by pilots, in some cases the aircraft went into a spiral when the pilot engaged or disengaged the auto-pilot. Although the operator was aware of the infringements to the ban and of the resulting incidents no action was taken. Any malfunction or mishandling of the auto-pilot has greater consequences on a Hiper DC-3 than on the normal DC-3, because of the greater sensibility of the rudder installed on the Hiper DC-3.

2. Analysis and conclusions

2.1 Analysis

The aircraft, which was flying at approximately 8 000 feet in excellent weather conditions, went into a spiral to the left at a point of its route where normally a 70° left-hand turn was initiated.

No indication of malfunction or failure of the engines was found.

Ten instances of malfunction were reported before and after the placard regarding the possible rudder force reversal and/or rudder lock was placed in the Hiper aircraft. Pilots had experienced malfunctioning of the rudder and a consequent loss of control both in calm weather and in turbulent conditions. In almost all cases there was no obvious defect or explanation of this malfunctioning. In most of these cases, reports of the incident were made by the pilots and test flights were in some instances carried out without establishing any positive result. In three cases the malfunctioning was experienced while engaging or disengaging the auto-pilot. In other cases, the aircraft was being turned when the rudder lock or reversal occurred. The malfunctioning might have resulted from an uncoordinated turn or from an unanticipated malfunctioning of the auto-pilot which produced conditions leading to loss of control. Flights aimed solely at testing the capacity and functional efficiency of the auto-pilot were never undertaken although the manufacturers and the CAA repeatedly emphasised the absolute necessity of specifically testing the adequacy of the auto-pilot and accomplishing its approval in accordance with the instructions laid down. The recovery was made sometimes by kicking the opposite rudder pedal with considerable force, once by the use of differential engine power but, more frequently, by working the trim tab. The matter was not investigated and no technique for effecting recovery was evolved or recommended nor were steps taken to check the rudder rigging or to investigate the auto-pilot system. Ground tests cannot be accepted as proof of the matching of the auto-pilot system, because of the aerodynamic forces on an aircraft in flight. With more powerful engines and a greater air speed, the follow-up ratios might well need alteration or some other adjustment might become necessary.

According to the evidence, neither the pilot-in-command nor the co-pilot had had any experience of rudder lock or rudder reversal, though they might have heard of it. The pilot-in-command contrary to the categorical directive, occupied the right-hand seat when the aircraft left Amritsar and it may be assumed that during the next half hour he continued to occupy the same seat. It should be noted that from this place he was not in a position to reach easily the rudder trim tab control. It was concluded that when the turn was being effected whether with or without the auto-pilot engaged, the rudder became locked. It is not known what and how soon corrective action to make a recovery was taken, but it proved ineffective. In the course of the rapid descent following the loss of control, speed built up rapidly and during an effort to "pull up" structural failure occurred due to overstressing. The loss of control, was in all probability, due to one or several of the following causes:

(1) The rudder bungee system was not installed correctly and this accentuated the tendency of the rudder to lock or reverse.

(2) The Jack & Heintz A-3A auto-pilot had not been specifically tested for its suitability in this aircraft.

(3) An improper handling or malfunctioning of the auto-pilot at the time of taking the turn might have caused rudder lock.

(4) The pilot might have made an inadvertent yawed turn which caused the rudder to lock and the aircraft to turn sharply to one side.

(5) The fact that neither the pilot-in-command nor the co-pilot had previous experience of this type of malfunctioning might have retarded the process of effecting a recovery. Neither of them might have thought of using differential engine power or operating the trim tab handle and insufficient force was applied to unlock the rudder.

2.2 Conclusions

Findings

The aircraft held a valid Certificate of Airworthiness.

The aircraft loading was within permissible limits though the centre of gravity had not been determined.

The members of the crew held valid licences.

The navigational equipment on board the aircraft was adequate for the flight.

The installation of the rudder control system was improper inasmuch as the bungees were not properly installed and adjusted during the initial rigging and this was not corrected during subsequent overhauls. There was no item relating to the rigging of the bungees or attending to the trim tab in the overhaul schedule and therefore it had probably escaped the attention of the engineers and mechanics carrying out the overhaul.

The pilot and the co-pilot had flown this very aircraft on the 1st, 2nd and 3rd June without experiencing loss of control.

The pilot's seat was occupied not by the pilot-in-command, but by the co-pilot while the pilot-in-command sat on the co-pilot's seat.

The rudder installed on the Hiper Dakota is more sensitive than the one on standard Dakota and it had a greater tendency to lock or reverse in certain conditions.

The Jack & Heintz A-3A auto-pilot which was originally installed on the aircraft before its conversion was not after conversion tested by means of specific test flights. This type of auto-pilot is not being used in the U.S.A. on civil aircraft and in the opinion of the Federal Aviation Agency, approval of this auto-pilot "should be accomplished in accordance with the instructions contained in note 13(g) of FAA Specification A-669." This was not done by the operators.

No proper investigation regarding the question of the suitability of the auto-pilot was made by the operators and although a placard forbidding its use during flight was prominently displayed in the cockpit, pilots continued to disregard this injunction and used the auto-pilot.

Mishandling of the auto-pilot at the time of engaging or disengaging it, uncoordinated turn or a sudden side gust of high intensity can, in the case of Hiper Dakota, cause sudden reversal or rudder lock.

As many as nine previous instances of similar loss of control, though not resulting in an accident, had been experienced and reported by pilots to I.A.C.

The weather at the time of the accident was calm and free from turbulence.

The Department of Civil Aviation did not take the initiative to enquire into the suitability of the auto-pilot and by remaining passive, allowed a curiously anomalous state of affairs to continue whereby despite the tacit approval of the auto-pilot, a placard banning its use continued to be displayed and yet most pilots, disregarding the injunction, brought the auto-pilot into use and even broke the wire-lock when they found that the auto-pilot had been rendered inoperative by this means.

Loss of control was experienced during the course of a turn and structural failure of the aircraft followed in an attempt at recovery.

Cause or
Probable cause(s)

The accident was caused by structural failure of the aircraft in the air following over-stressing as a result of loss of control.

The loss of control was caused by improper rigging of the rudder bungee system which helps to prevent the marked tendency of the rudder of the Hiper Dakota to reverse or lock under conditions of yawed turn and/or on encountering a severe side gust. It is equally likely that malfunctioning or improper operation of the auto-pilot may have initiated a yaw and accentuated the tendency of the rudder to lock.

3. Recommendations

1 If Hipers are to be flown in India, they should be subjected to the tests suggested by the U.S. Federal Aviation Agency, both for the removal of the placard relating to yawed flight and achieving the approval of the Jack & Heintz type of auto-pilot. Until this is done, the widest publicity of the characteristics of the Hiper Dakotas must be given to the pilots after making sure of the proper rigging of the rudder. Also the use of the auto-pilot must be prohibited.

2 The Indian Airlines Corporation's machinery for reporting, tabulating and co-ordinating reports on malfunctioning particularly those relating to incidents involving loss of control of aircraft must be improved and remedial action should be taken promptly. A suggestion during the investigation was made that certain directions were given by the Director General of Civil Aviation as a result of a meeting. These directions must be enlarged and implemented with greater vigour and promptness.

3 The Indian Airlines Corporation should have a proper engineering department, other than its normal maintenance staff, to assess the aerodynamic and structural problems arising out of modifications, evaluate their implications to the operator and suggest practical methods of implementing them.

4 When similar aircraft are used by civil operators and the Air Force, there should be a prompt and reciprocal exchange of information on all significant defects and incidents experienced by each. Steps should be taken to implement this on a high priority.

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ICAO Ref: AR/902

No. 19

Air-Inter Viscount 708 F-BGNV, accident near Lyon/Bron, France on 12 August 1963. Report released by the Ministry of Public Works and Transport, France, on 1 October 1964.

1. Investigation

1.1 History of the flight

Flight IT 2611 was a scheduled domestic flight from Lille to Nice with an intermediate stop at Lyon. It took off from Lille at 1151 hours GMT, on an IFR flight plan. Estimated flying time between Lille and Lyon was 1 hour 21 min., cruising at flight level 150. Until 1300 hours, when it began its descent, the flight had been normal; at 1309:50, it reported to Marseilles Control that it was above Tramoyes at flight level 40, and was cleared to Lyon Approach, which was contacted at approximately 1310:20. The flight was then in position for a direct approach to runway 17. At this point Lyon Control having a Caravelle ready to take off asked the aircraft to hold momentarily over Tramoyes at flight level 30. After having first agreed, the flight reported that it was in a severe storm and requested permission to descend below flight level 25, at 1313 hours. Lyon then cleared the flight for a straight-in approach to runway 17. This was acknowledged by the aircraft. Subsequent calls from Lyon Control were not replied.

The flight was seen by witnesses in the heart of a storm flying very low in an easterly direction around 1320 hours. At 1326 the aircraft was not visible on Satolas Control radar. It was subsequently found that the aircraft had hit trees, the roof of a farmhouse and a telephone pole before crashing into a field, 15 km from Lyon/Bron airport, at an altitude of 300 m (100 metres higher than the airport) at approximately 1319 hours.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	4	11	1
Non fatal		1	2
None			

1.3 Damage to aircraft

The aircraft was totally destroyed.

1.4 Other damage

Material damage was done to a farmhouse, an electrical cable, and crops.

1.5 Crew information

The pilot-in-command, age 38, held a valid airline transport pilot licence. He was qualified as pilot-in-command on Viscount 708 aircraft and had passed a medical examination four months before the accident. He had flown a total of 7,400 hours including 1,125 hours on Viscount 708's and had made 36 landings at Lyon in 1963, 24 of which following instrument approaches.

The co-pilot, age 33, held a commercial pilot licence, with type qualification on Viscount 708's. His medical examination was up-to-date, and he had a total flying time of 5 795 hours. Both pilots had their last airline flight check in March 1963 and their flying activity prior to the accident did not substantiate the possibility of fatigue. The two stewardesses held valid licences.

1.6 Aircraft information

The aircraft's certificate of airworthiness was valid until 8 September 1963. Maintenance of the aircraft had been properly carried out and its weight and centre of gravity were within the prescribed limits, both at take-off and at the time of the accident. The type of fuel being used was not mentioned in the report, but at the time of the accident 2700 litres of fuel were remaining aboard the aircraft.

1.7 Meteorological information

The crew were provided with the following weather forecast at Lille:

At the start of the flight: cloudy 4-5/8 cumulus, 900 m base 1 500 - 1 700 top.

After Dijon: many storms between Dijon and Le-Puy, locally 3 - 5/8 cumulonimbus, base 400 m top 10 000, severe icing in the cumulonimbus, severe turbulence. Wind at 3 000 m. 260°/30 kt as far as Dijon then 20 kt from Dijon to Lyon. Wind at 5 000 m. 250°/40 kt as far as Lyon; 0° isotherm rising from 2 600 to 4 100 m; ground visibility: 10 to 20 km except below thunderstorms, where reduced to 3 or 5 km.

Lyon landing forecast:	Surface wind:	180°/6 kt with occasional gusts to 23 kt
	Visibility:	15 km, occasionally 2 - 5 km
	Weather:	Cloudy, with occasional showers and thunderstorms.
	Clouds:	Lower layer: 2/8 Cb, base 600 m 3/8 Cu, base 750 m occasionally 6/8 Cb, base 300 m higher layer: 7/8 Ac, base 2 700 m occasionally 8/8 Ac, base 2 000 m.

The following weather information were supplied to the control tower by the Lyon MET Office PPI:

1245: - Special radar reports; two bands of thunderstorms, one from Ambert to Pontarlier, the other from Puy-en-Velay to Satolas. Squall towards North-West. Watch for sudden gusts from North-West to North.

1300 or shortly thereafter: - QAN 100°/11 kt - QBA 8 km QNY thunderstorm in South-East and North-West - QBB 7/8 at 1 000 metres, 5/8 at 2 500 metres - QNH 1009 - QFE 985.

1320: - Thunderstorm warning

1345: - QAN 320°/10 kt - QBA 800 metres QNY thunderstorm - QBB 5/8 at 300 metres and 8/8 at 800 metres - QNH 1011 - QFE 987.

The deterioration report (AVB) prepared at 1317 hours was not sent because the tower controller and the telephone were fully occupied with aircraft traffic. The only indication was a simple thunderstorm warning at 1320.

Between 1300 and 1305 hours, the following weather information was transmitted to flight IT 2611 by Lyon approach:

Here is the latest weather report. The wind is rather variable, force 8 knots. Visibility 10 km. Ceiling 4/8 at 1 200 metres, 7/8 above 2 500 metres.

QNH 1010. Pressure at ground level 987. Temperature 22° 8. I would point out that there is definitely going to be a fairly sudden change. There are two bands of thunderstorms, one from North - North-West extending from Ambert to Pontarlier and another in the South from Puy-en-Velay as far as Satolas for the moment. They are cumulonimbus and fairly violent storms.

This was acknowledged by the flight, which soon afterwards indicated that it was running into severe turbulence.

At the time of the accident the Lyon region was affected by a mass of unstable hot, moist air, in the heart of which many storm cells were building up.

The bulk of a thunderstorm which seemed to be moving in a southeasterly direction towards the airfield, finally passed north of it and only the southern portion affected the station. There was a roll cloud and a great deal of lightning at low level: rain shower at 1305 hours, hail at 1315; squall and gust 020°/30 kt at 1317 hours. Certain statements and reports implied that the electrical field was abnormally high near ground level, similarly all reports stressed the very black clouds and dark sky. All the reports mentioned the frequent, intense, electrical phenomena.

Horizontal visibility below the clouds and inside the precipitation was in the order of 500 metres and slant visibility was probably less.

According to the radiosonde estimated height of the cumulonimbus base and top were 800 and 10 000 metres respectively. Underneath the cumulonimbus, appendant pannus clouds developed, and in the centre of the cumulonimbus the pannus adhered to their base to form virtually a single mass.

The intensity of the thundershowers was 58.3 mm/h between 1313 and 1338 at Lyon/Bron. Some of the showers included hail. Hailstones 12 mm in diameter were reported at Montluel (near the site of the accident) between 1315 and 1345 hours.

The temperature shift (squall depression) was as much as -3.2° at Lyon at 1317 hours (from 22.1° to 18.9°). The pressure shift was +2.3 mb at Lyon at 1317 hours. In the centre of the Tramoyes storm the squall depression was estimated at about 3 to 4 mb, a value rarely reached during storms in France.

Witnesses in the Tramoyes region were unanimous in stating that at the time of the accident, the storm was very severe, with rain, wind and hail. At Tramoyes, horizontal visibility was less than 500 metres.

1.8 Aids to navigation

The following aids were available at Lyon/Bron:

An RTF transmitter, frequency 602 kHz located at Tramoyes, at 15 km on the 007° VOR beam from Lyon (FNL). Power at the time of the accident 150 kW.

A locator (BR) frequency 388 kHz, located 6.64 nautical miles (12.300 km) from the end of runway 35 and aligned with the centre line. Power 40 W and rated coverage 35 NM.

A VOR (FNL), frequency 117.4 MHz, located on the aerodrome.

An ILS, (LY), frequency 110.3 and 335 MHz, with three marker beacons. ILS approaches are lined up on 349°.

All those aids were operating normally at the time of the accident. At 1310 hours there was a brief failure of the glide path transmitter caused by the storm.

1.9 Communications

During the Lille-Lyon flight and before the accident, the aircraft had some difficulty in receiving communications from Marseilles Control on 126 MHz; at 1300 - 1301 hours, another aircraft of the same company acted as a temporary relay. After this F-BGNV's communications again became normal. The record shows that, between 1300 and 1305, F-BGNV received and understood a weather report transmitted by Lyon Approach.

1.10 Aerodrome and ground facilities

Not pertinent.

1.11 Flight recorders

Not reported.

1.12 Wreckage

The wreckage of the aircraft was located less than a kilometre away from the Tramoyes (FOL) wireless pylon and nearly 15 km from the beginning of runway 17. The tip of the aircraft's left wing hit a tree and separated from the aircraft; 20 m farther the aircraft hit another tree, bounced on the roof of a farmhouse and disintegrated against a concrete telegraph pole, at a distance of 160 m from the first tree. Impact marks ran in a 110° direction.

1.13 Fire

There was no fire.

1.14 Survival aspects

The alert phase was declared at 1321 hours, the distress phase at 1350 hours. Rescue party reached the wreckage at 1340 hours.

1.15 Tests and research

The panel clock of the aircraft and the co-pilot's watch were sent for expertise to Besançon. It was found that both stopped under a shock at 1323 hours and 1412:36 hours, respectively.

The engines and propellers were sent to the CEP at Saclay for detailed examination. It was concluded that the engines were all operating at the time of impact and that the pitch of the propellers were between 27° and 28°. It was estimated that the power developed by the engines was somewhere between 250 and 620 hp and that the speed of the aircraft at the time of the first impact was 120 kt or less.

The radio electrical equipment was sent to the Air Navigation Technical Service (STNA). It was found that VHF No. 1 was still working after the accident. Although the antenna of VHF No. 2 had been struck by lightning, examination of the valve filament in U.K. revealed that both VHF No. 2 and the radio altimeter were working at the time of impact. After replacement of a valve the radio altimeter was still working with an accuracy of - 10 feet.

Also indication of the RMI did correspond to the heading of the aircraft (110°). It was therefore concluded that no failure of the electric supply did occur prior to impact.

2.1 Analysis

No evidence of damage or failure of the aircraft or its engines prior to the first impact were found. The aircraft was flying in a fairly level attitude with undercarriage retracted and 20° of flaps. The gyrosin reading of 140° was somewhat incorrect but it might have been shifted in the accident.

The heading indicated by the radiocompasses were 080° and 330°, respectively. However, it was not ascertained that this corresponded to the headings indicated in flight in relation to FOL and BR beacons. The storm might have interfered with medium frequency reception and the indication might have been altered as soon as the electrical supply failed during the accident.

The QDM given by No. 2 VOR on the RMI (used to receive Lyon's VOR) was slightly incorrect (172° instead of 194°) but the last phase of the flight was carried out below the limit for normal reception of the VOR. The "left, right" needle on the ILS indicator was over to the left in the normal way. The brief failure of the glide path transmitter recorded at 1310 hours could not have caused any trouble to the crew which were at the time on the reverse QFU, probably using the back beam of the localizer which was operating normally at all times. It was also noted that the pilot-in-command of another aircraft flying at the edge of the storm, had obtained relatively usable bearings from the Tramoyes RTF transmitter.

The Lyon Approach (121.1 MHz) and Marseille Control (126.7 MHz) frequencies were displayed on the No. 2 and No. 1 VHF, respectively. Expert examination showed that despite marks of lightning on No. 2 antenna, the VHFs were in good working order.

Weather conditions were exceptionally bad in the area of the accident. A violent thunderstorm existed at the time with a great deal of low-altitude lightning, rain and hail, and heavy turbulence, the horizontal visibility on the ground being between 0 and 500 m. Although the crew was properly briefed of the weather situation before departing, the Board believed that neither the approach controller nor the pilot-in-command of the aircraft did fully realize that the weather situation was so exceptionally bad in the Tramoyes area when the aircraft reached it.

Even though the weather radar of Lyon/Bron was usually operated on a permanent basis, observations were only intermittent due to shortage of personnel. Furthermore, when cumulonimbus passed over, the radar and power were switched off. Also, except when cloud base and visibility were respectively below 300 m and less than 2 km, QAMs were normally transmitted by the weather station to the control tower on an hourly basis only. This explained why the latest weather report transmitted to the aircraft around 1305 hours was in fact the 1200 hours QAM, supplemented by the 1245 hours special radar observation, why the approach controller did request the aircraft to hold on the FOL beacon and why the pilot-in-command agreed to this request.

From the evidence available the Board concluded that the accident occurred around 1319 hours. However, it was believed that something serious occurred around 1313 hours because, although the VHF equipment of the aircraft was in good working condition no call, or reply to calls, were made after that time and also because the co-pilot's watch received a significant shock at that time. It was also concluded that the aircraft was in slight descent, at a very low altitude (around 100 m) for at least two minutes prior to the accident. Several hypothesis were examined in trying to explain why the crew did not apparently react before hitting the trees.

Loss of control. The Board did not believe that if a loss of control had occurred in heavy turbulence around flight level 40 control of the aircraft would have been regained before hitting the ground.

Deliberate low flying. The pilot-in-command did request at 1312:20 hours permission to descend below flight level 25, which was already below the minimum safe flight altitude. However, the Board considered that should deliberate low flying have been carried out during the last two minutes of the flight, it would have been carried out on a VOR radial leading away from the RTF antenna and not in a west to east direction.

Altimeter error. The QNH at the time of the accident was 1010 mb, one of the altimeters was found in the wreckage at 1011 mb, the other one at 1013 mb. The impact with the first tree occurred at an elevation of 1015 ft. It was found that taking into account all possible errors, the altimeters could have been overestimating the true altitude by a maximum of 100 ft. and 185 ft., respectively. The Board concluded that this could not be sufficient to explain the accident.

Misinterpretation of the altimeter reading. A reading of 1055 ft. or 1110 ft. on a Kollsman three pointers altimeter could not be misinterpreted for a reading of 2000, 2500 or 3000 ft.

The fact that one of the altimeters was still at the QNH setting, instead of being at the QFE setting, was also considered. Had the crew believed that it was set at the QFE, as it should have been, this would have resulted in overestimating the altitude of the aircraft by approximately 670 ft. The Board considered, however, that this would not explain the shock at 1313, the absence of communication after that time and the easterly course during the last two minutes of flight. Furthermore evidence was found that the radio altimeter was working on low altitude scale at the time of impact.

Lack of crew co-ordination. It was determined that the co-pilot was flying the aircraft from the right hand seat and was also assuming the radio communications during the first part of the flight. It was also determined that the pilot-in-command took over the radio communications with Lyon Approach, but whether he also took over control of the aircraft could not be determined. However, the pilot-in-command and the co-pilot having flown 30 hours together during the six months prior to the accident, including 28 take-offs and landings, the Board considered that a lack of crew co-ordination was highly improbable.

Lightning. Evidence was found that the VHF No. 2 antenna of the aircraft had been struck by lightning. Although the electrical supply, the VHFs and the instruments were not damaged, the crew might have been subjected to electrocution or dazzling. Electrocution of both pilots simultaneously was considered as improbable, but the possibility that both pilots had been dazzled by one or more bolts of lightning just in front of them appeared much more probable. Several instances of dazzling with temporary loss of vision, lasting from 30 seconds to several minutes, were quoted at the inquiry.

2.2 Conclusions

Findings

- The crew was properly certificated and fully qualified for the flight;
- The aircraft had been equipped, maintained, loaded and balanced in the usual way and was airworthy. No evidence of damage to or failure of the aircraft structure or systems prior to impact was found and its engines were operating at the time of the accident.
- The exceptionally inclement weather conditions were not fully recognized, both by the approach controller and the pilot-in-command. For this reason the flight was requested and agreed to hold on FOL, in order that a Caravelle might take off from Lyon/Bron. The Board noted that the pilot-in-command of another aircraft, who was in a better position to appreciate the violence of the storm over Tramoyes, received a similar request around the same time, but preferred to hold away from the storm.

Cause or Probable cause(s)

The Board considered:

- that the aircraft would probably have landed safely if it had been able to carry through the approach it had initiated;
- that the accident resulted from the exceptionally bad weather conditions in the area where the aircraft was holding at the request of Lyon Approach.

The Board did not rule out the possibility of a flash of lightning dazzling the crew and causing temporary blindness or appreciably incapacitating both crew members.

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ICAO Ref: AR/897

No. 20

Swissair SE-210 Caravelle HB-ICV, accident at Dürrenäsch (near Zurich/Kloten Airport), Switzerland on 4 September 1963. Report, dated 10 March 1965, released by the Swiss Accident Investigation Commission

1. Investigation

1.1 History of the flight

Flight SR-306 was a scheduled international flight from Zurich to Rome, with an intermediate stop at Geneva. Dense fog was existing at the time of departure and at 0600 hours the flight was informed that the RVR was 180 m for runway 34 and 60 m for runway 16, and that there was a light northerly wind (1 to 2 kt). At 0604 hours the flight was authorized to taxi to runway 34 behind an accompanying vehicle. At 0605 the crew reported that they will taxi half way down runway 34 to inspect the fog condition and then return to take-off position. This was done, using at times considerable engine power probably in an attempt to disperse the fog. Around 0612 hours the aircraft was back to the threshold of runway 34 and permission to take-off was granted. The flight took off at 0613 hours and started to climb to flight level 150, its cruising altitude. (See Figure 19) Four minutes later witnesses on the ground noticed a whitish trail of smoke on the left side of the aircraft and suddenly a long flame from the left wing-root. Around 0620 hours the aircraft reached an altitude of approximately 2 700 m, it then began to loose height, entered a gentle left turn loosing height more rapidly and finally went into a steep dive. Parts of the aircraft became detached and at 0621 hours a "MAYDAY" message was received. At 0622 hours the aircraft crashed into the ground on the outskirts of Dürrenäsch, at an elevation of 559 m, approximately 35 km from Zurich/Kloten Airport.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	6	74	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was destroyed.

1.4 Other damage

Damage to property on the ground was considerable and amounted to "almost 100 000 Swiss francs".

1.5 Crew information

The pilot-in-command, age 39, had a valid airline transport pilot's licence and a total of 7 600 flying hours including 380 hours on Caravelles. He was in good health, with an above-average rating; he had had two days rest before the flight.

The co-pilot, age 39, had also a valid airline transport pilot's licence. He had over 6 000 hours of flying with Swissair, more than 380 hours being on Caravelles. He was in good health, his rating upon retraining for Caravelle was average, and he had had three days rest before the accident.

Qualifications of the four cabin attendants were not mentioned in the report.

1.6 Aircraft information

The certificate of airworthiness of the aircraft was valid until 31 December 1964.

The last 250-hour T check had been carried out on 30 August 1963, around 35 flying hours before the accident. The entries in the relevant documents indicated that the prescribed maintenance and servicing had been carried out at the prescribed times. No major defects or deficiencies had occurred, nor had the aircraft been damaged at any time. A "K-check" and a "V-check" were carried out at Zurich and nothing abnormal was found.

At the time of departure the aircraft's gross weight was 44 635 kg and the centre of gravity was 29.8%, both within the permissible limits.

The type of fuel used was not mentioned in the report.

1.7 Meteorological information

The general meteorological conditions were marked by a high-pressure ridge over Central Europe. The rising warm air increased the cloud formation and extensive fog descended in the early morning. Zurich airport was shrouded in dense fog. Above the fog there were 2/8 Sc at 3 000 m and 4/8 to 6/8 Ci at 7 000 to 8 000 m. An observation station 550 metres from the end of the runway 34 reported the following:

	at 0550 hours	at 0620 hours
runway visual range:	60 m	300 m
vertical visual range:	90 ft	100 ft

The mobile station at the beginning of runway 34 reported a runway visual range of: 210 m at 0500, 180 m at 0600 and 210 m at 0632 hours.

1.8 Aids to navigation

When taking off on runway 34, two beacons (OZ and Rhein) located respectively at 5.5 km and 11 km from the end of the runway, may be used.

1.9 Communications

Communications were normal until 0616 hours approximately; then, after a silence of about 5 min, the emergency call was sent. This was the last message of the aircraft.

1.10 Aerodrome and ground facilities

Runway 34 is 3 700 m long and lights on the edge of the runway are spaced 30 m.

1.11 Flight recorders

The aircraft was equipped with a Fairchild flight recorder. The tape was damaged during the accident, however, most of it was readable.

In the period from 0608:46 to 0611:55, no interruption in the readings of minor speed increases due to vertical acceleration or changes in direction normally associated with the halting of an aircraft were observed. The speeds during this period were occasionally somewhat greater than normal during taxiing operations. The following average speeds were read out:

	distance	speed
- from parking location to runway No. 34	(1 000 m)	10 kt
- taxiing on runway No. 34	(1 450 m)	13 kt
- taxiing back on runway No. 34	(1 800 m)	18.5 kt

Take-off began at 0612:43, lift-off at 0613:25. Other read out of interest were:

0613:45 Changes course to 220 (over outer marker).

:55 Speed increases somewhat irregularly to 202 kt, altitude increases steadily to 6 500 ft above sea level.

0618:31 Speed drops - slowly at first - then increasingly rapidly to 155 kt, altitude increases steadily to 8 600 ft above sea level.

0619:52 Speed increases again towards 175 kt (speed unreadable hereafter). Altitude increases steadily to 8 780 ft above level.

0620:05 Altitude decreases to 8 600 ft above sea level.

0620:43 Vertical acceleration indicates switch-over in electrical current. Altitude decreases more rapidly.

0620:50 At 7 900 ft above sea level (altitude unreadable hereafter).

0621:04 (Emergency message: MAYDAY - MAYDAY)

Acceleration recordings cease (failure of current)

1.12 Wreckage

Following the crash, fragments of the outer locking ring of the tire of No. 4 wheel, a grounding cable complete with connecting cables, a "blow-off" mark, as well as small quantities of hydraulic oil were found on the threshold of runway 34. The track of the aircraft during the take-off run was visible for a distance of approximately 1 600 m from the runway threshold. The "blow-off" mark was found between the tracks of the two pairs of wheels of the left landing gear. After that point traces of hydraulic oil were found at regular intervals of approximately 140 cm over a distance of around 60 m on the left side of the track. Fragments of the tyre of No. 4 wheel were found between 1 350 m and 1 700 m from the threshold of runway 34.

Along the flight path, over a distance of approximately 12 km, a number of parts of the aircraft were found, originating from the left landing gear shaft, the rear portion of the left wing, the lower surface of the fuselage behind the trailing edge and the tail. In the vicinity of the crash site the number of parts increased steadily. Important components of the brake parachute installation were found 5 km from the accident site, those of the bracing of the tail hull 3 km, the left landing flap 2 km, and the tail gangway 1.7 km from the accident site.

The devastation caused by the accident covered a rectangle approximately 400 m by 230 m. About one third along its longitudinal axis, there was a crater 20 m in diameter and about 6 m deep. Most of the wreckage was found at the crash site; remains of passengers and crew were only found at this location. Approximately 90% of the entire aircraft structure was recovered and identified.

1.13 Fire

Further to the initial in-flight fire, a violent fire, which lasted about 2 1/2 hours, broke out at impact.

1.14 Survival aspects

None.

1.15 Tests and research

The fragments of No. 4 wheel's rim flange which were found on the runway, and fragments of No. 3 wheel rim revealed intergranular fracture structure, which could only be duplicated at temperatures of over 250°C. It also revealed deposits of burned hydraulic oil.

Detailed mechanico-technological, metallographic and X-ray examinations of the wheels' body did not reveal defects or flaws. Tire parts were examined, signs of explosion were found on No. 1, 2 and 4 wheels' tires (left landing gear), whereas no sign of explosion were found on No. 5 to 8 wheels' tires (right landing gear).

Braking tests were conducted both on the test bench and during aircraft taxiing. It was found during the bench tests that when the brake discs became white hot, the wheel flange burst off from the whole circumference of the wheel rim with fragments flying off at high speed. The fracture structure was identical in shape and nature (intergranular) to that found on No. 4 wheel. Following the fracture, hydraulic oil leaking from the fractured leads and the tire padding caught fire.

1.16 Fog dispersal method

The following fog dispersal method was contained in paragraph 10.2.7 of the "Flight Training and Flying Procedures SE-210", Training Manual 1st Edition, published by Swissair in November 1961:

"FOG DISPERSAL-TAKE-OFF

If ground fog persists with a runway visibility below the normal take-off minimum of 400 m, fog may be temporarily lifted with the following conditions:

a) Visibility on the runway at least 100 m.

b) Wind speeds less than 3 kts (no obvious drifting of fog).

c) Back track on the runway for at least 1,000 m close to runway edge for take-off, rpm 6,000 - 6,500, brakes smoothly applied to avoid acceleration of aircraft.

d) Stop twice on the way down (1/2 way + 100 m before take-off point), apply 7,000 - 7,500 rpm for 15 sec., reduce power again to 6,000 and start taxiing on.

e) Assistance of ground van inspecting visibility increase is of utmost value.

f) Start take-off as quickly as possible. This fog dispersal procedure will provide a tunnel 40 m wide, 25 feet high, visibility 400 - 800 m, effective for 2 - 5 minutes.

g) Warning: It must be stressed

- that crosswind will close the tunnel again and
- that careful use of brakes is necessary to avoid hot brakes on take-off."

This was deleted from the 2nd Edition of the Training Manual published in November 1962. However the method was mentioned during the retraining course followed by the two pilots of the ill-fated aircraft, from November 1962 to February 1963.

2. Analysis and conclusions

2.1 Analysis

It was determined that the wheel flange of No. 4 wheel split while the aircraft was performing a turn in order to position itself in the take-off direction and that the tire exploded as a direct consequence thereof. The condition of the brake discs and tappets, as well as of the brake shoes, indicated that the brake system had become overheated prior to take-off, as a result of prolonged braking. Tests and calculations showed that such overheating could lead to a wheel fracture of this kind.

At least at the beginning of its outboard run down runway 34 the aircraft was taxiing at a relatively high number of revolutions per minute; the return run showed occasional high rpm and was most likely carried out without any intermediate stops. The pilot-in-command most likely did not use the fog dispersal method but tried to improve runway visibility temporarily by increasing engine power without stopping.

It was considered that deliberate braking by the pilot-in-command most probably caused the overheating of the brakes. Whether intentional or accidental braking caused any additional effects, was not ascertained. There were no positive indications of accidental braking due to irregularities or defects in the braking system. However, although overheating of the brakes was found on both landing gears, the possibility of an accidental braking could not be ruled out.

Testimonies revealed a rapid transition, a few minutes after take-off, from a white smoke trail to an extensive fire in the area of the left landing gear shaft. Tests and calculations showed that the wheel rims reached their maximum temperatures only a few minutes after the braking operation. Examination of the wreckage revealed that a primary source of fire existed in the left landing gear shaft in the area of Nos. 3 and 4 wheels, and that No. 3 wheel burned in the air. Traces on the runway showed that hydraulic oil must have leaked from the No. 4 wheel braking system and burned, even at the beginning of the take-off run.

Therefore the outbreak of the fire might have been caused either by the fracture of No. 3 wheel in the air, due to overheating of the brakes, or the spreading of the fire caused by the fracture of No. 4 wheel on the runway.

Evidence of heavy demands on the entire braking system before take-off was found. Statistics proved that No. 4 wheel was one of the wheels bearing an above-average load, however this did not exclude a similar possibility for No. 3 wheel. It is quite possible that the rim of No. 3 wheel only reached its critical temperature during flight. Exactly when No. 3 wheel burst in the air was not determined, but it was not considered as particularly essential.

The fracture of the rim might have damaged fuel lines and the leaking fuel might have become ignited on the overheated brake parts. The neighbouring fuel lines might also have been damaged by the fracture or might have melted due to the fire. The overheating due to the heat from the brakes and the fire also burst Nos. 1 and 2 wheels. This caused further damages which must have led to further spreading of the fire. Subsequently, the fire -- fed by fuel -- spread from the left landing gear shaft to both the outside and inside of the fuselage and also affected the rear of the fuselage and the tail unit.

Another possibility was that the fire which resulted from the fracture of No. 4 wheel on the runway, had not been quite extinguished when the landing gear was retracted. Following lift-off and immediately prior to retraction, the fire might have been fed by hydraulic oil leaking from the wheels or might have become re-ignited after having been temporarily extinguished. Such a fire might first have spread to the tires and then to the wheel rim of No. 3 wheel. Because of the air current prevailing in the landing gear shaft during flight No. 3 wheel must have been especially exposed to the effects of the burning gases from No. 4 wheel which was located just above it. Also the deformation of the rim fragments from No. 3 wheel could hardly be explained without prior effects of burning with localized, concentrated increases in temperature. It therefore appeared more likely that the fracture of No. 3 wheel was a consequence of the fracture of No. 4 wheel (See Figure 20).

The flight appeared normal for the first five minutes following take-off. The increasing loss of speed which occurred after 0618 hours reflected the first obvious effects of the fire on the aircraft's performance. It was assumed that the crew became then fully aware of serious difficulties and tried to identify and correct them. This would explain the radio silence at that time.

The flight recorder data showed that difficulties increased after 0620 hours: the aircraft veered to the left, its altitude decreased rapidly, switch-over operations indicated a malfunctioning of the electrical system. As a result of the fire, different aircraft parts broke off with increasing frequency and the flaps were presumably extended to approximately 20° in an attempt to keep control of the aircraft. Whether the left power plant had been deliverately cut off, or lost due to an interruption in the fuel supply, was not determined. The emergency call at 0621 was sent when the crew realized that their efforts were hopeless and that disaster was inevitable. The final loss of control, which was clearly indicated by the dive, was caused by one or more of the following factors:

- The structural stiffness of the left wing, the rear of the fuselage and the flight control system might have diminished under the influence of the heat and resulted in a considerable deterioration of the aircraft's flying qualities.

- The hydraulic system might have been damaged in such a way as to possibly cause loss of aileron elevator and rudder control.

- The destruction of the rear of the fuselage might have damaged the setting of the elevator unit to such an extent as to make the elevator control ineffective.

The explosions at impact were caused by the mechanical effects of the impact and the subsequent atomization of fuel which created, at least in some areas, an explosive gas mixture.

2.2 Conclusions

Findings

The pilot-in-command and the co-pilot were duly certificated and qualified for the flight.

The aircraft had a valid certificate of airworthiness and had been properly maintained. Its gross weight and center of gravity at the time of departure were within permissible limits.

Extensive fog existed on runway 34 at the time of take-off and the pilot-in-command decided to taxi halfway down the runway to inspect the fog condition and then return to take-off position.

During this process overheating of the brakes occurred, No. 4 wheel's rim flange exploded and hydraulic oil leaks caught fire. When the undercarriage was retracted after take-off, the fire spread in the left gear shaft and No. 3 wheel exploded in turn, probably damaging fuel lines. The fire became intense, different parts of the aircraft broke off and damage to the aircraft's structure finally resulted in a complete loss of control.

Cause or Probable Cause(s)

The crash was due to the destruction of essential structural parts of the aircraft by a fire caused by overheating of the brakes during the taxiing phase.

3. Recommendations

No recommendations were contained in the report.

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ICAO Ref: AR/886

ACCIDENT TO SE-210, CARAVELLE HB-ICV,
OF SWISSAIR, AT DÜRRENÄSH, SWITZERLAND.
4 SEPTEMBER 1963

TAXIING AND TAKE-OFF PHASE

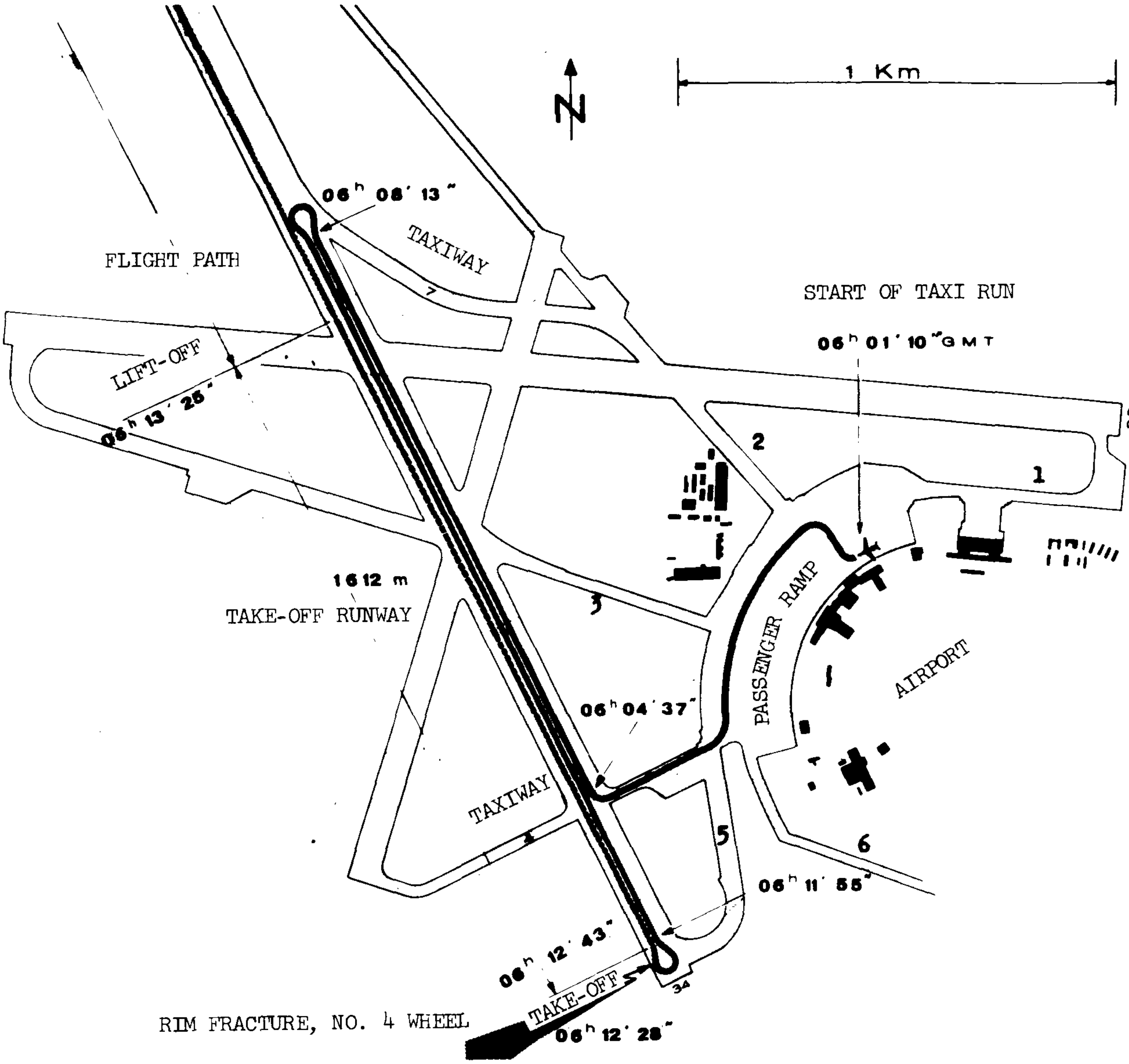

FIGURE 19

ACCIDENT TO SE-210, CARAVELLE HB-ICV,
OF SWISSAIR, AT DÜRRENÄSH, SWITZERLAND.
4 SEPTEMBER 1963

PRESUMED PATH OF THE FIRE

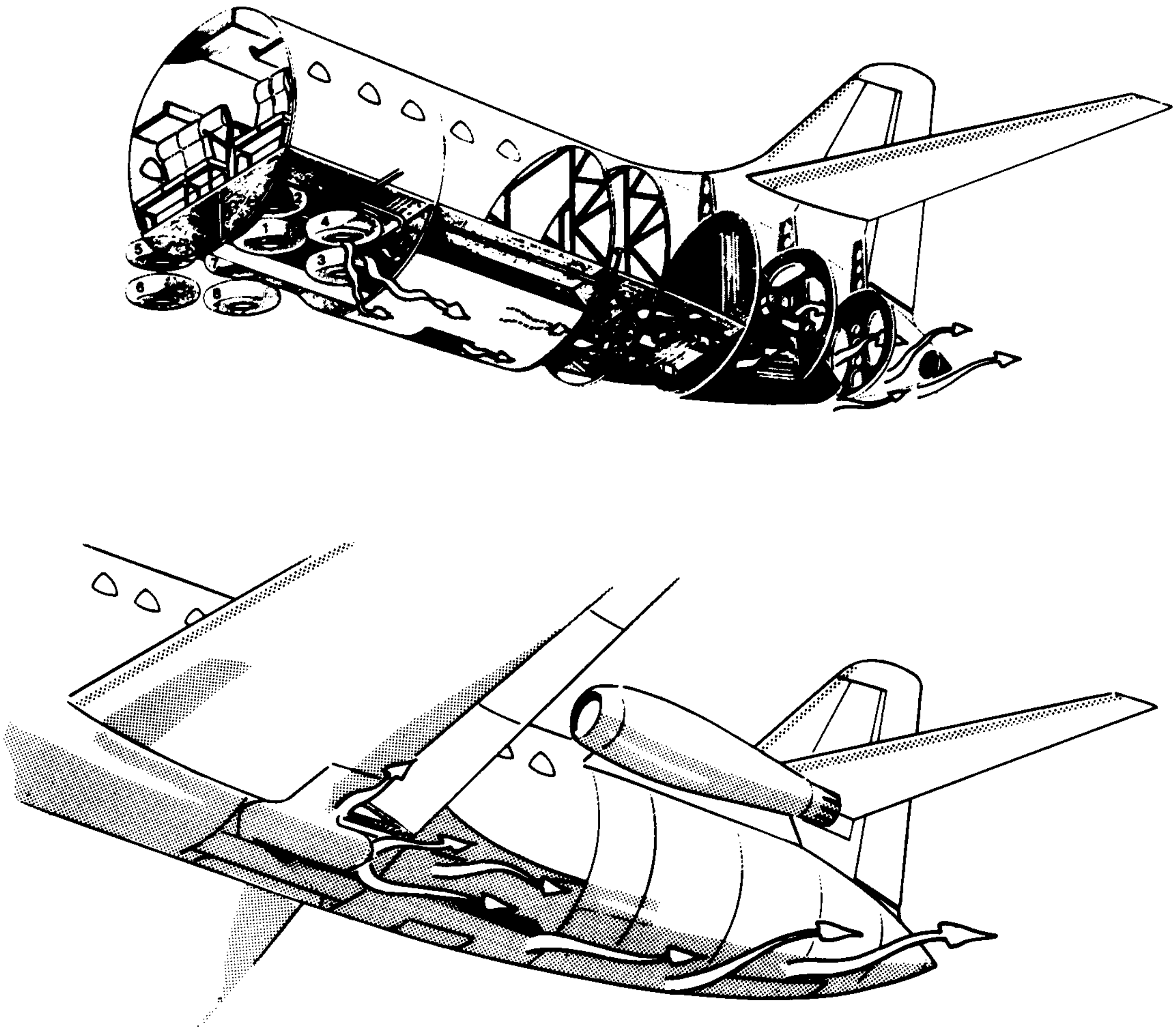

FIGURE 20

No. 21

Indian Airlines Corporation Vickers-Armstrong Viscount VT-DIO accident near Patti, India on 11 September 1963. Report released by the Ministry of Civil Aviation of India on 30 September 1964

1. Investigation

1.1 History of the flight

On 10 September 1963, Viscount aircraft VT-DIO was on a scheduled domestic flight, operating the Night Air Mail Service on the route Madras/Nagpur/Delhi. It took off from Madras at 2240 hours Indian standard time and the flight to Nagpur was uneventful. The aircraft took off from Nagpur with another crew at 0237 hours on 11 September. Communications difficulties were encountered commencing at 0258 hours; the last message known to be sent by the aircraft was at 0336 hours; at that time VT-DIO was flying normally at an altitude of 16 500 ft, the sky was clear and the estimated time of arrival to the Delhi Control boundary was given as 0405. There was enough fuel in the aircraft to maintain flight until 0950 hours. At approximately 0400 hours, the aircraft crashed in a field near village Patti, 15 miles from Agra. The impact resulted in immediate explosion and fire, all aboard being killed.

1.2 Injuries to persons

Injuries	Crew	Passengers	Others
Fatal	5	13	
Non fatal			
None			

1.3 Damage to aircraft

The aircraft was completely destroyed.

1.4 Other damage

None reported.

1.5 Crew Information

Both the pilot-in-command and the co-pilot had considerable flying experience and held valid licences. The pilot-in-command has passed the regular six-monthly medical examination on 29 August 1963, although the Medical Board had advised him to reduce his weight. The co-pilot was also physically fit. *

* Note from the Secretariat: Detailed information regarding the age, flying experience of the pilots and qualifications of the radio operator were contained in Appendices to the report. These Appendices were not attached to the report received by the Secretariat.

1.6 Aircraft information

The aircraft had a valid certificate of airworthiness, its last overhaul was carried out on 6 August 1963.

A normal pre-flight check had been carried out at Madras before departure and the aircraft was found airworthy. At Nagpur the aircraft was refuelled with 3 200 l of fuel and had enough fuel to fly until 0950 hours. A through-flight inspection was also carried out, although this had no bearing on the accident, it was found that it had been carried out rather hurriedly and was certified by somebody who was not properly entitled to do so.

The all-up weight of the aircraft was within the permissible limit.

1.7 Meteorological information

A route weather forecast was provided to the pilot-in-command just before taking off from Nagpur. Weather conditions throughout the journey from Nagpur to the crash site were in every aspect favourable. The sky was clear, visibility was good, there were no high winds and the atmosphere was free from turbulence and icing.

1.8 Aids to navigation

Not relevant.

1.9 Communications

At 0258 hours the aircraft established communications with New Delhi/Palam to report its position, however, communication difficulties were experienced and the position report was not received by Palam. Subsequent calls made by Palam were not replied by the aircraft. At 0336 hours the aircraft established communication with Bombay/Santa Cruz, passed its position report and requested that it be relayed immediately to Santa Cruz. This was not done until 0436 hours. This was the last message of the aircraft.

1.10 Aerodrome and ground facilities

Not relevant.

1.11 Flight recorders

Not mentioned in the report.

1.12 Wreckage

Most of the wreckage lay inside or just outside a huge crater. The rest of the wreckage was scattered fan-wise around the crater within a radius of about 100 yds.

1.13 Fire

Explosion and fire occurred upon impact, completely destroying the aircraft and burning the bodies of those on board beyond recognition.

1.14 Survival aspects

Not applicable.

1.15 Tests and research

The entire wreckage was transported to New Delhi, laid out in a hangar and carefully examined. Engineers from Rolls Royce and Dowty Rotols Ltd. examined the engines and the propellers. The flame tubes of the engines were sent to the Rolls Royce laboratories for a special hardness test, in order to determine their temperature at time of impact. These tests revealed that the temperature of the tubes at the time of crumpling were comprised between 600°C and slightly over 700°C. There were also evidence of high speed rotation particularly in the bending of the turbine blades and compressor rotator guide vanes against the direction of normal rotation. It was therefore concluded that the four engines were operating at the time of impact.

The eight fuel booster pumps and two fuel gauges were sent at the Aircraft Laboratories, British Aircraft Corporation, Weybridge. It was determined that both booster pumps of No. 1 engine and one booster pump of No. 4 engine were operating at the time of impact and that one booster pump of No. 3 engine was not operating. No conclusions were reached concerning the other four pumps. No useful conclusions were reached, on the fuel carried by the aircraft at the time of impact from the fuel contents gauges.

The Bendix Airspeed Indicator was also sent to Weybridge. Radiograph of this instrument indicated that the relative positions of the quadrant and cog corresponded to a rotation of the pointer to an indicated speed between 120 and 180 kt.

2. Analysis and conclusions

2.1 Analysis

The last message sent by the aircraft was a position report at 0336 hours, there was nothing to indicate any difficulties, sky was reported as clear and the aircraft was flying at 16 500 ft. Witnesses' statements indicated that some 6 miles before the crash site, the aircraft appeared to be flying normally, but that soon afterwards, it descended steeply and crashed. The aircraft struck the ground almost vertically, slightly on its back and with the right wing low. The flaps, nose-wheel and main undercarriage were in the retracted position. The engines were operating and the pitch angle of the propellers was between 48° and 51° at the time of impact. Although the radiograph of the airspeed indicator indicated a speed between 120 and 180 kt it was believed that the aircraft's speed was more of the order of 250 to 330 kt at impact. Several hypothesis were considered in an attempt to discover the probable cause(s) of this accident.

No evidences were found to substantiate any of the following hypothesis:

- structural failure, explosion or fire;
- malfunction of flying controls;
- engines or propellers malfunctioning or failures;
- fuel contamination or shortage;
- icing;
- sudden incapacitation of the pilot-in-command;
- sudden decompression of cabin;
- severe turbulence from wing-tip vortices of another aircraft.

The only two hypothesis which were considered as a possible explanation of this accident are discussed hereunder:

Malfunctioning of the auto-pilot

Numerous malfunctioning of the Viscount auto-pilot had been reported in the past. Between 1 January 1960 and 30 August 1963 as many as 129 auto-pilot snags were reported on the subject aircraft. However, they were not of a serious nature and never lead to a loss of control of the aircraft.

The only serious auto-pilot malfunctioning which involved a partial loss of control and a loss of about 4 000 ft of altitude, occurred on 22 August 1963 on another aircraft. However, this incident occurred during a descent through clouds with the auto-pilot engaged and was considered to be partly due to pilot error.

In the present case the aircraft was flying on a steady course, at an altitude of 16 500 ft and it was concluded that under these circumstances no mishandling of the auto-pilot could have occurred.

Failure of the electrical system

In case of a complete DC and AC failure (or even of a partial AC failure) the vital flight instruments, radio and auto-pilot would fail. The crew would be confronted with a very difficult situation, especially during a dark night. The aircraft would tend to fly in accordance with the trim setting existing at the time the auto-pilot stop functioning. This might further disorientate the pilot who will fly by that time only from sensations.

Evidences were found that the AC supply to both artificial horizons and the omnibearing indicator had been cut off at some stage prior to impact. This could infer either that the pilot had deliberately turned off those instruments or the failure of the AC current. It was believed that the second inference was more probable than the first one, especially in view of the fact that no radiotelegraphy or radiotelephony messages were received from the aircraft between 0336 hours and 0400 hours, the time of the accident.

2.2 Conclusions

Findings

The aircraft held a valid certificate of airworthiness.

The aircraft loading was within permissible limits.

The members of the crew held valid licences.

The navigational equipment on board the aircraft was adequate for the flight.

The quantity of fuel carried by the aircraft was adequate.

The weather at the time of the accident was calm and free from turbulence.

The pilot sent the usual departure message after becoming airborne and an hour later, at 0340 hours, transmitted another message giving his position.

There was no fire or explosion in the aircraft while it was airborne and the aircraft descended and crashed to the ground as one integrated unit. Fire and explosion followed impact causing the death of all the persons on board and total destruction of the aircraft.

Cause or
Probable cause(s)

The cause of the accident could not be established.

Although there is little substantial evidence to support the assumption, it is possible that a sudden malfunctioning of the auto-pilot and/or a sudden failure of the electrical power may have created conditions which made it impossible for the crew to retain control of the aircraft, thus causing it to lose height rapidly and crash to the ground.

3. Recommendations

1) Snag Reports should be attended to more promptly and as far as possible snags should not be carried forward and there should be no attempt to conceal information on this point from the Director of Aeronautical Inspection.

2) All serious snags, and more particularly reports of loss of control of aircraft should be enquired into with greater care.

3) Through Flight Inspection should be made by a properly licenced Aircraft Maintenance Engineer.

4) Instructions regarding the minimum fuel permissible in tanks should be carefully observed.

5) A sample of the fuel uplifted by the aircraft, taken at the time of refuelling, should be retained after 24 hours if a question regarding the contamination of the fuel is likely to arise.

6) Deficiency list for the Viscount aircraft duly approved by the Department of Civil Aviation should be issued without any further delay.

7) Relighting of at least two engines must be carried out during six monthly flight checks.

8) A portable flash light must always be carried on all aircraft undertaking flights involving night flights.

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ICAO Ref: AR/903

No. 22

Finnair DC-3, OY-LCA, accident near Mariehamn Airport, Finland, on 8 November 1963. Report released by the Ministry of Communications and Public Works of Finland on 29 January 1964.

1. Investigation

1.1 History of the flight

Flight AY 217 was on a scheduled domestic flight from Helsinki to Mariehamn with an intermediate stop at Turku. The flight to Turku was routine and the aircraft took off from Turku at 1620 GMT, with a crew of three and 21 passengers plus one former Finnair pilot* who was in the cockpit without ticket or permit. The flight from Turku to Mariehamn was carried out at an altitude of 2 000 ft and nothing abnormal was reported by the aircraft. The approach to the Mariehamn NDB (MAR) was made from the East-North-East and at 1657 hours the aircraft reported over the NDB on the inbound track to runway 20. During the final approach the aircraft which was flying strictly on the inbound track struck trees in a nearly horizontal attitude 1 470 metres before the threshold of the runway. Upon impact the aircraft flipped over on its back around its longitudinal axis and caught fire immediately. The accident occurred at 1659 hours.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	2	19	1*
Non fatal	1	2	
None			

1.3 Damage to Aircraft

The aircraft was destroyed by the impact and the subsequent fire.

1.4 Other Damage

None reported.

1.5 Crew Information

The pilot-in-command, age 30, held a valid airline pilot licence with instrument and type ratings. He had flown a total of 7 228 hours including 2 772 hours as pilot-in-command of DC-3 aircraft.

The co-pilot, age 26, held a valid commercial pilot's licence with instrument and type ratings; he had flown a total of 1 078 hours.

The stewardess was also properly certificated.

No adverse remarks were made regarding the physical and mental state of the crew, or its behaviour during the days prior to the accident.

1.6 Aircraft Information

The aircraft's certificate of airworthiness was valid until 30 April 1964. It had flown a total of 30 672 hours, including 476 hours since the last major overhaul. All inspections, repairs and maintenance had been performed in accordance with instructions and approved procedures. However, the maintenance record of the pilot-in-command's altimeter had an entry regarding the replacement of the "toothed sector and hand axis", and it was found that the toothed wheel was replaced but not the toothed sector. It was not possible to establish whether the counterweight of the toothed sector had been the object of any manipulation.

The aircraft's weight and centre of gravity were within the prescribed limits.

The type of fuel used was not mentioned in the report.

1.7 Meteorological Information

Before taking off from Turku the following weather information was available to the crew: Turku and Mariehamn: Horizontal visibility 600 m, fog, vertical visibility 200 ft; Stockholm/Arlanda: Horizontal visibility 10 km, clouds 4/8 at 210 m, 8/8 at 3 000 m.

In flight the crew received for Mariehamn the following information from the ATC at 1637 hours: Surface wind 180/6 kt, vertical visibility 200 ft, horizontal visibility 600 m, fog, QNH 989 mb; at 1657 hours: Surface wind 180/3 kt, QNH 989 mb. This was acknowledged by the crew and information on the approach lights was requested. The air traffic controller confirmed that the approach lights were on, but that he could not see them because the visibility was somewhat poorer.

1.8 Aids to Navigation

There were two radio beacons located on the extended center line of runway 20 for aid on approach and landing: the NDB "MAR" (392 kc/s) and the locator "S" respectively located at 6 800 m and at 1 420 m from the runway threshold. It is known that the signals emitted by these low frequency beacons are not always very clearly received at long distance because of other transmitters working on the same or adjacent frequencies and of atmospheric phenomena. However it was not established if this had any bearing on the accident since the aircraft was close to the beacons.

There is no GCA at Mariehamn and although the installation of ILS equipment started two years before the accident, it had not been completed because of land acquisition problems.

1.9 Communications

These were normal until the time of the accident.

1.10 Aerodrome and Ground Facilities

Mariehamn Airport has low intensity runway and threshold lights and a line of low intensity approach lights which begins 1 020 m before the threshold of runway 20. At the beginning of the line of approach lights there is a flashing light, which is located amongst trees approximately at the break off point of the obstacle clearance surface.

1.11 Flight Recorders

Not mentioned in the report.

1.12 Wreckage

No details or diagrams on the distribution of the wreckage were provided in the report.

1.13 Fire

Fire commenced immediately after contact with the ground and destroyed the entire fuselage except the rear section, which had broken off on impact. - No information on fire fighting is provided in the report.

1.14 Survival Aspects

When the Air Traffic Controller did not receive any reply from the aircraft to his radio calls, he immediately initiated search operations. The fire brigade and other rescue services were alerted between 1705 and 1708 hours. The arrival at the scene of the accident was hampered by the fog and the lack of appropriate service roads towards the approach line.

As a result of the impact the seats in the cabin were torn from the cabin floor and were packed together against the cockpit wall. The frames of the seats were partly bent but did not break and the seat belts probably resisted. The acceleration forces at impact were estimated to be arount 12 g.

1.15 Tests and Research

The engines and their accessories were dismantled and investigated at Kuorevesi with help from the Finnish Air Force. The instruments were checked first at the Airport, and then at the Air Force Depot and particular care was taken in checking the altimeters.

It was found that the pilot-in-command's and the co-pilot's altimeter settings were respectively 988.3 mb and 988.4 mb. The QNH transmitted to the aircraft two minutes before the accident was 989 mb. This would account only for a maximum error of about 20 ft. When the pilot-in-command's altimeter was opened at the Air Force Depot the counterweight of the toothed sector and its screw were found loose and the aneroid capsule was dented. It was determined that the damage to the aneroid capsule had been probably caused by overpressure when the extinguishers exploded in the fire subsequent to the accident. Also the screws, which are normally locked by lac or paint, were not locked.

1.16 Weather minima at Mariehamn Airport

The instrument approach chart for Mariehamn Airport, published in January 1962 by the Department of Civil Aviation, gave an obstacle clearance limit (OCL) of 566 feet (amsl) for the approach to runway 20, when using the two NDB approach procedures.

The landing minimum on the instrument approach charts for Mariehamn Airport, used by Finnair and approved by the DCA, is 316 feet (asml), which is 250 feet below the OCL. The "planning minima" approved for Mariehamn are vertical visibility 150 ft above the aerodrome and horizontal visibility 700 m.

2. Analysis and conclusions

2.1 Analysis

No evidence of malfunction or failure were found in the aircraft, controls, engines or systems. Under the prevailing weather conditions there was no risk of icing at 2 000 ft and nothing indicated that carburetor icing might have occurred during the approach.

The weather information available to the crew at Turku indicated for Mariehamn an horizontal visibility of 600 m, i.e. 100 m below the company's "planning minima". The decision of the pilot-in-command to carry out the flight was probably influenced by his knowledge of the route and of the weather inconstancy at Mariehamn under the prevailing meteorological conditions. However when the pilot-in-command was informed over "MAR" NDB that the visibility had worsened, he should have discontinued the approach. At the time of the accident the aerodrome and the approach sector to runway 20 were covered by a comparatively thick fog, although a few minutes after the accident stars were visible from the ground and the weather improved for about one hour. It was concluded that the pilots had no visual reference to the ground during the final approach and that the low intensity runway and approach lights were hidden by the hill located before the beginning of the approach lights. Also the flashing light at the beginning of the approach lights was located amongst trees and could not be seen from faraway, especially at low altitude. Finally no obstruction light existed at the time on the highest point of the obstacle profile.

In trying to explain why the aircraft was too low during the final approach it was considered that the pilots might have misjudged their altitude or position or both.

The normal practice amongst the Finnair crews is for the pilot-in-command to monitor continuously the altitude and for the co-pilot to be mainly responsible for the look out.

It was considered that the pilot-in-command's altimeter might have begun to work incorrectly during the flight. It is highly probable that the counterweight was already loose during the flight. Although the tests had shown that the absence of the counterweight does not, by itself, occasioned any important errors in the altimeter values, it is possible that the counterweight or its screw, by getting wedged in the altimeter mechanism during the flight could have occasioned an operational disturbance of the altimeter. As a result the pilot-in-command might have had a false idea of his altitude. If the pilot tried to keep the minimum altitude, as it is normally done when approaching to a locator beacon, a sudden error in the altimeter indication of about 130-140 feet in the dangerous direction would be enough to occasion the impact against the trees in the condition in question.

The use of the reserve static system could also have occasioned an error in the altimeter indication of nearly the same magnitude. The control lever of the system was found after the accident, in the lower position i. e. "reserve static" but it was impossible to ascertain whether it was in that position prior to or as a result of the accident. The State Institute for Technical Research could only establish that the control lever was bent as a result of some blow it had received.

The Board did not find any reason why the pilot should have shifted over to reserve static system. The pre-flight checks include the checking of this lever in its upper position ("pilot-static system") at take-off. There is a possibility that the reserve static system had been tried during the flight and that the lever was forgotten in that position, but this does not seem probable. The magnitude of the error occasioned by the use of the reserve static system is variable to a certain degree and highly dependent on the flying speed. Therefore any pilot who would have tried the reserve static system before beginning the approach would have carefully shifted over to the normal system again, especially in the prevailing weather conditions.

Another reason, which might have given the pilot an erroneous conception of his altitude, would have been the correction of a known altimeter error in the wrong direction by mistake. As reported by another pilot, the pilot-in-command's altimeter of the subject aircraft indicated about 50 feet too much on the day prior to the accident (the maximum error permissible is 65 feet). If error had been the same on the day of the accident and if the pilot had mentally performed the correction in the wrong direction, there would have been an error of 100 feet. In this case the error would have been in the dangerous direction.

However, an error of this magnitude would not have been sufficient by itself to occasion an impact with the trees at the place in question. But if the pilot deliberately or unconsciously had flown some 30 or 40 feet below the minimum permitted an impact against the trees would then have been the result. Even a conscientious pilot could deliberately go that much below the minimum as there would still remain a margin of about 100 feet provided that the pilot is aware of the value of the altimeter's error and had taken it into account in the right way.

The Board considered it obvious that the pilot-in-command had an erroneous conception of his altitude. He was flying almost exactly horizontally when he struck the trees, awaiting to be passing the locator "S" on final approach, and to see the line of approach lights appear. It is not likely that he consciously flew at the altitude at which he was actually flying, as he was perfectly aware of the circumstances and the obstacle heights in the approach sector.

It is also possible that the pilot-in-command of the aircraft had an erroneous conception of the aircraft's position and that, assuming that he had already passed the locator, he went below the minimum altitude permissible in order to be able to see the line of approach lights or the runway lights.

After the accident, Finnair pilots stated that with the radio compass tuned to the locator "S" frequency sometimes wrong indications were obtained. As a result a pilot might believe having passed the locator on final approach though he, in reality, would not have passed it yet.

The wrong indication of the radio compass is a specific deficiency of the system in question, especially appearing when the aircraft is far away from the locator.

The reports of the Finnair pilots mostly concerned cases of this kind. But, when the aircraft is near the locator, errors of some importance are scarcely possible. This was confirmed by experts from the State Institute of Technical Research and The Board of Posts and Telegraphs. The Board therefore considered that there was no evidence to prove that the pilot of the aircraft, believed having already passed the locator. The almost horizontal flight path of the aircraft at impact gives no support whatever for such a hypothesis.

In the opinion of his superiors as well as of his subordinates the pilot-in-command of the fatal flight was an extremely conscientious and careful pilot. It is therefore very unlikely that he consciously and deliberately flew 130 to 140 feet below the minimum permissible altitude, endangering the safety of the flight.

2.2 Conclusions

Findings

The crew were properly certificated.

The certificate of airworthiness of the aircraft was valid. The maintenance of the aircraft had been performed in accordance with instructions and approved procedures, however, a discrepancy was found in the maintenance record of the pilot-in-command's altimeter.

The aircraft's weight and center of gravity were within the prescribed limits at the time of take-off from Turku.

The weather at Mariehamn was below the company prescribed minima.

The counterweight of the toothed sector and its screw were found loose in the pilot-in-command's altimeter. The aircraft flew into trees in the final approach to runway 20 when making an NDB approach procedure, probably because of a wrong altitude indication.

Cause or Probable cause(s)

The Board considered that the ultimate cause of the accident was the pilot's misconception of his altitude. It was impossible to determine whether this was due to a wrong indication of the altimeter or to human error. The defect, found in the pilot-in-command's altimeter, was regarded however as sufficient to have brought a wrong indication of the altitude which the pilot could not foresee. The cause of the accident was therefore established as follows:

As a result of a wrong indication of the aircraft's pilot's altimeter during an instrument approach carried out in weather conditions worse than the weather minima approved for runway 20 at Mariehamn, the aircraft came below the safe flying altitude and hit trees on the approach line.

3. Recommendations

The improvement of landing aids at airports should be started urgently. It should urgently be endeavoured to acquire ILS and GCA radar equipment for facilitation of aeronautical activity in Finland;

The weather minima related to NDB procedures for Finnish aerodromes should be revised taking into consideration the OCL values recommended by ICAO;

The concept "Planning minima", which does not appear in the recommendations of ICAO should be entirely abolished;

When determining the length of the line of approach lights the terrain and obstruction profile of the corresponding approach sector should be taken into consideration so that the lights cannot be hidden by the obstruction of terrain profile even in the case of an aircraft flying at a low altitude. All aerodromes should be equipped with lines of high intensity approach lights;

In overhaul and repair of altimeters and other similar aeronautical instruments, the possibility of fixing screws in frame and mechanism becoming loose should be taken into consideration;

Improvement of the fastening of seats and the endurance of seat belts at reasonable costs should be examined;

During approach pilots should follow uniform working procedures to ensure a continuous utilisation of both altimeters and speed indicators and comparison of their readings;

All air traffic control units should be equipped with sound recorders for recording radiotelephone conversations with aircraft and orders given in connexion with alarm and rescue activity;

Meteorological observations and weather data should be brought to a degree of accuracy higher than they are at several meteorological stations at present;

The possibility of increasing the number of ATC personnel at small airports, where the traffic frequency is relatively small, should be considered;

In the immediate vicinity of the center lines of approach and climbing sectors of runways at airports, catastrophy and service roads to a length of at least 1.5 - 2 km from the end of the runway should be built;

Alarm sirens at airports should be modified to work automatically;

Rescue service training should be intensified by arranging joint exercises for participants from different administrations;

The station service procedures at airports should be revised so that embarcation of outsiders should be rendered impossible;

Authorities supervising air traffic and airline operators should intensify their supervising activities and adopt methods such to ensure the observance of air service regulations and prescribed weather minima.

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ICAO Ref.: AR/911

PART II

AIRCRAFT ACCIDENT STATISTICS 1963

INTRODUCTION

GENERAL COMMENTS

1. This section of the Aircraft Accident Digest No. 15 contains a detailed analysis of the statistics for the year 1963, as well as selected data for the years 1925 to 1965 inclusive. Figures for the years subsequent to 1951 were obtained largely from the ICAO Air Transport Reporting Forms G (Aircraft Accidents; see pages 215 and 216) filed by Contracting States. In order to arrive at as complete a picture as possible of accidents in which public aircraft were involved, other sources had to be used for those countries which have not yet filed the required reporting Form.

2. The statistics shown are the best available to date but are subject to adjustment when additional Forms G are filed.

DESCRIPTION OF TABLES AND CHART

3. CHART Passenger fatality rate and traffic on scheduled air services 1945 - 1965.

TABLE A-1 Accidents with passenger fatalities on scheduled air services 1925 - 1965.

TABLE A-2 Number of fatal accidents, passenger fatalities and survivors of turbo-jet, propeller-driven (turbine and piston) aircraft - scheduled air services 1960 - 1965.

4. Three tables are given for the year 1963. The accident data have been recorded under the country in which the airline which suffered an accident is registered, not under the country where the accident took place. These three tables give the following information:

TABLE B Passenger fatalities occurring on scheduled international and domestic operations.

TABLE C Aircraft accident summary of all operators engaged in public air transport.

TABLE D Aircraft accident summary of all operators engaged in public air transport by type of operation.

SAFETY RECORD

5. The preliminary reports so far received on accidents in world air transport in the years 1964 and 1965 show a substantial further drop in accident rates on scheduled services (international and domestic combined). These are the fourth and fifth successive

years in which accident rates have improved. As can be seen from Table A-1, the passenger fatality rate has in fact been halved in five years, falling from 0.78 fatalities per 100 million passenger-kilometres in 1960 to 0.38 in 1964 and 0.35 in 1965 (1.25 to 0.62 and 0.56 respectively, fatalities per 100 million passenger-miles). The reduction in the absolute number of fatal accidents and passenger fatalities was, of course, not so great, owing to the steady expansion in the volume of operations and in the number of passengers carried per aircraft, but this figure, too, has fallen: the number of fatal accidents, at 24 in 1964 and 1965, was at its lowest since 1952. A large element of statistical chance enters into these figures, since they are based on a relatively small number of accidents and it must be noted, for example, that the addition of a single accident involving the collision of two large airliners could have raised the number of passenger fatalities for 1964 to a figure above the record figure of 847 experienced in 1960. Nevertheless, the consistency of the downward trend in the accident rates and in the absolute number of fatalities suggests that all the work being done to improve air safety is producing substantial results. Had the accident rates of ten years ago for instance, been applicable in 1964, there would have been about 50 fatal accidents instead of 24 on scheduled air services, and about 1 500 passenger fatalities instead of 658.

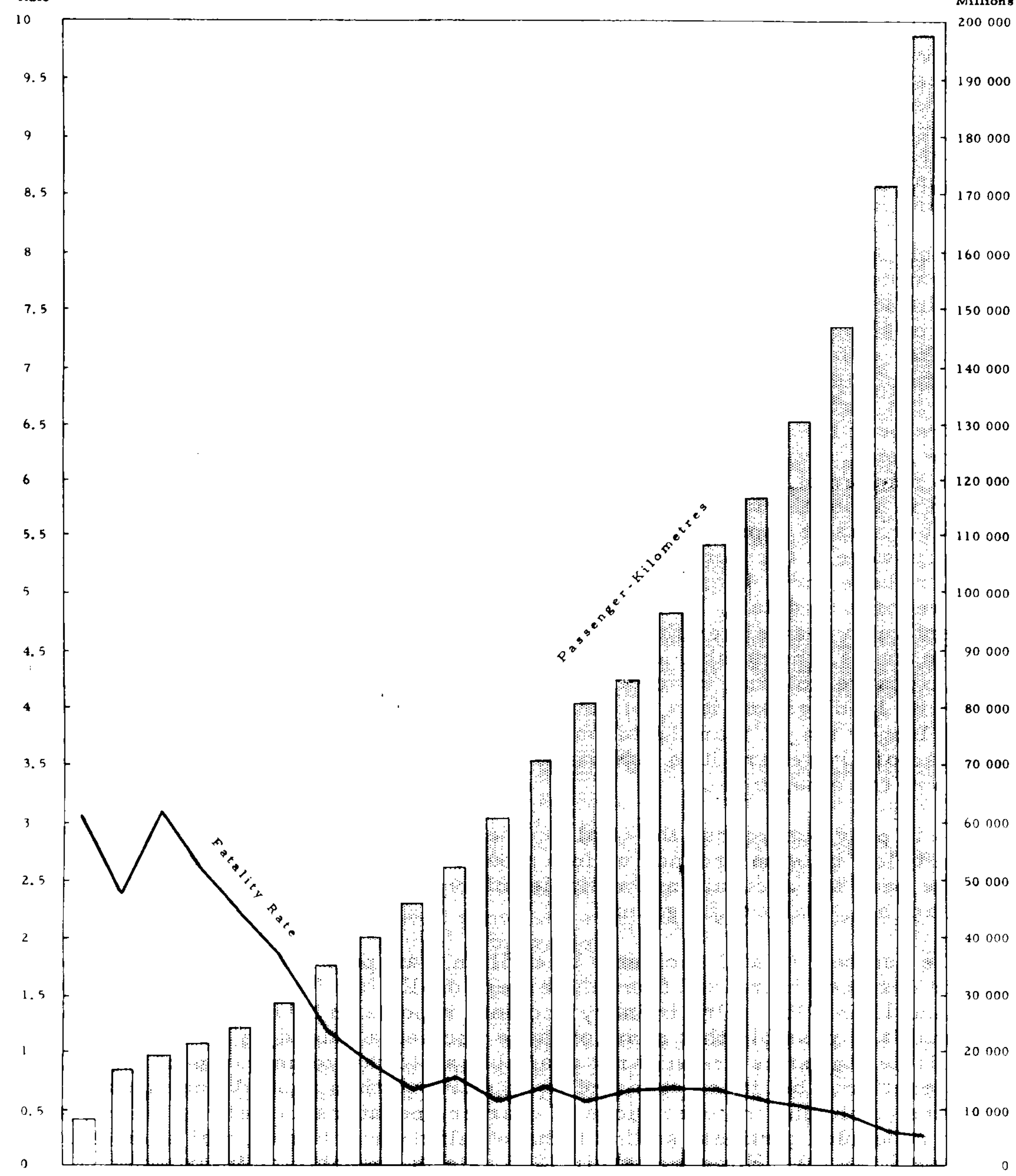
6. Table A-2 shows how accidents on world scheduled air services, 1960 to 1965, were divided among turbo-jet, turbo-propeller and piston-engined aircraft. With regard to 1964, it will be seen that the turbo-jets had an extremely satisfactory year from the point of view of safety. The turbo-props did not have quite such a good record, but the absolute number of fatal accidents remained at approximately the same level as in past years, in spite of some increase in their operations. The absolute number of fatal accidents for the turbo-jet and piston-engined aircraft for 1965 comes close to the average figure over the six years, while the turbo-props had an extremely satisfactory year from the point of view of safety (the lowest number in the six-year period). With regard to the number of passengers killed, the turbo-prop aircraft showed a very good safety record in 1965; the turbo-jets did not have quite such a good record, although the absolute number was at approximately the same level as in past years; the piston-engined aircraft had, however, the worst record since 1960. Complete figures of passenger-kilometres for these three broad types of aircraft are not available in order to compare their safety records in detail, but it seems clear that the turbo-jets achieved considerably lower accident rates than either the turbo-props or the older piston-engined aircraft. In such comparisons, the number of flights made produces a particularly meaningful measure of exposure-to-risk, since a high proportion of fatal accidents takes place in association with landings and it is, of course, true that the turbo-jets on the average fly considerably longer stages than the turbo-props or piston-engined aircraft. Even allowing for this factor, however, it is estimated that the turbo-jets have about half the accident rate of the other types.

7. As in previous years, the fatal accidents contained a high proportion of cases where aircraft flew into the ground, or into mountains, in bad visibility - emphasizing once again the need for accurate and reliable information in the cockpit concerning the aircraft's exact height above the ground.

8. The number of fatal accidents to civilian transport-type aircraft on other than scheduled air services increased from the exceptionally low figure of 7 in 1963 to about 11 in 1964, and 12 in 1965. Preliminary accident reports in this sector are often incomplete and it is possible that some of these accidents should be excluded for some reason. Reliable statistics are still not available as to the volume of non-scheduled passenger operations, but it is estimated to be no more than about 12 per cent of scheduled operations (including the operations of charter operators as well as the charter flights of the scheduled airlines) so that to have half the number of fatal accidents is certainly not a good record. However, their 1965 rate is probably an improvement on 1964.

PASSENGER FATALITY RATE AND TRAFFIC

SCHEDULED AIR SERVICES 1945 - 1965*



NOTES: Fatality rate equals number of passengers killed per 100 million passenger-kilometres flown

* Preliminary

TABLE A-1

ACCIDENTS WITH PASSENGER FATALITIES ON SCHEDULED AIR SERVICE

1925 - 1965

YEARS	Accidents in which Passengers were killed: Number of Aircraft Involved	Number of Passengers Killed	Passenger-Kilometres Flown (millions)	Fatality Rate per 100 million Pass-Kms.	Millions of Pass-Kms. per Fatality	Aircraft Hours Flown (millions)	Fatal Accidents per 100 000 Aircraft Hours
YEARLY AVERAGE							
1925 - 1929	...	36	130	28	4	...	...
1930 - 1934	...	80	445	18	6	...	...
1935 - 1939	...	133	1 475	9	11	...	...
1940 - 1944	...	114	3 795	3	33	...	...
YEAR							
1945	...	247	8 000	3.09	32	2.5	...
1946	...	376	16 000	2.35	43	3.8	...
1947	...	590	19 000	3.11	32	4.2	...
1948	...	543	21 000	2.59	39	4.6	...
1949	...	556	24 000	2.32	43	4.8	...
1950	27	551	28 000	1.97	51	5.0	0.54
1951	20	443	35 000	1.27	79	5.6	0.36
1952	21	386	40 000	0.97	104	6.0	0.35
1953	28	356	46 000	0.77	129	6.4	0.44
1954	28	447	52 000	0.86	116	6.7	0.42
1955	26	407	61 000	0.67	150	7.3	0.36
1956	27a/	552	71 000	0.78	129	8.0	0.34
1957	31	507	81 000	0.63	160	8.7	0.36
1958	30	615	85 000	0.72	138	8.8	0.34
1959	28	611	97 000	0.63	159	8.9	0.31
1960	32a/	847	109 000	0.78	129	8.6	0.37
1961	25	805	117 000	0.69	145	7.9	0.32
1962	28	765	130 000	0.59	170	7.7	0.36
1963	30	717	147 000	0.49	205	7.8	0.38
1964	24	658	171 000	0.38	260	8.3	0.29
1965*	24	684	198 000	0.35	289	8.8	0.27

NOTES: * Preliminary figures.
a/ Includes mid-air collision counted as one accident.
Exclusions: The People's Republic of China, the USSR and other States which were not members of ICAO at 31 December 1965.

TABLE A-2

1960 - 1965

Type of Aircraft	Fatal Passenger Accidents						Passengers Killed						Passengers Surviving					
	1960	1961	1962	1963	1964	1965*	1960	1961	1962	1963	1964	1965*	1960	1961	1962	1963	1964	1965*
Turbo-Jet	3	6	7	5	3	5	113	257	424	347	136	250	16	105	79	88	180	51
Propeller-driven (turbine)	7a/	6	7	5	6	2	264	192	100	47	252	35	15	13	23	1	205	0
Propeller-driven (piston)	23a/	13	14	20b/	15	17	470	356	241	323b/	270	399	173	52	81	169	117	[illegible]
Total	33	25	28	30	24	24	847	805	765	717	658	684	204	170	183	[illegible]	[illegible]	[illegible]

NOTES: * Preliminary figures.
a/ Includes one mid-air collision between a turbo-jet and a propeller-driven (piston) aircraft (counted as two accidents in the total).
b/ Includes 1 helicopter with 3 passenger fatalities.
Exclusions: The People's Republic of China, the USSR and other States which were not members of ICAO at 31 December 1965.

1963

TABLE B

CONTRACTING STATES OF ICAO PASSENGER FATALITIES OCCURRING ON SCHEDULED INTERNATIONAL AND DOMESTIC OPERATIONS FOR 1963

Description	Country Total of Hours Flown	Accidents in which Passengers were killed: Number of Aircraft Involved	Accidents in which Passengers were killed: Number of Passengers Killed	Country Total of Passenger-Kilometres	Fatality Rate per 100 Million Pass-Kms.	Millions of Passenger-Kilometres per Fatality
	(thousands)			(millions)		
Total Scheduled Operations						
Bolivia	9	1	36	43		
Brazil	278	4	59	3 080		
Burma	16+	1	15	58		
Canada	255	1	111	5 786		
Colombia	152+	1	3	1 205+		
Finland	41	1	20	313		
France	220	1	11	6 005		
Iceland	26	1	7	524		
India	129+	2	38	1 689+		
Italy	120	1	5	3 050		
Ivory Coast	4	1	48	43		
Japan	147+	3	25	3 128+		
Lebanon	35	1	11	443		
Malagasy	13	1	3	83		
New Zealand	76	1	20	624		
Philippines	70	1	24	528		
Switzerland	71	1	74	1 842		
United Arab Republic	28	2	84	384		
United States	3 606+	6	123	81 048+		
All Other States	2 527	-	-	36 918		
Total	7 823	30	717	146 794	0.49	205
International Scheduled Operations						
Bolivia	2	1	36	14		
Iceland	22	1	7	509		
Ivory Coast	3	1	48	41		
Lebanon	35	1	11	443		
Switzerland	69	1	74	1 824		
United Arab Republic	21	1	54	341		
United States	477/+	1	73	19 258/+		
All Other States	1 756	-	-	42 022		
Total	2 385	7	303	64 452	0.47	213
Domestic Scheduled Operations						
Brazil	251	4	59	2 290		
Burma	11	1	15	37		
Canada	182	1	111	3 368		
Colombia	142/+	1	3	923/+		
Finland	26	1	20	127		
France	43	1	11	477		
India	98+	2	38	693+		
Italy	38	1	5	435		
Japan	120+	2	25	1 916+		
Malagasy	11	1	3	36		
New Zealand	65	1	20	359		
Philippines	65	1	24	377		
United Arab Republic	7	1	30	43		
United States	3 130+	5	50	61 790+		
All Other States	1 249	-	-	9 471		
Total	5 438	23	414	82 342	0.50	199

NOTES:

Accident data have been recorded under the country in which the airline is registered and not under the country where the accident took place.

Under "Total Scheduled Operations" are listed all countries with scheduled airlines which had aircraft accidents resulting in passenger fatalities. These data have been segregated as to those fatalities occurring on a scheduled international flight and/or a scheduled domestic flight.

Source of data: ICAO Air Transport Reporting Forms and outside sources.

/ Includes Territorial Operations.
\+ Provisional data.

CONTRACTING STATES OF ICAO
AIRCRAFT ACCIDENT SUMMARY FOR 1963
OF ALL OPERATORS ENGAGED IN PUBLIC AIR TRANSPORT

1963

TABLE C

Contracting States of ICAO at 31 December	Number of Accidents		Passenger Injury			Crew Injury			Others Injured		By Operators With an Accident		During Year by all Operators Engaged in Public Air Transport	
	Total	Fatal	Fatal	Serious	Minor or None	Fatal	Serious	Minor or None	Fatal	Serious	Number of Landings	Hours Flown	Hours Flown	Aircraft Landings
ø Afghanistan	1	1	-	-	-	3	-	-	-	-				
Algeria	-													
Argentina	-													
ø Australia	1	-	-	-	3	-	-	1	-	-	...	5 346	344 399	-
ø Austria	-	-	-	-	-	-	-	-	-	-			17 105	11 812
Belgium	-													
Bolivia a/	1	1	36b/	-	-	4	-	-	-	-				
Brazil a/	4	4	59	38	-	13	4	-	-	-				
ø Burma	1	1	15	-	-	6	-	-	-	-	18 232	21 243		
ø Cambodia	-	-	-	-	-	-	-	-	-	-				
Cameroun	-													
ø Canada	32	8	117	15	177	14	1	33	-	-	374 368	390 091	390 091	374 368
Central African Republic	-													
Ceylon a/	-	-	-	-	-	-	-	-	-	-				
Chad	-													
ø Chile	2	0	-	-	63	-	-	6	-	-	16 339	24 747	48 434	24 506
ø China	-	-	-	-	-	-	-	-	-	-				
ø Colombia	4	1	3	3	22	-	1	3	-	-	...	30 807	163 192	159 586
Congo (Brazzaville)	-													
Congo (Leopoldville)	-													
Costa Rica	1	1	6	-	-	1	-	-	-	-				
Cuba	-													
ø Cyprus	-	-	-	-	-	-	-	-	-	-			1 809	1 665
ø Czechoslovakia	2	-	-	-	-	-	-	-	-	-			49 938	53 578
Dahomey	-													
Denmark	-													
Dominican Republic	-													
Ecuador	-													
El Salvador	-													
Ethiopia	-													
ø Finland	3	1	20	-	98	2	1	10	-	-	43 495	47 872	47 872	43 495
ø France	2	1	11	1	-	4	-	3	1	2	114 073	219 138	250 173	114 073
Gabon	-													
ø Germany (Fed. Rep. of)	7	-	-	-	5	-	-	9	-	1	26 398	14 277	124 469	157 847
ø Ghana	-	-	-	-	-	-	-	-	-	-			9 771	1 979
ø Greece	-	-	-	-	-	-	-	-	-	-			28 928	19 746
Guatemala	-													
Guinea	-													
Haiti	-													
Honduras	-													
Iceland	1	1	7	-	-	5	-	-	-	-				
India	2	2	38	-	-	9	-	-	-	-				
ø Indonesia	-	-	-	-	-	-	-	-	-	-				
Iran	-													
Iraq	-													
ø Ireland	-	-	-	-	-	-	-	-	-	-			46 437	56 071
Israel	-													
ø Italy	1	1	5	-	-	3	-	-	-	-	3 695	3 148	136 854	87 873
ø Ivory Coast	1	1	48	-	-	6	-	-	-	-	5 811c/	29 866	31 103	6 534c/
Jamaica	-													
ø Japan	4	3	25	8	24	3	6	1	-	-	69 408	84 054	171 124	113 717
Jordan	-													
Korea	-													
Kuwait	-													
Laos	-													
ø Lebanon	1	1	11	-	-	3	-	-	90	50			13 165	5 557
Liberia	-													
Libya	-													
Luxembourg	-													
ø Malagasy	1	1	3	5	-	4	-	-	-	-	19 000	13 353	13 353	19 000
Malaysia (Fed. of)	-													
Mali	-													
Mauritania	-													
Mexico	-													
Morocco	-													
Nepal	-													
ø Netherlands	-	-	-	-	-	-	-	-	-	-			144 013	63 899
ø New Zealand	7	2	24	-	56	4	-	7	-	-	61 562	61 659		
Nicaragua	-													
Niger	-													
Nigeria	-													
Norway	-													
Pakistan	-													
Panama	-													
Paraguay	-													
Peru	-													
Philippines	1	1	24	-	-	3	-	-	-	-				
Poland	-													
ø Portugal	-	-	-	-	-	-	-	-	-	-			39 533	24 834
Saudi Arabia	-													
Senegal	-													
Sierra Leone	-													
ø South Africa	9	-	-	-	-	-	-	-	-	-	74 627	48 685	105 086	106 419
ø Spain	-	-	-	-	-	-	-	-	-	-			97 227	55 605
Sudan	-													
ø Sweden	8	2	1	-	10	3	1	11	-	-	26 571	47 892	130 000d/	161 358d/
ø Switzerland	1	1	74	-	-	6	-	-	-	-	56 854	75 135	75 135	56 854
Syrian Arab Republic	-													
Tanganyika	-													
Thailand	-													
Trinidad & Tobago	-													
Tunisia	-													
ø Turkey	-	-	-	-	-	-	-	-	-	-			21 533	19 051
ø United Arab Republic	7	2	84	-	88	12	-	16	-	-			29 241	14 437
ø United Kingdom	17	1	-	-	406	-	2	59	1	1	160 063	252 692	620 560	413 033
ø United States	72	13	222	45	1 907	42	14	260	-	-	2 962 074	3 475 593	3 905 560e/	3 885 698e/
Upper Volta	-													
Uruguay	-													
Venezuela	-													
ø Viet-Nam (Rep. of)	-	-	-	-	-	-	-	-	-	-			18 821	13 920
Yugoslavia	-													
Total for 101 States	194	51	833	115	2 859	150	30	419	92	54				

TYPE OF OPERATIONS see Table D

NOTES: Source of data: Air Transport Reporting Form "G" filed by countries indicated with a ø. All other country data from outside sources.

a/ Confirmation letter received.
b/ Including 1 infant.
c/ Number of flights.
d/ Only the Swedish quota of Scandinavian Airlines System's operations is included.
e/ Certificated route air carrier industry only. (all services).

1963

CONTRACTING STATES OF ICAO
AIRCRAFT ACCIDENT SUMMARY FOR 1963
OF ALL OPERATORS ENGAGED IN PUBLIC AIR TRANSPORT
BY TYPE OF OPERATION

TABLE D

Type of Operation Contracting States of ICAO at 31 December	Number of Accidents		Passenger Injury			Crew Injury			Others Injured		By Operators With an Accident	
	Total	Fatal	Fatal	Serious	Minor or None	Fatal	Serious	Minor or None	Fatal	Serious	Number of Landings	Hours Flown
SCHEDULED INTERNATIONAL OPERATIONS												
ø Afghanistan	1	1	-	-	-	3	-	-	-	-		
Bolivia a/	1	1	36b/	-	-	4	-	-	-	-	-	-
ø Canada	1	-	-	-	90	-	-	7	-	-	27 886	50 055
ø Czechoslovakia	2	-	-	-	-	-	-	-	-	-	-	-
Iceland	1	1	7	-	-	5	-	-	-	-		
ø Ivory Coast	1	1	48	-	-	6	-	-	-	-	5 777c/	29 425
ø Lebanon	1	1	11	-	-	3	-	-	90	50		
ø Switzerland	1	1	74	-	-	6	-	-	-	-	47 125	68 705
ø United Arab Republic	4	1	54	-	88	8	-	14	-	-		
ø United Kingdom	7	-	-	-	250	-	1	32	-	1	73 653	113 688
ø United States	8	1	73	4	581	8	3	49	-	-	104 230	223 549
Total for 10 States	28	8	303	4	1 009	43	4	102	90	51		
SCHEDULED DOMESTIC OPERATIONS												
Brazil a/	4	4	59	38	-	13	4	-	-	-		
ø Burma	1	1	15	-	-	6	-	-	-	-	18 232	21 243
ø Canada	2	1	111	12	52	7	-	5	-	-	106 584	123 623
ø Chile	2	0	-	-	63	-	-	6	-	-	16 339	24 747
ø Colombia	4	1	3	3	22	-	1	3	-	-	-	26 828
ø Finland	1	1	20	-	2	2	1	-	-	-	23 110	21 426
ø France	2	1	11	1	-	4	-	3	1	2	11 903	43 463
ø Germany (Fed. Rep. of)	1	-	-	-	-	-	-	1	-	-	-	-
India	2	2	38	-	-	9	-	-	-	-		
ø Italy	1	1	5	-	-	3	-	-	-	-	3 208	2 327
ø Japan	4	3	25	8	24	3	6	1	-	-	66 662	63 539
ø Malagasy	1	1	3	5	-	4	-	-	-	-	19 000	13 353
ø New Zealand	2	1	20	-	37	3	-	3	-	-	52 229	54 859
Philippines	1	1	24	-	-	3	-	-	-	-		
ø United Arab Republic	1	1	30	-	-	4	-	-	-	-		
ø United Kingdom	3	-	-	-	18	-	1	4	-	-	1 889	1 533
ø United States	45	5	50	39	1 228	18	5	178	-	-	2 542 816	2 506 374
Total 17 States	77	24	414	106	1 446	79	18	203	1	2		
NON-SCHEDULED INTERNATIONAL OPERATIONS												
ø Finland	2	-	-	-	96	-	-	10	-	-	1 525	4 296
ø Sweden	2	1	-	-	4	3	-	1	-	-	-	5 437
ø United Kingdom	6	1	-	-	136	-	-	22	1	-	21 016	63 738
ø United States	1	1	95	-	-	6	-	-	-	-	286	1 588
Total 4 States	11	3	95	-	236	9	-	33	1	-		
NON-SCHEDULED DOMESTIC OPERATIONS												
ø Australia	1	-	-	-	3	-	-	1	-	-	-	5 346
ø Canada d/	29	7	6	3	35	7	1	21	-	-	239 898	216 413
Costa Rica	1	1	6	-	-	1	-	-	-	-		
ø Germany (Fed. Rep. of)	6	-	-	-	5	-	-	8	-	1	26 125	13 577
ø New Zealand	5	1	4	-	19	1	-	4	-	-	7 067	2 714
ø South Africa	9	-	-	-	-	-	-	-	-	-	74 627	48 685
ø Sweden	5	1	1	-	6	-	1	7	-	-	14 666	12 859
ø United Arab Republic	2	-	-	-	-	-	-	2	-	-		
ø United Kingdom	1	-	-	-	2	-	-	1	-	-	5 568	4 501
ø United States	13	4	4	2	98	6	4	21	-	-	13 885	138 023
Total for 10 States	72	14	21	5	168	15	6	65	-	1		
NON-REVENUE OPERATIONS												
ø Sweden	1	-	-	-	-	-	-	3	-	-	575	843
ø United States	5	2	-	-	-	4	2	12	-	-	-	9 173
Total for 2 States	6	2	-	-	-	4	2	15	-	-		
Total Operations	194	51	833	115	2 859	150	30	419	92	54		

NOTES: Source of Data: Air Transport Reporting Form G filed by countries indicated with a ø. All other country data collected from outside sources.

a/ Confirmation letter received.
b/ Including 1 infant.
c/ Number of flights.
d/ Includes non-scheduled international operations.

INTERNATIONAL CIVIL AVIATION ORGANIZATION

FORM G

AIR TRANSPORT REPORTING FORM

AIRCRAFT ACCIDENTS

Year ended:

Country:

Name of Operator	Type of Operation	Number of Landings	Aircraft Hours	Number of Accidents		Number of Persons Aboard		Number of Persons Injured					
								Passengers Injured		Crew Members Injured		Others Injured	
				Total	Fatal	Passengers	Crew	Fatal	Serious	Fatal	Serious	Fatal	Serious
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*	*j*	*k*	*l*	*m*	*n*
	Scheduled international												
	Scheduled territorial												
	Scheduled domestic												
	Non-scheduled international												
	Non-scheduled territorial												
	Non-scheduled domestic												
	Non-revenue												
	Scheduled international												
	Scheduled territorial												
	Scheduled domestic												
	Non-scheduled international												
	Non-scheduled territorial												
	Non-scheduled domestic												
	Non-revenue												
	Scheduled international												
	Scheduled territorial												
	Scheduled domestic												
	Non-scheduled international												
	Non-scheduled territorial												
	Non-scheduled domestic												
	Non-revenue												

Total hours flown and number of landings during the year by all operators engaged in public air transport:	Aircraft hours Landings	**Remarks:**

1960 Edition — 2/60, E/P1/1500

The attention of ICAO should be drawn to any unavoidable deviation from the instructions.

FORM G

INSTRUCTIONS

Form to be filed by **each State,** in respect of operators, registered in the country, which are engaged in public air transport, regardless of the occurrence of aircraft accidents.

This form is to be filed **ANNUALLY,** not later than **2 months** after the end of the year to which it refers.

DATA TO BE REPORTED

Data in columns *a* to *n* for an **individual operator** is to be reported only if its aircraft is involved in an accident (regardless of where the accident takes place).

Data should be reported in columns c and *d* relating to the total activities of the operator during the year, subdivided into the types of operation indicated.

Data should be reported in columns e to *n* opposite the type of operation in which the aircraft was engaged at the time of the accident.

NOTES:

A collision between two or more aircraft should be reported separately for each operator involved, and additional details should be provided under "Remarks".

Accidents resulting in only minor injuries or damages should not be reported.

Each State is to report the 'hours flown' and 'landings made' in the lower left hand corner of the Form, whether or not an accident has been reported.

EXPLANATION OF TERMS

Aircraft accident means an occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight until such time as all such persons have disembarked, in which:

a) any person suffers death or serious injury as a result of being in or upon the aircraft or by direct contact with the aircraft or anything attached thereto, or

b) the aircraft receives substantial damage (Annex 13).

Scheduled and **non-scheduled operations** relate to operations for which remuneration is received. The terms apply to the stages of an operation, but not necessarily to the operator; thus, an airline whose operations are predominantly scheduled may, from time to time, operate non-scheduled flights.

Non-revenue relates to operations such as positioning flights, test flights, training flights, etc.

International, territorial and **domestic** are classifications according to the rules given below for the classification of flight stages, a "flight stage" being the operation of an aircraft from take-off to landing:

International:

A "flight stage" with one or both terminals in the territory of a State other than the one in which the airline is registered.

Territorial:

A "flight stage" with both terminals in the territory of the State in which the airline is registered, passing, for relatively substantial distances, over foreign territory or international waters.

Domestic:

A "flight stage" not classifiable as 'international' or 'territorial'.

COLUMNS

Number of landings (Column c and lower left):

If the number of landings cannot be ascertained without difficulty, an estimate may be given and a note inserted under "Remarks" indicating that the figure is an estimate.

Aircraft hours (Column *d* and lower left):

Report to nearest number of whole hours. Indicate under "Remarks" basis used — such as "block-to-block", "wheels off-wheels on", etc.

Passengers injured (Columns *i, j*):

Include the total number of passengers involved, both revenue and non-revenue.

Crew members injured (Columns *k, l*):

Include hostesses, stewards and supernumerary crew in addition to flight crew.

Others injured (Columns *m, n*):

Include all persons injured other than those aboard the aircraft.

PART III

SURVIVAL IN THE OUTBACK

Reprinted from Aviation Safety Digest No. 46, June 1966, published by the Australian Department of Civil Aviation

When an aircraft is forced down in dry, arid parts of the Australian outback, the occupants need no longer die of thirst if their water reserves become exhausted while awaiting rescue. A few small items of equipment carried in the luggage compartment can now make all the difference. A simple water still has recently been developed which, using the energy of the sun, can extract small amounts of water from soil that looks quite dry.

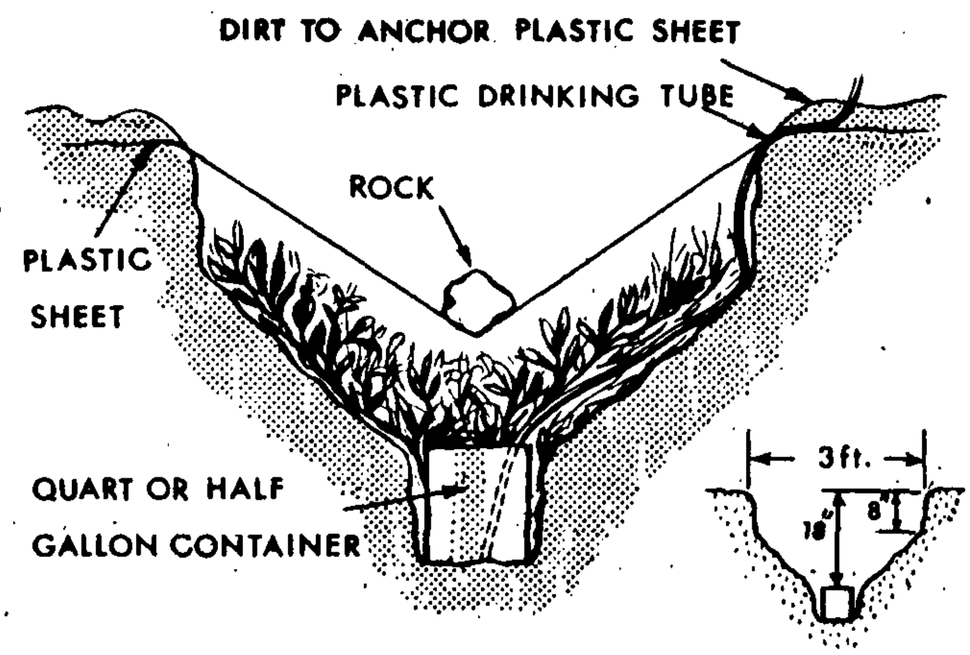
This method of obtaining drinking water from the ground in dry areas has been developed by Doctors R. D. Jackson and C. H. M. van Bavel, of the United States Water Conservation Laboratory in Arizona. It was demonstrated recently in Australia by the C. S. I. R. O and we are grateful to Dr. R. O. Slatyer, of their Arid Zone Research Section, for providing us with the material for this article.

Basically, the still consists of a sheet of clear polythene which is placed over a hole in the ground, preferably containing freshly cut or broken-off pieces of desert shrubbery. The sun shining through the polythene heats the soil and plant surfaces, causing water to evaporate from them. Some of the resulting vapour then condenses on the polythene sheet, which is kept relatively cool by the outside air blowing over it. The sheet is weighted with soil or stones so as to sag in the centre and form an inverted cone over a container placed underneath in the hole, and the condensed droplets then run down the sheet and drip into the container. In this way, about one pint of water per 24 hours can be obtained from a hole about three feet square dug in apparently dry desert soil. If the soil is moist, or if green vegetation is available, up to three pints of water can be obtained per day, but it is wise only to count on one pint per hole.

In mid-summer, the average person requires at least six pints of water daily for indefinite survival. He can survive on less for a short time, provided he rests as much as possible, preferably in any shade that may be available. To ensure survival for several days therefore, it is necessary to have four or more sheets of polythene, each about four feet square, for each person in the aircraft, and a small container for each sheet, capable of holding 2-3 pints. It is suggested that pilots should carry, in their luggage lockers, enough sheets of polythene to provide for the maximum number of persons that can be seated in their aircraft, an appropriate number of containers, and a shovel. It is also desirable, but not essential, to carry a length of polythene tubing for each hole, so that water can be sucked out of the containers as it accumulates, without having to remove the sheet.

Clear polythene which "wets" easily is best for this purpose but ordinary clear kitchen polythene sheet (or preferably the thicker .004-in. variety such as is laid down before concrete floors, etc. , are poured) is satisfactory, particularly if its surface is roughened so that the droplets of water will cling to it more easily and are not wasted by dropping off before they run down to the point of the cone. It is wise to cut the sheets to size and roughen them with sandpaper before they are stored in the aircraft, rather than waiting until one is stranded somewhere in the outback. If a "nesting" set of containers are obtained and the sheets and tubing rolled inside them, a very compact bundle can be made. But see that it is very well wrapped - it may have to lie around in the luggage compartment for a long time before it is needed.

SETTING UP THE SURVIVAL KIT



Schematic Diagram of Water Still.

Select a spot close to your aircraft but in the sun, well away from the shade of trees. If possible, choose moist soil, or a small depression or creekbed where the soil is likely to be more moist. However, this is not essential, since water can still be obtained from soil which appears quite dry.

Dig four holes for each person, preferably completely setting up each hole before starting on the next one. The holes should be about 3 feet square, 8 inches deep at the edges, tapering to about 18 inches deep in the centre if green leaves, roots, etc., are to be placed in it; shallower if these are not available nearby. Make an additional small excavation in the centre of each hole. Place a container in this, with a piece of tubing starting from the very bottom of the container and extending right outside the hole. If no sticky-tape is available to secure the tube to the side of the container, wedge the end of the tubing in with a clean dry stick or stone.

If green leaves or shrubbery are available, pick an armful, break it up and place it in the hole. Although this is desirable it is not essential, particularly if the soil is moist. Make sure the leaves do not touch the lip of the container or the plastic sheet, lest they give the water a bad taste. Cover the hole with the polythene sheet as quickly as possible and place soil all around the edges to prevent the water vapour escaping.

Place a stone or a handful of sand in the centre so that the plastic sags to form an inverted cone. Carefully centre the point of the cone over the container, so that water droplets will run down the sheet and drip into the container (see picture below).

The still in action. Note the water droplets condensing on the plastic sheet.

The first still is now operational, and other holes can be dug and set up in the same way. Water will generally begin to condense in about six hours, and enough will be available for drinking an hour or two later. Do not remove the sheet at this stage, however. Instead, obtain the water by sucking through the tube. If no tubing is available, it is best to remove the water as infrequently as possible, preferably late at night after the soil has cooled off, to avoid upsetting the operation of the still. After about 24 hours most of the water available in the top inch of soil, and in the plant material, will have evaporated. At this stage, remove the polythene and take out the container. Deepen the hole by scraping out an inch or so of soil and replace the vegetation with fresh material. Body wastes, scraps of food, etc., can also be added to the hole, since pure water will be obtained from them also provided of course that care is taken not to contaminate the container or the plastic sheet by direct contact. The container can then be replaced, the hole re-covered, and the still is operational again.

If you do not have as much polythene sheeting as has been suggested, it is still worth setting up as many stills as you can with whatever material is available. Even if you only obtain one pint a day, it will increase your chances of survival and enable you to eke out your other sources of water, such as in food and drinks.

The best way of reducing your own water requirements is to make a shelter from the wind and sun and stay in it protected, as far as possible, from exposure. And don't wait too long before starting to carry out these jobs. Exhaustion can come very suddenly once you are only a little dehydrated! A further article in the next issue of Aviation Safety Digest will discuss these aspects of desert survival in greater detail.

The importance of remaining with your aircraft cannot be stressed too much. Not only is the distance a person can walk very limited, but the aircraft itself is far more readily discernible to the crew of a searching aircraft than people on the ground or even laid-out ground signals. This may seem an obvious statement, but experience has shown that it is not generally realised how difficult it is to sight a person on the ground from the air if he is not near some more easily recognisable object such as an aircraft, vehicle, tent or hut. Then, too, the track likely to have been flown by a missing aircraft is usually in some way predictable from the information pieced together by the search and rescue organisation, but the direction survivors of a downed aircraft might have taken, could be anybody's guess!

The instructions contained in this article are not intended to imply that equipment for constructing water stills can be regarded as a substitute for carrying adequate reserves of water. Far from it! In fact, it would be hard to sum up the situation better than in the old adage. "A bird in the hand is worth two in the bush" - the water-still equipment should only be regarded as a back-up to water reserves carried in the aircraft.

Remember that in the Australian outback there is virtually no wet season and it is always dangerous to fly without adequate water reserves. Be well prepared on both counts, should you be unlucky enough to make a forced landing remote from help. The advice contained in this article could save lives.

APPROACH SPEED CONTROL

Reprinted from the Boeing Airliner,
December 1965, published by the Boeing Company

During the final approach before touchdown, pilots must maintain strict control of speed and rate of descent. A speed that is too high at touchdown requires more stopping effort because the kinetic energy of the aeroplane that must be dissipated during a stop varies roughly as the square of the aeroplane speed. On the other hand, a speed that is too low may cause the aeroplane to land short of the runway. A lower than recommended approach speed is believed to have been a factor in several of the short landings that have occurred since jetliners have entered commercial service.

Basic differences between jet and prop-powered aeroplanes in their response to power applications at low speeds appear to remain a problem, particularly with new pilots and their limited experience in jets. Analysis of the short landings to date indicate another possible complicating factor that may have contributed to short and/or hard landings. This factor is the decay or fall-off in wind velocity as the aeroplane gets closer to the ground. These two factors are considered in detail in the following analysis.

POWER APPLICATION TO INCREASE LIFT

As explained in the article, "Leading-Edge Flaps," (page 3, AIRLINER for December 1958) and charted in Fig. 1, propeller aeroplanes have two stalling speeds - one with power off and a lower one with power on. This difference in stalling speeds is due to the slipstream effect from the propellers around the wings. When power is on, the propellers generate a flow of air around the wing that does not occur when power is off. This increased flow of air generates additional lift and allows a propeller aeroplane to fly slower than if the airflow around the wings comes only from the aeroplane's forward motion.

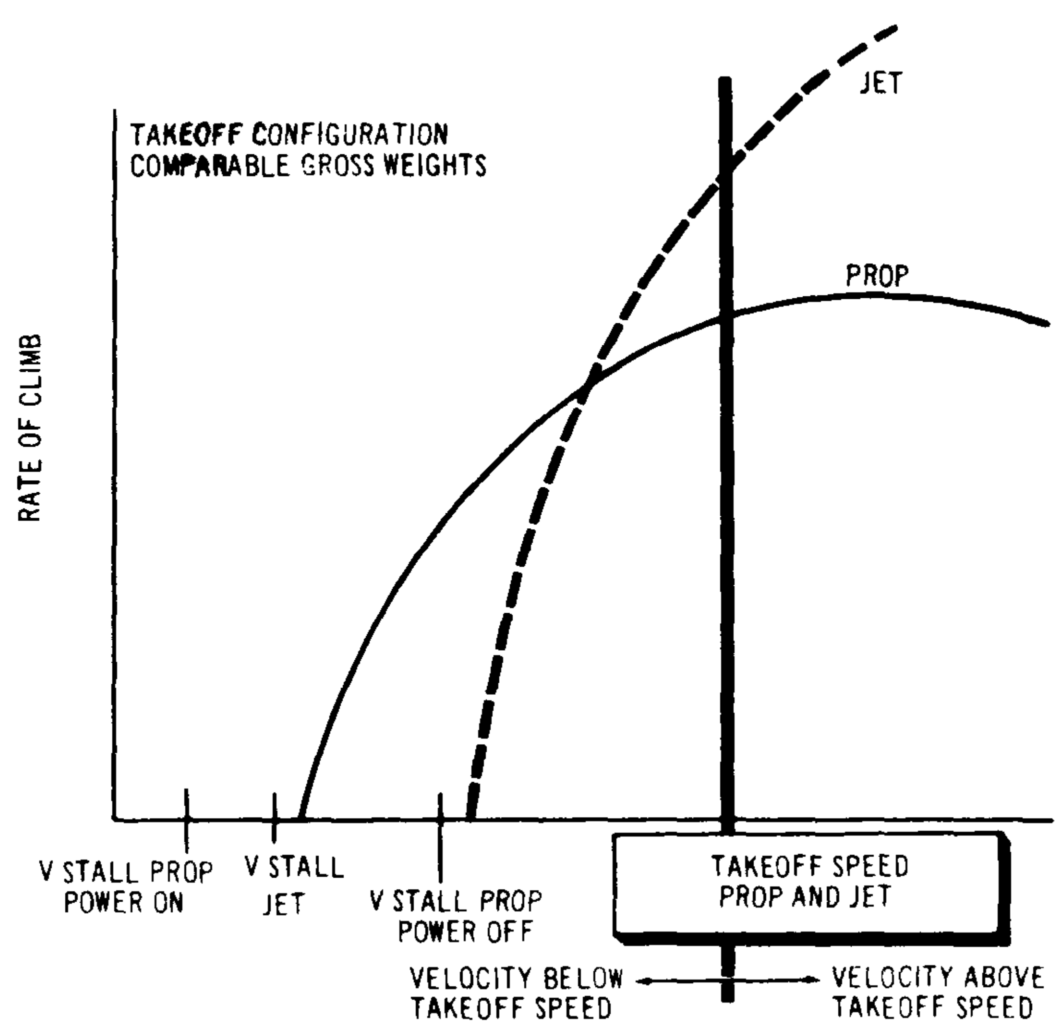


FIG. 1 — Difference in stall speed of propeller-driven airplanes with power on and with power off results from prop-wash around wings. Jet airplanes exhibit essentially the same stall pattern with or without power due to lack of air stream from props.

Jet aeroplanes, on the other hand, show a much smaller difference between power-on or power-off operation at low speeds. On a jet, airflow around the wing varies only when the forward speed of the aeroplane varies.

This difference between the lift characteristics of the propeller and jet aeroplanes with and without power requires a different handling technique during landings. For example, when a prop aeroplane appears to be settling down a trifle short of the intended touchdown spot on the runway, a pilot can ease the throttles forward slightly to increase power. Immediately, as the engine and props increase power, the added airflow around the wing generates additional lift. With more lift, the aeroplane reduces its rate of descent and stretches its glide to reach the desired touchdown point. During this manoeuvre, there may be very little change in the propeller aeroplane's forward velocity.

Such a procedure is not possible with the jets due to their lack of propeller slipstream. When a jet appears to be settling in short of the desired touchdown point, the nose should be raised with elevator control to increase lift and establish a new glide path. At the same time, throttles should be advanced to provide the additional thrust needed to counteract the added drag resulting from the increased angle of attack. When correcting glide path in this way, the desired approach speed should be maintained (rather than increased) with engine thrust as the glide path angle is adjusted with elevator control. Without propellers, additional lift to change the glide path can be generated quickly only by increasing the angle of attack of the wing. A jet's glide path can be readily adjusted provided enough elevator control and additional thrust are applied soon enough. Since drag increases rapidly with increased angle of attack, throttles must be advanced rapidly, even more than might be required for sustained operation, then retarded as necessary to maintain the desired airspeed.

LOW ALTITUDE WIND GRADIENTS

For years pilots have known that winds tend to decrease in velocity near the ground. The extent of this wind-velocity gradient is generally known to be similar to the curves shown in Fig. 3. Studies indicate that the greatest changes in wind velocity occur between 300 feet and the earth's surface. Most of the information on wind gradients, as shown in Fig. 3, pertain only to winds over grassy and otherwise unobstructed terrain. It is known, however, that wind gradients can be affected by terrain contours, wind velocities at altitude, the temperature lapse rate, and convective influences due to heating or cooling of the surface. Although wind velocities at various heights above the ground are difficult to predict, wind direction remains fairly constant below the 300-foot level. Another factor that complicates the problem of attempting to anticipate wind gradients during approaches is the non-uniform height at which wind velocities are measured at airports around the world. Measuring heights may vary from 5 to 100 feet at different airports.

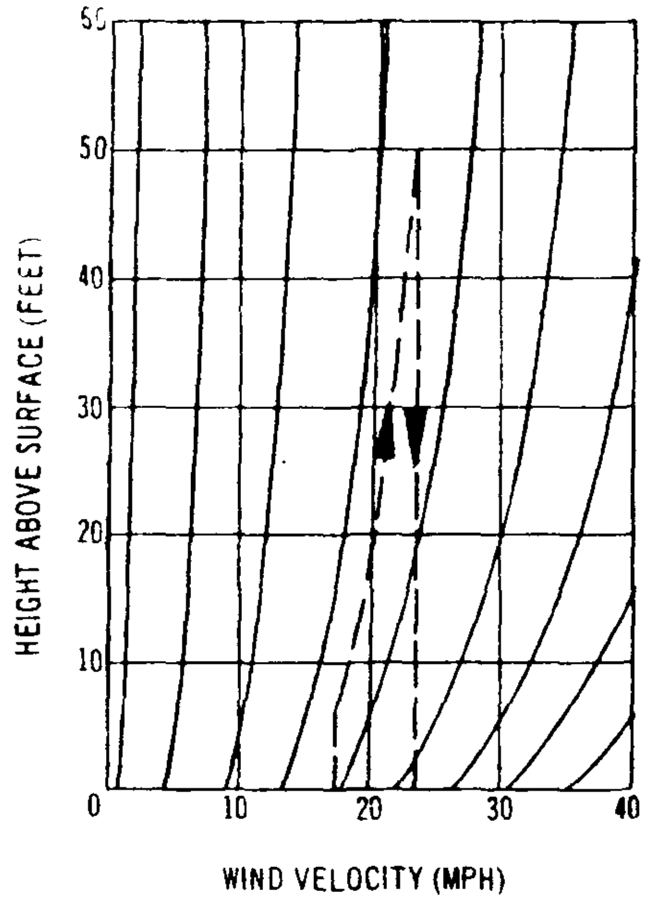


FIG. 2 – Average wind velocity differences relative to heights above the ground. By using this chart, pilots can relate wind speeds to be expected at ground level to the height where wind velocities are measured. Data from CAM 4b.

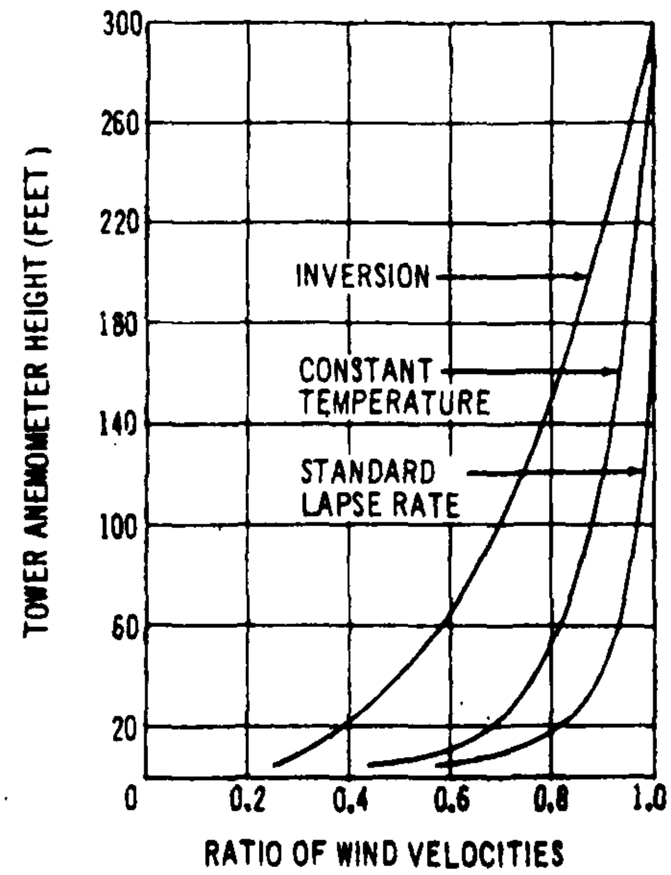


FIG. 3 — Variation of wind velocity expressed as ratios of wind velocity on the ground to velocity at various heights above the ground. Data from Handbook of Geophysics, ARDC, U. S. Air Force.

Wind gradient effects normally benefit an aeroplane during takeoff, because, as the aeroplane climbs into increasing wind velocity, the indicated airspeed increases faster than the aeroplane actually accelerates relative to the ground. Just the opposite occurs on landing. A high level headwind that decreases as the aeroplane approaches the ground causes a decrease in indicated airspeed that could, under certain conditions, allow the aeroplane to touch down earlier than expected. This is particularly true if the approach is over trees or relatively high buildings. At least one of the short landings reported during 707 operations to date has been laid to a sudden drop off in headwind velocity coupled with a lower than recommended approach airspeed before touchdown.

Following the analysis of wind gradient effects on approaches and landing, a change to the 707 Pilot Training Manual (Document D6-3529) has been recommended calling for an increase in the indicated airspeed to be used during approach. Due to the lack of definitive information on a wind gradient as it might exist at a destination airport, the following rule of thumb is being incorporated in the Pilot Training Manual to partially compensate for wind gradient effect.

One-half of the tower-reported wind velocity should be added to the V_{ref} on the approach to obtain the target speed. During this approach procedure, the airspeed bug should be left at the V_{ref} for the particular gross weight. As the aeroplane descends to the runway some bleed-off in airspeed should be expected. During the last portion of the descent, a pilot should be prepared to add considerable thrust to accelerate the aeroplane in case the airspeed bleed-off due to wind gradient is more than expected. To isolate the effects of wind gradient, flaps should be completely extended to the full landing position and airspeed stabilized before reaching the 300-foot level above the runway. Under these conditions, changes in airspeed due to wind gradient are readily apparent. In other words, as aeroplane passes through the 300-foot level above the runway, airspeed indication should be V_{ref} + 1/2 V_{wind} (wind velocity as reported by the tower) with landing flaps fully extended. As noted below the 1/2 V_{wind} addition should not exceed 20 knots. The curves in Fig. 3 indicate that a considerable wind gradient can be expected under certain conditions.

Gustiness must also be considered. Theoretically at least, gust effects should be added to any wind gradient correction. However, because the pilot can partially compensate with power and elevator control and some margins are already built into the 1.3 V_s reference speed recommended for approaches, the total speed correction added to the 1.3 V_s should not be more than 20 knots (maximum for combined gust and wind gradient corrections). Theoretically, the incremental approach speed increase due to gradient and gustiness approaches zero for the 90-degree crosswind. However, gustiness should still call for a speed increase over V_{ref} because of the possible directional shifts in the gusts. To cover both of these theoretical considerations, the following paragraph is being added to the Pilot Training Manual:

"The full value of the gusts should be added to V_{ref} in addition to the allowance for the wind gradient effect, except that the total velocity increment for both gusts and gradient need not exceed 20 knots. In the case of crosswinds, the component of wind down the runway only need be considered for gradient allowance; however, the full gust allowance would still apply regardless of wind direction."

What could happen if a headwind should fall off 10 knots below 300 feet is diagramed in Fig. 4. The short approaches indicated would occur only if a pilot made no correction to engine power or aeroplane attitude to extend his glide. Both diagrams show the flight paths followed by aeroplanes that hold the same airspeed as the wind velocity falls off. These examples show two things:

1. That pilots must be alert to changes in the glide path and make appropriate corrections to enable them to touch down 1000 feet from the end of the runway. When an allowance for headwind has been added to the reference speed, airspeed should be permitted to bleed off rather than attempt to hold the approach speed plus the 1/2 V_{wind} allowance.

2. Corrections are more difficult during a flat approach with a low rate of descent (Fig. 4B) than during a normal approach along an ILS glide slope (Fig. 4A).

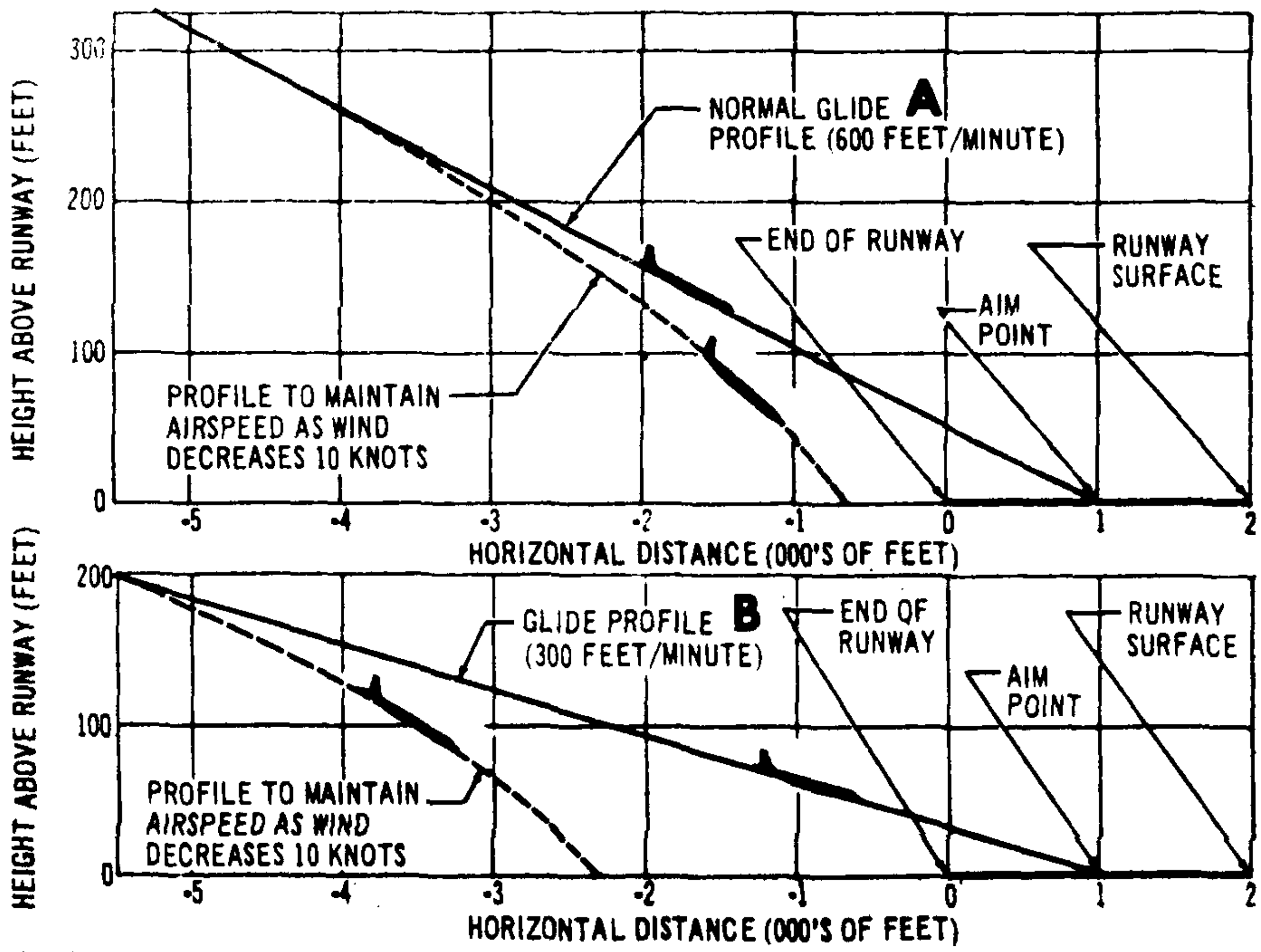


FIG. 4—(A) Wind gradient effect on a normal glide slope could change the flight profile as indicated unless pilot is alert to the changes required to continue to the desired touchdown point. (B) Flat glide slope requires greater correction to prevent landing short when wind velocity falls off close to the ground.

The pilot's judgment should remain the controlling factor during any landing, as the wind pattern and behaviour on every landing approach can vary considerably. Any rule or statement regarding wind characteristics near the ground can at best be only a crude generalization. The above discussion on the nature of wind gradients should help to clear up some of the questions and make pilots more aware of the nature of wind effects during approach and landing.

APPROACH PATH ANGLE

Closely allied with speed control during approach is the control of glide path angle (Figs. 4A and 4B). As the training manual indicates, final approach at V_{ref} with a descent rate of 600-800 feet/minute works out to a glide path angle very close to 3 degrees, which is quite often the ILS glide slope angle for instrument approaches. Attempts to fly the 707/720, or any airplane at a flatter angle than the 2.5 to 3-degree recommended glide slope makes judgment of height over the ground and glide path aim point extremely difficult, particularly at night. If other factors should be less than optimum, a flat glide path angle could easily result in an inadvertent touchdown short of the runway. Due to the inherent differences between propeller-driven and jet aeroplanes, pilots should practice the 3-degree glide path approach even when visibility conditions do not require the use of ILS.

A recommended approach and landing consists primarily of --

1. Aiming at a point on the runway about 1000 feet from the end and maintaining a close control over airspeed during the final approach.

2. Making a slight but definite flare to reduce sink rate.

3. Getting the main gear wheels onto the runway immediately after the flare (even if forward speed should exceed the desired touchdown speed).

If pilots will consistently follow these procedures, there will be less chance of undershooting the runway or of over-running the end of the runway due to floating. If runway surface conditions are less than ideal, using up available runway by "floating" will make it difficult to stop the aeroplane within the remaining runway. (See "Stopping Under Adverse Conditions, "AIRLINER for December 1960, page 3.)

STOPPING UNDER ADVERSE CONDITIONS

Reprinted from the Boeing Airliner,
December 1965, published by the Boeing Company

Adverse weather conditions at a destination airport have contributed to several landing incidents in which a 707 has either partially lost directional control and veered to the side of the runway or has gone beyond the end of the runway. Since adverse weather can affect a number of factors during a landing, it is important to the safe and efficient operation of 707 and 720 airplanes for pilots to know how to -

1. Operate the airplane during the approach in a way that will minimize stopping requirements after touchdown without running the risk of landing "short." These are "in-the-air" factors.

2. Stop the airplane in the shortest distance when the runway is wet, short (runway remaining from point of touchdown), or icy. These are "on-the-ground" factors.

Obviously it is more difficult to stop an airplane within the available runway if it touches down 20 knots over the recommended touchdown speed. A number of other factors, such as excessive height over the threshold, glide path angle, drag and lift configuration, and gross weight also affect stopping requirements. Many of these factors are within the control of the pilot. Once on the ground, stopping distance varies with the coefficient of friction between tires and runway surface, timing and technique of braking action, operation of thrust reversers, and control surface handling technique. An analysis of these air and ground factors will enable operating personnel to utilize fully the maximum stopping ability of the airplane under whatever conditions may be existing during a landing.

In the accompanying charts, total landing distance is defined as the measured distance from the point at which the airplane is at a height of 50 feet with an airspeed of 1.3 V_s (V_s = stall speed) to the point where the airplane is stopped (Fig. 1). The total landing distance should not be confused with the handbook landing field length which is greater and is used for planning.

Fig. 1 - Defined distances and nomenclature used in the text. Total landing distance is based on a reference condition where the airplane is 50 feet over the end of the runway and touches down 1 000 feet from the end. The term, total landing distance, should not be confused with handbook field length which is used for planning.

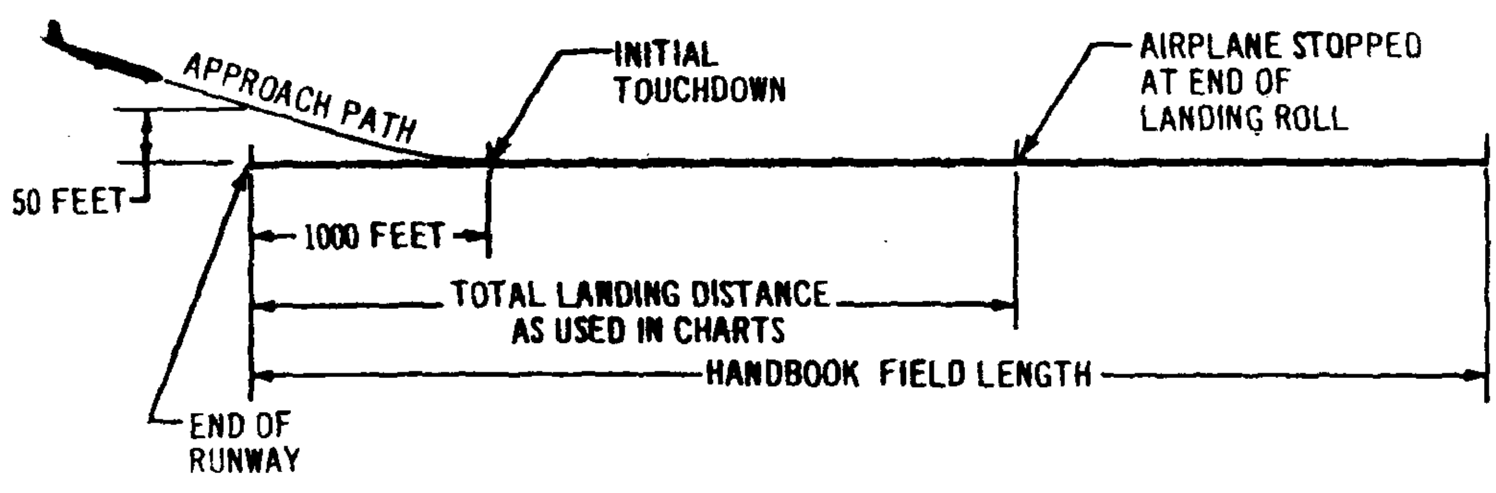


FIG. 1 —Defined distances and nomenclature used in the text. Total landing distance is based on a reference condition where the airplane is 50 feet over the end of the runway and touches down 1000 feet from the end. The term, total landing distance, should not be confused with handbook field length which is used for planning.

With so many factors affecting total landing distance, a meaningful analysis can only be made by holding all other factors constant while varying the one factor. This method of analysis will not achieve any absolute values, but it will show trends. Once these trends are understood, they can be compared to determine which of the factors are most important and which are negligible.

Trends for the factors which affect landing are shown in Figs. 2 to 9. Although these curves were drawn specifically for 720 aeroplanes, they also apply to 707 aeroplanes when allowances for gross weight differences are applied.

IN-THE-AIR FACTORS

Aeroplane handling by the pilot during the final approach can affect the total stopping distance, but pilots should be warned against trying to touchdown near the end of the runway. Aiming at a touchdown point 1 000 feet from the end of the runway will still provide sufficient distance to bring the aeroplane to a stop. Landing short of the runway can have even more serious consequences than overrunning the end at low speed. Floating just off the runway surface for several thousand feet before touchdown must be avoided as this procedure uses up a large portion of the available runway. If the aeroplane should be over the recommended speed at the point of intended touchdown, deceleration on the runway is about three times greater than in the air. Therefore, in such a case, the aeroplane should be set onto the runway as near the 1 000-foot point as possible rather than allow the aeroplane to float in the air to bleed off speed.

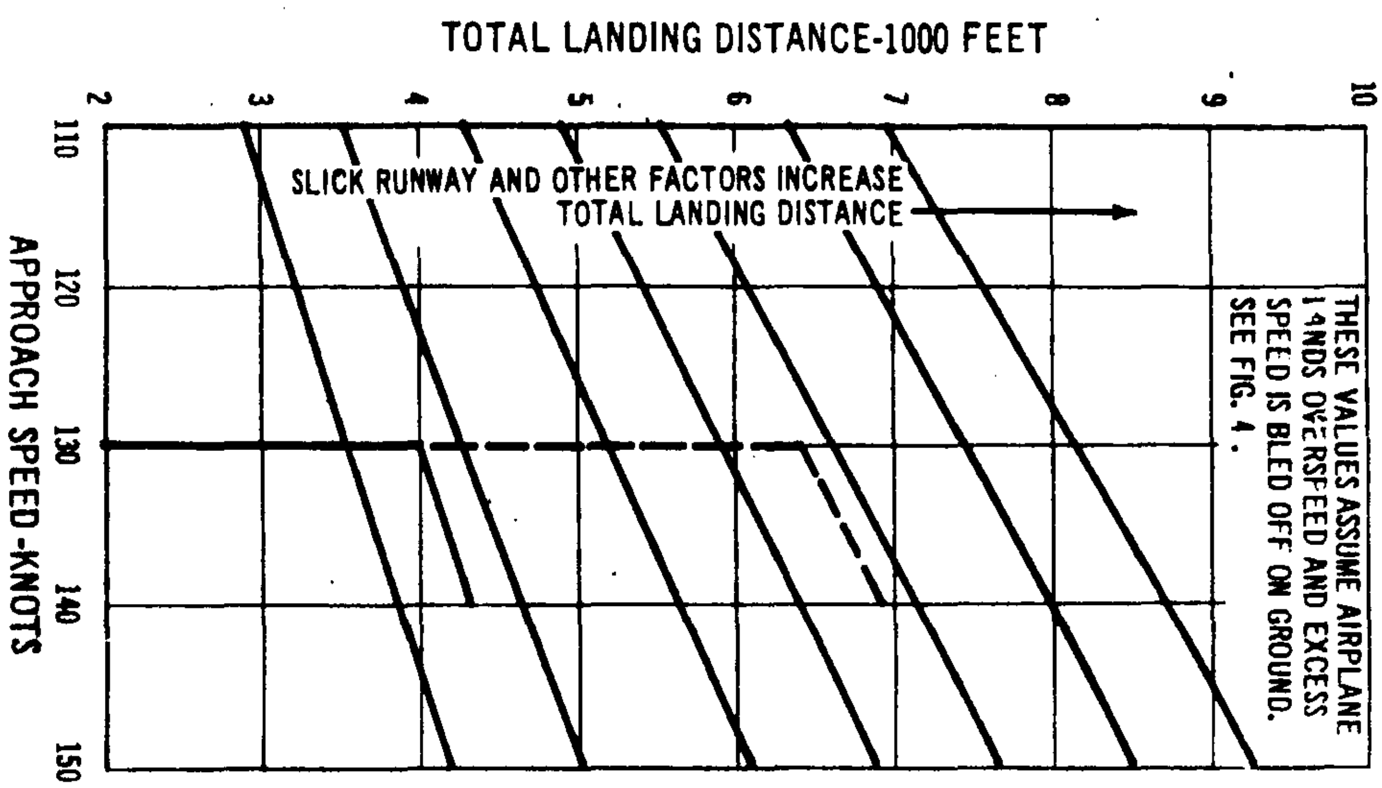


FIG. 2—Trend lines for effect of varying approach speeds on landing distance. Example lines show how to use different trend lines when other conditions, such as slick runway, high approach, or other variables change landing distance from 4000 feet to 6500 feet.

Approach velocity differences affect total landing distance in accordance with the trends in Fig. 2. Consider an aeroplane that would normally approach at 130 knots and require a normal landing distance of 4 000 feet. With other conditions constant, flying over the threshold with 10 knots excess speed at 140 and touching down 10 knots overspeed would increase total landing distance only 350 feet. If this 10 knots excess speed is bled off in the air before touchdown, landing distance will be increased by about 1 200 to 1 500 feet. See Fig. 3.

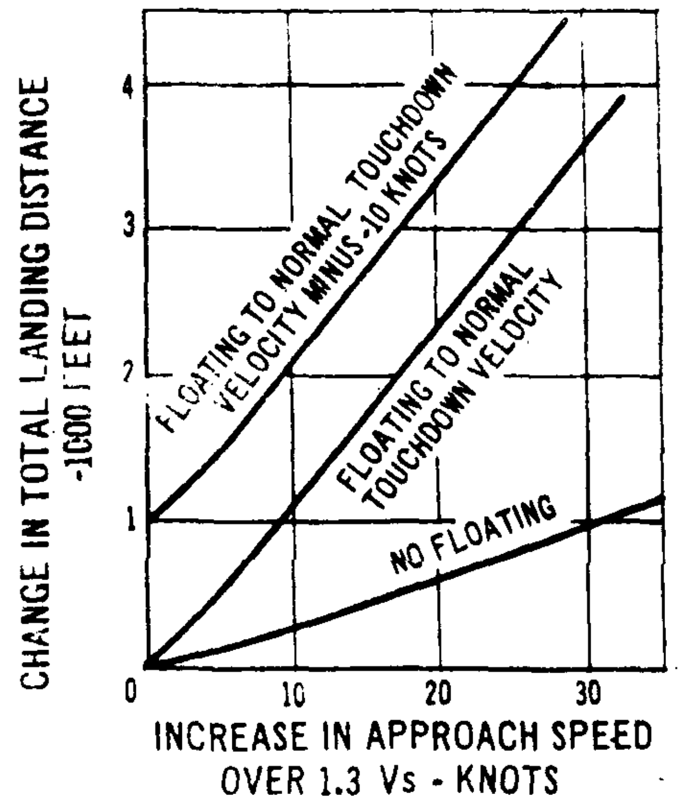


FIG. 3 —Floating before touchdown penalizes landing distance. Bleeding 10 knots below correct speed in air before touchdown increases landing distance by 1000 feet. If approach is 10 knots overspeed, floating and touching down on speed uses 1100 feet compared to 350 feet if deceleration is on runway rather than in air.

TYPICAL LANDING WEIGHT
COEFFICIENT OF FRICTION = 0.25
FLIGHT PATH ANGLE = 3°
SEA LEVEL
STANDARD DAY
RUNWAY SLOPE = 0
4 ENGINES AT IDLE THRUST

Under slick runway conditions, if 6 500 feet total landing distance would be required at an approach speed of 130 KIAS, coming in at 140 knots and touching down 10 knots overspeed would increase distance by 500 feet in accordance with the dotted lines shown in Fig. 2.

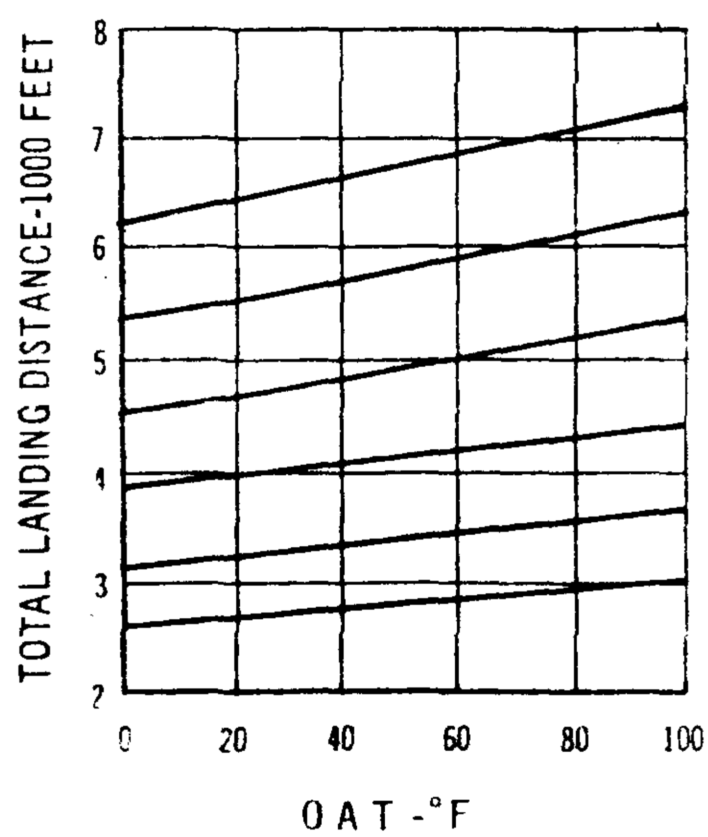


FIG. 4 —Trend lines for effect of outside air temperature on total landing distance. Here again, which trend line to be used depends on what landing distance would be required for any combination of variables other than OAT. Once a distance is known, trend lines show the variation expected for a change in OAT.

Height of the aeroplane over the end of the runway also has a very significant effect on total landing distance. The relatively steep trend lines of Fig. 5 show this effect for a range of glide slope paths. This chart indicates a change in total landing distance directly. For example, flying over the end of the runway at 100 feet altitude rather than 50 feet could increase the total landing distance by 950 feet on a 3-degree glide path. This change in total landing distance, results primarily because of the length of runway used up before the aeroplane actually touches down. Glide path angle also affects total landing distance as shown in Fig. 5.

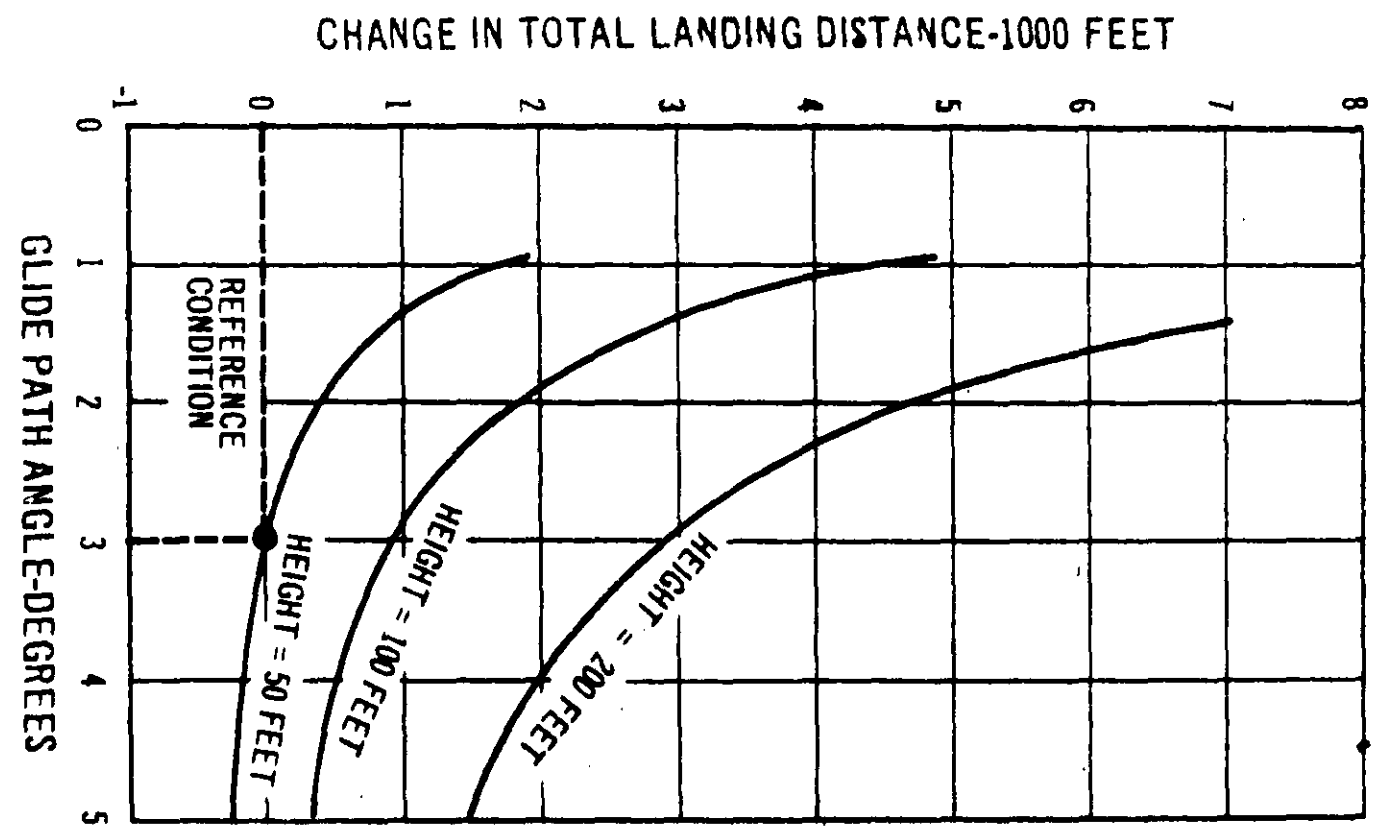


FIG. 5—Flat glide slope path and excessive height over end of runway combine to extend landing distance required due to runway used before touchdown. Reference conditions call for 50 feet over threshold while on 3-degree glide slope path.

Even while maintaining the 50-foot height over the end of the runway, total landing distance is increased as the approach path becomes flatter. A combination of excess height over the end of the runway and a flat approach uses up runway in a hurry. Glide path angle is a function of pilot technique and best results will be obtained at a normal ILS glide slope angle.

Usually, a wet or slick runway condition is accompanied by adverse weather conditions. Under these conditions an unsatisfactory approach may cause the aeroplane to run off the runway. If weather should contribute to a poor approach, pilots should be prepared to make an early decision to go around rather than touchdown far beyond the 1 000-foot aim point and run the chance of overrunning the end of the runway.

ON-THE-GROUND EFFECTS

Regardless of a pilot's technique in the air, the aeroplane must still be brought to a stop on the ground. Here again, pilot technique and the conditions existing at the airport affect the total landing distance.

Probably the most important factor that affects total landing distance is the coefficient of friction between tires and runway surface. This coefficient is a result of many variables, such as tire tread design, runway material, water or ice cover on the runway, air temperature, and rolling speed of tires. A normal effective coefficient of friction on dry concrete may be expected to vary between .25 and .30. On icy runways at temperatures near 32°F, tire friction may drop as low as .05. The range can be considerable, and the effects of these variations are shown in Fig. 6. It can be seen from this chart that landing distance can be significantly increased when a runway is covered with water and/or ice with other conditions constant.

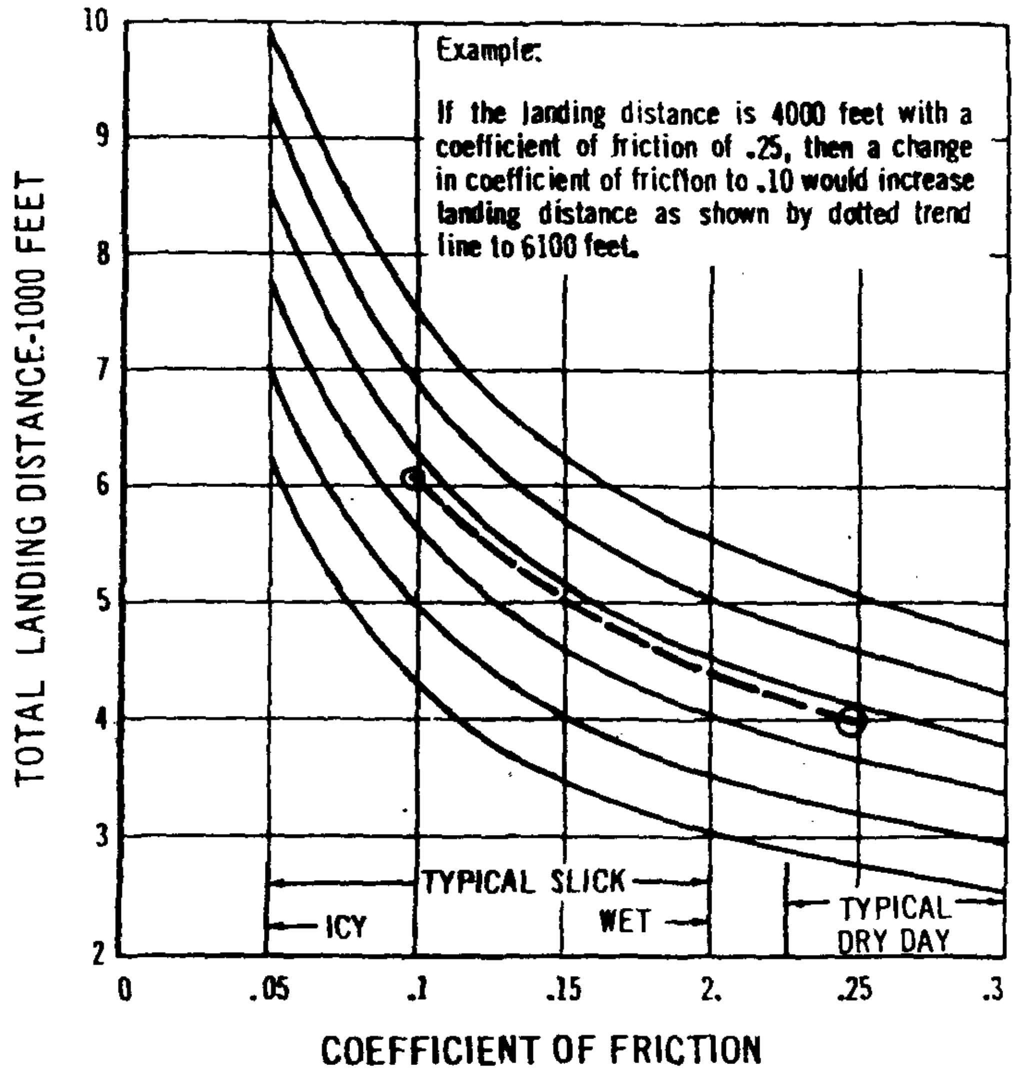


FIG. 6 —Trend lines for coefficient of friction show increase in stopping distance on wet or icy runway surfaces. Trend lines show only effect of friction. Which trend line used must be determined from length of runway required by variation of all other factors that affect distance.

Two related factors, coefficient of lift (C_L) and coefficient of drag (C_D), during the braking roll also affect landing distance even though the aeroplane is on the ground.

Basically, the C_L is constant for any specific aeroplane at the same configuration. However, aeroplane attitude and speed brake deflection affect C_L. Keeping the nose wheel off the ground, for example, produces a higher angle of attack for the wing than if the nose gear is rolling on the runway. This higher angle of attack develops lift and prevents the brakes from working to their full capacity, regardless of the condition of the runway. Therefore, immediately after touchdown, the nose wheels should be lowered to the runway and held there positively until taxi speed is reached. Speed brakes increase drag and lessen or "spoil" wing lift and, therefore, affect C_L during landing. The chart in Fig. 7 shows how a variation of C_L affects total landing distance. Aeroplane drag is not increased by keeping a nose-high attitude on the ground during landing roll.

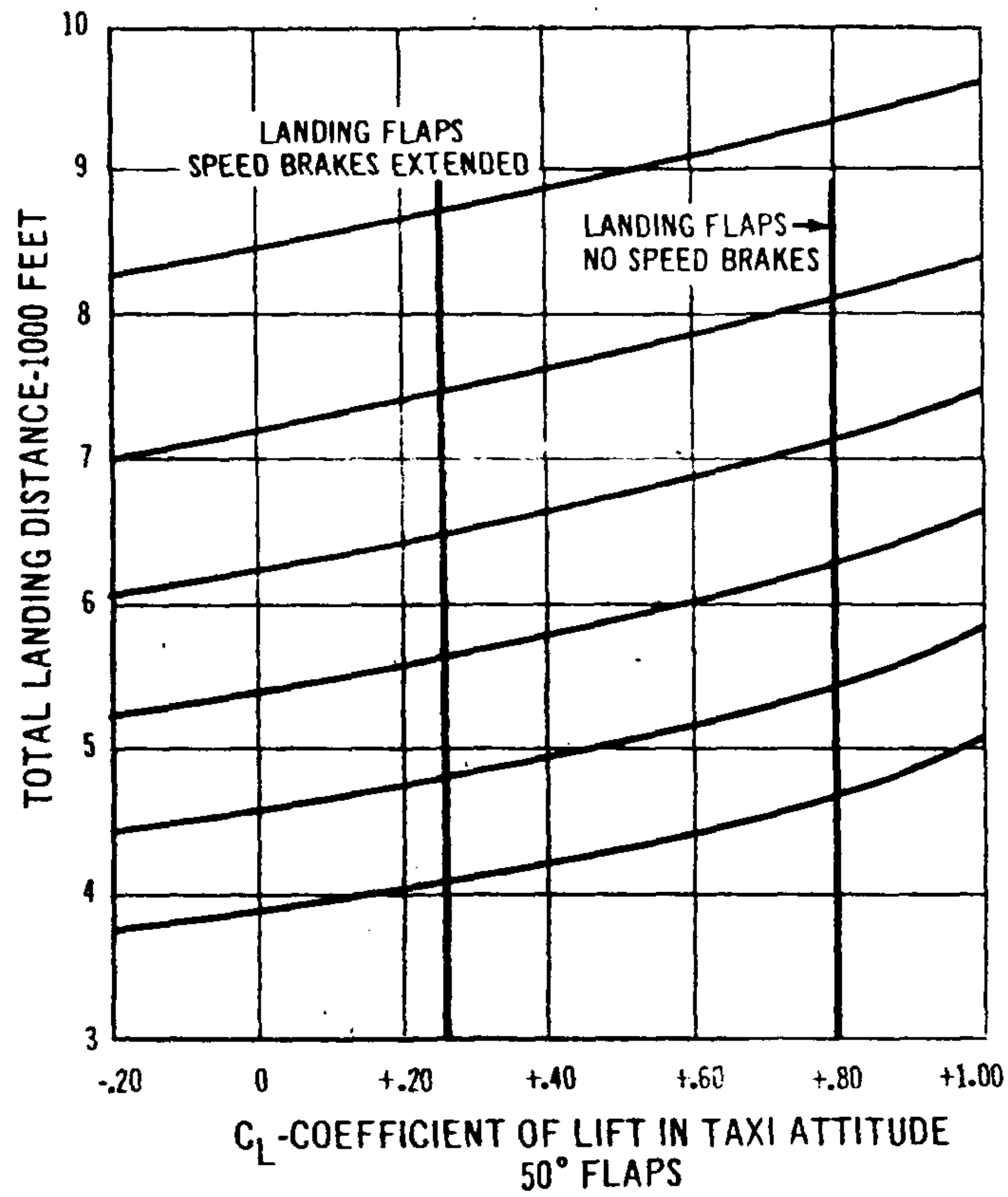


FIG. 7—Trend lines show variations in coefficient of lift. Difference in lift with speed brakes deflected and not deflected are shown between lines. Flaps are extended to 50 degrees.

Coefficient of drag (C_D) affects landing distance in accordance with the chart in Fig. 6 above. The major change in C_D over which a pilot has control is speed brake position. The effects of reduced lift and increased drag are additive in shortening landing distance.

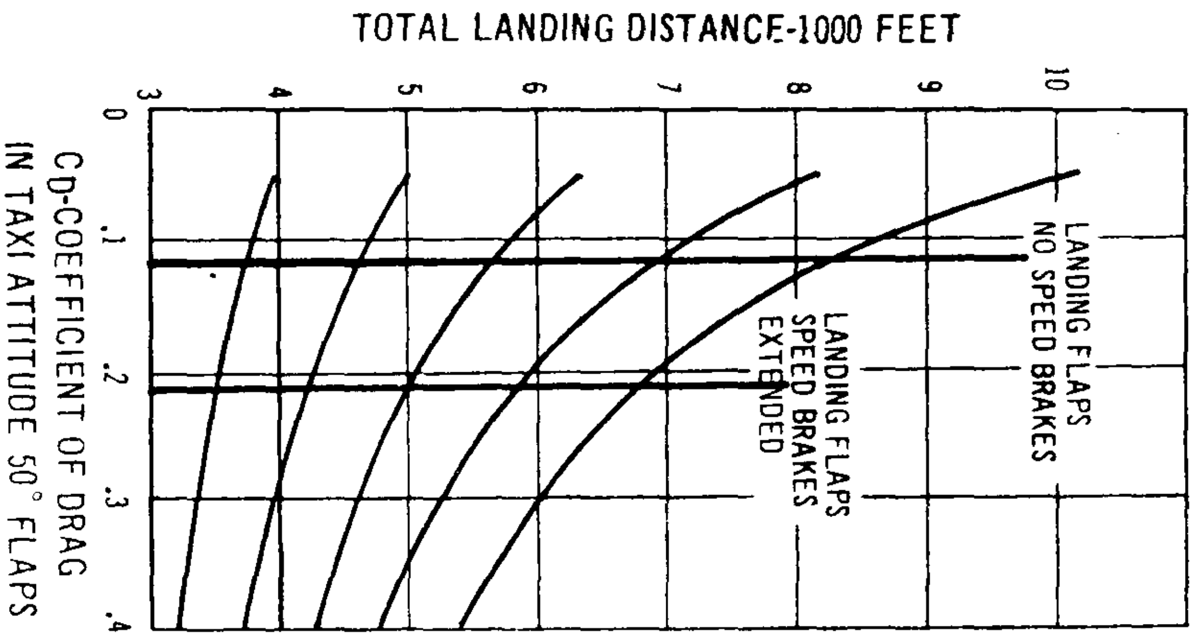


FIG. 8—Trend lines show effects of drag. As landing distance increases due to other factors, effect of speed brakes becomes progressively greater. Flaps are assumed at 50 degrees for both example lines.

Thrust reversers can be used to shorten the stopping distance once the aeroplane is on the ground and, thereby, shorten the total landing distance. By operating the thrust reversers at published limits during normal operation from touchdown to 60 knots indicated air speed, significant reductions in landing distance can be achieved. Fig. 9 (based on 60 knots cutoff) indicates how much of a reduction in landing distance is possible under the stated conditions. Normally, ingestion of exhaust gases may cause engine surging if thrust reversers are continued in full use at speeds below 60 knots. Partial reverse thrust can be used until taxi speed without ingestion.

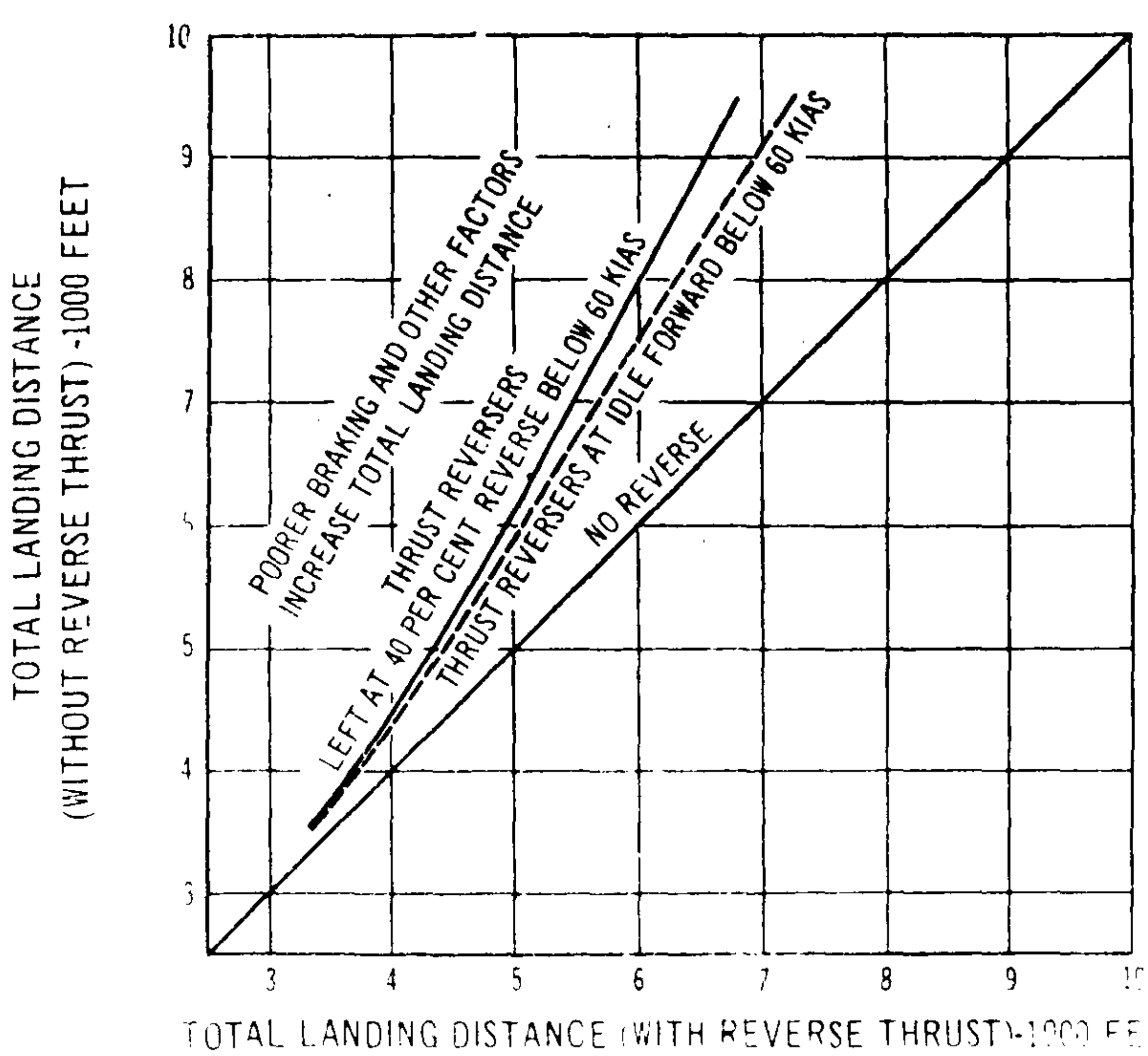


FIG. 9 - During normal landings, thrust reversers can reduce landing distance by differing amounts depending on whether thrust reversers are left in reverse or in idle when cut off below 60 knots. During emergency conditions, thrust reversers can be used below 60 knots, but effect on landing distance varies according to usage.

Transition time between touchdown and brake application affects total landing distance in accordance with the chart in Fig. 10.

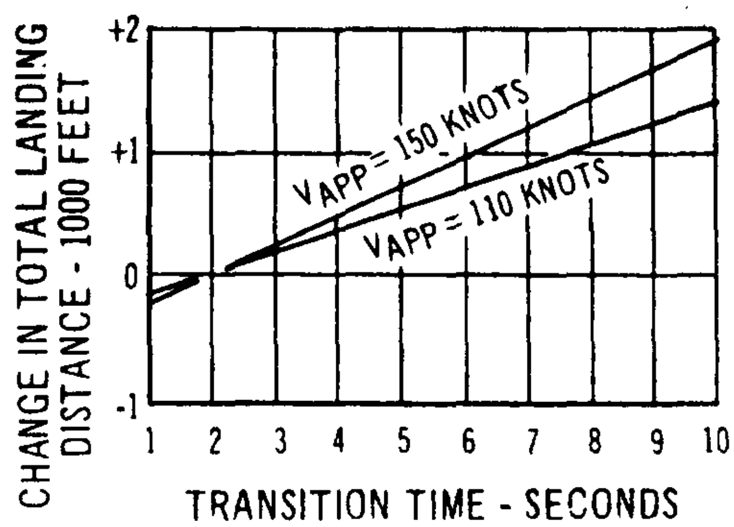


FIG. 10—Delay in applying brakes increases landing distance as shown for different speeds at touchdown. Normal time between wheels rolling on runway and brake application is two seconds.

STOPPING TECHNIQUES

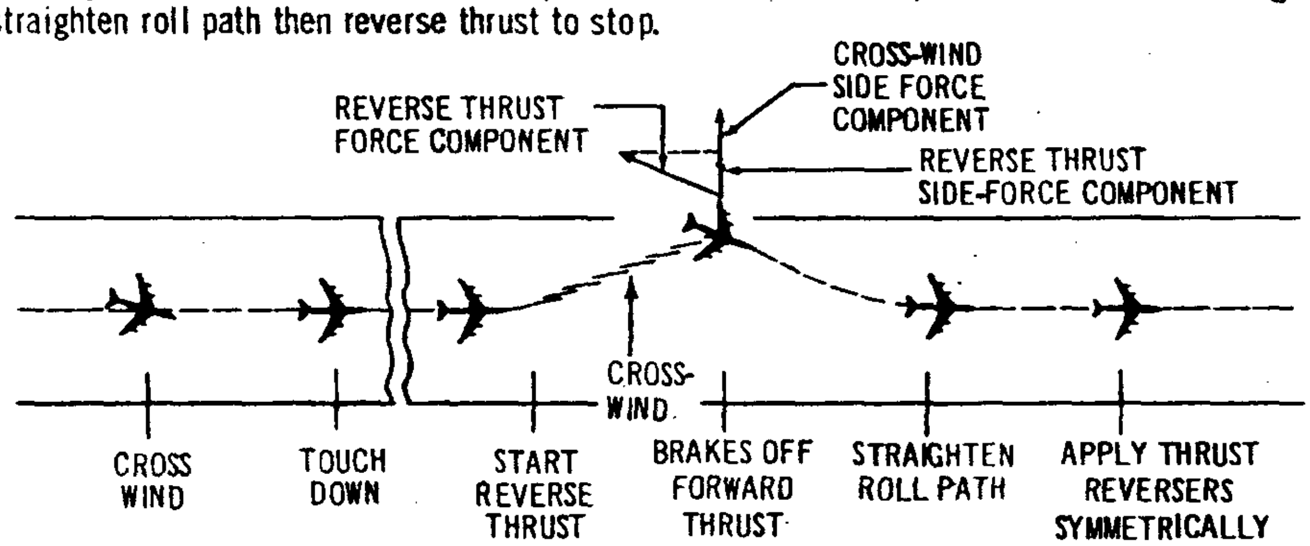
Actually, due to the many allowances applied in developing landing field lengths, a jetliner can normally be stopped with a good portion of the runway remaining. A number of factors which increase landing distance might combine to extend the normal distance required. Landing far beyond the 1 000-foot aim point may shorten the available distance to a critical length. If the runway is also slick, the combination of landing too far down the runway and the reduced braking effectiveness may require more runway distance than is available for normal stopping. Under emergency conditions, every available means for stopping should be exercised.

The importance of timing during the use of all means for stopping the aeroplane can not be over-emphasized. As soon as it is definitely known that the main wheels are rolling on the runway, use elevators to bring the nose wheels onto the runway smoothly and hold them there. Immediately, raise speed brakes to their full 60-degree deflection, apply wheel brakes, and actuate thrust reversers.

As noted earlier, raising speed brakes reduces wing lift and increases drag, both of which help to slow the aeroplane. Bringing the nose gear down to the runway also reduces wing lift and increases the effectiveness of the brakes. Throughout the landing roll, keep enough forward pressure on the control column to hold the nose wheels on the runway. Keeping the nose wheels on the runway noticeably improves directional stability particularly in cross-winds.

Thrust reversers should be used symmetrically at high power as soon as possible during the landing roll. The brakes and thrust reversers should be applied together. Due to the 3-to-5 second delay before the build-up of full effective reverse thrust, brakes will normally be operating before reverse thrust. Braking thus counteracts any pitch-up tendency that may develop. Since thrust reversers are most active in reducing landing distance when applied during the high speed portion of the landing roll, it is important that they be in operation early at maximum allowable power. Under emergency conditions, the normal thrust reverser engine and ground speed restrictions may be exceeded by using full throttle down to a complete stop. Normally, of course, thrust limitations for reverse thrust applicable to each aeroplane must be observed. Engine surging may begin to occur at around 60 knots due to cross ingestion of exhaust gases. When this happens, it may be desirable to back off on the inboard engine throttles to minimize surging. Actually, when a jet engine is surging, it is developing very little thrust; therefore, nothing is lost by reducing throttle position. Outboard engines are not sensitive to ingestion of exhaust gas when throttles are reduced on inboard engines. Should it be necessary to reduce inboard engine power, it is preferable to leave the inboard engines in reverse at about 40-45 per cent of N_1 RPM rather than idle forward to eliminate the forward thrust which would be present. Fig. 9 shows the advantage of keeping the engines in reverse below 60 knots rather than idle forward. This is particularly applicable to turbofan engines that develop considerable thrust at idle.

FIG. 11-During cross-wind landing side thrust from thrust reversers, once airplane is canted to centerline, plus cross-wind can drive airplane off runway. To correct path, return all engines to forward thrust at low power to return to center, use differential braking to straighten roll path then reverse thrust to stop.



Thrust reversers must be used symmetrically at high power and the application of differential reverse thrust should be avoided. During the application of reverse thrust, all levers should be rotated simultaneously. If one reverser should fail to move into reverse position immediately, its opposite should also be left at the interlock. The pair of engines that were originally left at interlock may be tried again in case a slow-acting rather than a malfunctioning reverser caused one reverser lever to stop at the interlock position.

Attempting to use asymmetrical thrust will not gain any stopping advantage, because brakes must be eased off on one side to keep the aeroplane headed straight. The reduction in braking offsets any benefit that might be derived from using asymmetrical thrust. Also, when runway conditions are slick, brakes may not be sufficient to prevent asymmetrical thrust from veering the aeroplane to one side (Fig. 13). Under certain conditions, reverse thrust and a strong cross-wind may drive the aeroplane off the centerline. Corrective action to straighten the aeroplane roll path is to return all engines to forward thrust (to reduce the thrust element tending to drive the aeroplane to the side and to get the aeroplane back near the center on the runway) and use differential wheel brakes and rudder to straighten the landing roll. Once the aeroplane is straight with the runway and near the center, thrust reversers should again be set up symmetrically if needed.

Reverser lights in the cockpit are for the purpose of indicating when thrust reverser clam-shell doors are not in their cruise position. They should not be used as a guide to indicate when reverse levers may be lifted to apply reverse thrust. This can be determined by the release of the reverse lever interlock.

The 707 anti-skid system prevents excessive skidding or a locked wheel condition under all runway and operating conditions. During a landing, a sensor in each tandem pair of wheels senses a wheel skid and automatically relieves hydraulic pressure to those wheels until they begin rolling again. The rate of anti-skid cycling during a landing roll depends on how much brake pressure is being applied and the coefficient of friction between tire and runway surface. During a portion of every skid cycle, a wheel is producing considerably less braking effort than when it is rolling but being braked to the point just before starting to skid. During cycling when brake pressure is being relieved and later reapplied, tires produce little braking. Therefore, excessive cycling of the anti-skid system reduces total braking effort roughly in proportion to the cycling rate (Fig. 12).

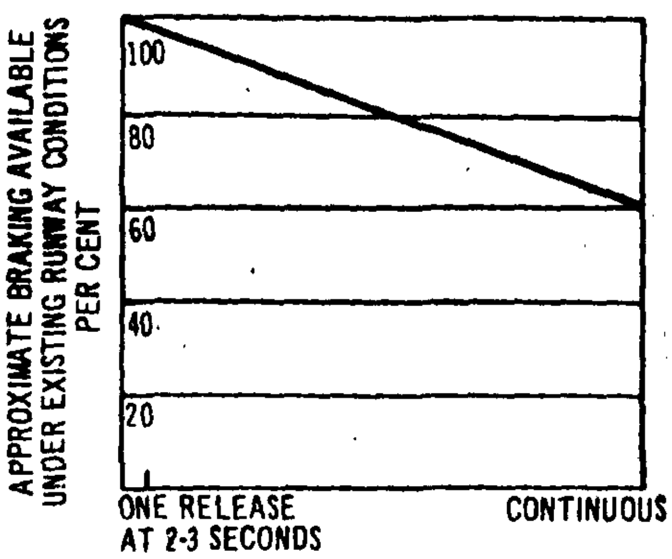


FIG. 12- Braking effectiveness drops as rapidity of anti-skid cycling increases. One release about every 2 to 3 seconds develops near the maximum braking possible under existing conditions.

Maximum braking effort from wheels occurs when only enough brake pedal pressure is used to produce an occasional anti-skid brake release; that is, approximately one release every 2 to 3 seconds. A pilot can feel anti-skid cycling from a "kick" in the brake pedals. Large differences in cycling rates, due to the difference in brake pressure to left and right landing gear, a cross-wind, or runway conditions could cause an airplane to veer off to one side or the other (Fig. 13).

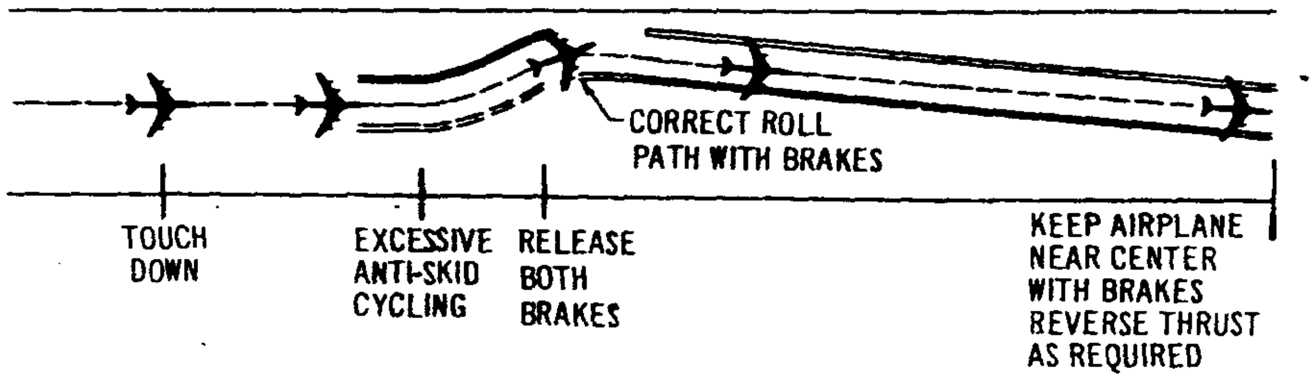


FIG. 13—Reduced braking effectiveness due to anti-skid cycling on one side may cause airplane to veer toward one side of the runway. Corrective action for this is to release pressure to both brakes, then apply brakes to one side. When airplane is again headed toward center of runway, apply all brakes to slow airplane. Reducing pressure to rapidly cycling brakes increases braking capability.

Under wet or icy runway conditions relatively light pedal pressure can produce excessive cycling. The pilot must realize that the pedal pressure which keeps him at a minimum cycling rate provides the best braking possible under the existing conditions.

To correct an aeroplane's veering course due to anti-skid cycling and cross-wind effects, let off on both brakes while keeping wings level. Immediately apply differential braking on the side necessary to bring the aeroplane back toward the center of the runway. When the aeroplane is again rolling parallel with the runway and near the centre, apply pedal pressure to develop maximum braking. This calls for adjusting pedal pressure such that one anti-skid release occurs about once every two to three seconds. An anti-skid release can be felt by a kick in the brake pedals. The rudder should also be used to maintain directional control. Under emergency conditions nose-wheel steering can be used for directional control rather than differential braking.

In summary, when a 707 is due to land on a runway that has become slick due to ice, snow, or excessive water, the pilots should be warned before making the approach. The aeroplane should then be handled before touchdown in a manner that will keep the total landing distance short and use as much as possible of the full-strength runway surface without risking a "short" landing. During the approach a pilot should --

1. Aim for a touchdown about 1 000 feet from the end of the hard surface runway. On the recommended glide slope path (3 degrees), this calls for a 50-foot height over the end of the runway. While it is important not to land long, it is even more important not to land short of the runway.

2. Maintain a close control over approach speed to keep it at the speed recommended for existing conditions. Extreme care should be taken to keep speed high enough to avoid a partial stall due to gusts or to a decay in headwind velocity near the ground.

3. Control glide slope path to get the wheels on the runway at about 1 000 feet from the end of the runway. Probably the major cause of long landings is holding the aeroplane off the ground. The aeroplane should be touched down at the aim point even if speed is excessive.

In case an unsatisfactory approach is likely to cause a touchdown far down the runway, go around and make a second approach.

Once on the ground, the crew should strive for --

1. Best braking effectiveness and maximum reverse thrust consistent with existing runway conditions. This means keeping as much pedal pressure on brakes as possible without excessive cycling of the antiskid release and using thrust reversers immediately after touchdown.

2. Minimum lift coefficient; that is, speed brakes 60 degrees and nose wheels on the runway.

3. Maximum drag; that is, flaps full down, speed brakes 60 degrees, and aeroplane in taxi position.

Keeping these factors in mind will permit stopping the aeroplane with the least landing roll.

PART IV

List of Laws and Regulations of States containing provisions relating to "Aircraft Accident Investigation"

(Replacing list in Digest No. 14)

ARGENTINA

1952	oct.	9	Resolución Núm. 100 (S. A. C.) - Normas para la investigación de accidentes de aviación civil y directivas generales para la investigación. Ampliada el 8 de enero de 1954.
1954	enero	12	Decreto Núm. 299 - Creación de la Junta de Investigaciones de Accidentes de Aviación y competencia de la Subsecretaría de Aviación Civil y Comando en Jefe de la Fuerza Aérea Argentina en la Investigación de Accidentes Civiles y Militares respectivamente.
	julio	15	Ley Núm. 14. 307 - Código Aeronáutico de la Nación: Título XVIII. - Disposiciones varias (Art. 208).
1957	feb.	19	Normas para investigación de accidentes de aeronaves de propiedad particular.

AUSTRALIA

1947	Aug.	6	The Air Navigation Regulations, S. R. No. 112/1947, as amended: Part XVI. - Accident Inquiry (Regs. 270-297).

AUSTRIA

1957	Dec.	2	The Federal Air Law: Part VIII. - D) Investigation of civil aircraft accidents.
1958	March	29	Ordinance No. 68 relating to aircraft accident investigation.

BOLIVIA

1964	agosto	28	Decreto Supremo Núm. 06877 - Reglamentación Técnica y Administrativa de la Ley de creación de la DGAC de 25 de octubre de 1947: (Art. 1 t).

BRAZIL

1948	April	15	Accident Inquiry Service Regulations (Decreto Núm. 24. 749).
1951	July	24	Portaria 280 - Recommendations relating to aircraft accident investigation.
1955	Feb.	28	Aviso Núm. 6 - Establishment of time for the accident inquiry service regulations.
1955	Sept.	9	Aviso Núm. 34-GM-4 - Interdiction of aircraft accident.

BULGARIA

1963			Law on Civil Aviation (Official Gazette No. 1 - 4 January 1963): VI. - Section 44.

BURMA

1934			The Union of Burma Aircraft Act, 1934 (XXII of 1934): Section 7. - Power of the President of the Union to make rules for investigation of accidents.
1937			The Union of Burma Aircraft Rules, as amended: Part X. - Investigation of Accidents.
1949	August		Notice to Airmen No. 5/1949 - Aircraft Accident and Incident Investigations.

CANADA

1960	Dec.	29	The Air Regulations, Order in Council P. C. 1960-1775 (SOR/61-10), as amended: Part I. Sec. 101. (6), (7) - Interpretation. Sec. 102. - Application. Part VIII. Div. III. - Accidents and Boards of Inquiry.
1964	Oct.	7	Air Navigation Order, Series VIII, No. 1 - Aircraft Accidents and Missing Aircraft (SOR/64-433).

CEYLON

1950	March	29	Air Navigation Act, No. 15/1950: Part I. Section 12. - Power to provide for investigation into accidents.
1955	May	4	Civil Air Navigation Regulations: Ch. XVI. - Accident Inquiry (Regs. 260-271).

CHAD

1963	avril	11	Décret N° 78/PR/TP portant Code de l'Aviation Civile: Livre I^{er} - Titre IV. - Des Accidents.

CHILE

*1951			Manual sobre Investigación de Accidentes de Aviación (Publicación de la Dirección de Aeronáutica MT 4-9).

CHINA (TAIWAN)

1953	Oct.	21	Civil Air Regulations No. 102 - Accident Reporting and Investigation.

* The text does not exist in the files of ICAO.

COLOMBIA

1960	julio	18	Decreto Supremo Núm. 1721 por medio del cual se crea y organiza el Departamento Administrativo de Aeronáutica Civil y se fijan sus funciones: II. Art. 5 c), IV. Art. 10 b), XII. Art. 38 d), XIII. Art. 40 b), XXII. Art. 61.
1964			Manual de Reglamentos Aeronáuticos: Parte VIII. - Seguridad Aérea - 82. Investigación de Accidentes.

COSTA RICA

1949	oct.	18	Ley General de Aviación Civil Núm. 762: Parte I. - Título I. - Cap. 2 Sección VIII. - Accidentes.
*1957	nov.	27	Decreto Ejecutivo Núm. 47 - Regulaciones aéreas: Parte VI. Accidentes. (La Gaceta, 12. 12. 57)

CUBA

1964	sept.	18	Ley Núm. 1160 por la que se crea el "Instituto de Aeronáutica Civil de Cuba": Art. 2. d). (Gaceta Oficial Núm. 30 - 22. 9. 64, p. 585)

CZECHOSLOVAKIA

1947			Decree of Ministry of Interior on accident investigation, No. 1600/47.
1956	Sept.	24	Civil Aviation Act: Para. 45. - Investigation of Aircraft Accidents.
*1961			Regulations on Administrative Investigation of Aircraft Accident Causes.

DAHOMEY

1963	déc.	27	Ordonnance N° 26/GRPD/MTP portant Code de l'Aviation Civile et Commerciale: Livre Ier - Titre IV. - Des Accidents.

DENMARK

1960	June	10	The Civil Aviation Act. Came into force on 1 January 1962: Chapter XI. - Investigation of Accidents (Paras. 134-144).

EAST AFRICA

*1965			The Civil Aviation (Investigation of Accidents) Regulations, as amended.

EAST GERMANY

1963	July	31	Civil Aviation Law: IX. Flight Operation - Para. 44 - Investigation of Incidents.

* The text does not exist in the files of ICAO.

ECUADOR

1954	julio	8	Acuerdo Ministerial Núm. 7 - Reglamento de Aeronáutica Civil del Ecuador: Título II. Parte 8. - Investigaciones y encuestas de accidentes de aviación.

EL SALVADOR

1955	dic.	22	Decreto Núm. 2011 - Ley de Aeronáutica Civil: Cap. XV. - De la Investigación de Accidentes Aéreos (Art. 173-187).

ETHIOPIA

*1961	March	1	Investigation of Accident Regulations.
1962	Aug.	27	The Civil Aviation Decree No. 48/1962: 2. (b) (xiv) - Power of the Civil Aviation Administration to provide for investigation of accidents.

FRANCE

1937	avril	21	Décret relatif à la déclaration des accidents d'aviation.
1953	janv.	3	Instruction interministérielle relative à la coordination de l'information judiciaire et de l'enquête technique et administrative en cas d'accident survenu à un aéronef français ou étranger sur le territoire de la Métropole et les territoires d'Outre-mer.
1957	juin	3	Instruction du Secrétaire d'Etat aux Travaux Publics, aux Transports et au Tourisme no 300 IGAC/SA, concernant les dispositions à prendre en cas d'irrégularité, d'incident ou d'accident d'aviation.
*1961	nov.	2	Arrêté relatif aux commissions d'enquête sur les accidents d'aviation.
1962	juin	20	Arrêté portant organisation et attributions du bureau "Enquêtes - Accidents" à l'inspection générale de l'aviation civile.

GERMANY (FEDERAL REPUBLIC OF)

1959	Jan.	10	The Aeronautics Act, as amended on January 8, 1961: Article 32 6).
1960	Aug.	16	General Administrative rules with respect to the technical inquiry in case of accidents occurring during the operation of aircraft.

GHANA

1958			Civil Aviation Act, 1958: Part II. - Paragraph 8 - Investigation of Accidents.

* The text does not exist in the files of ICAO.

GREECE

*1955	Dec.	30	Royal Decree on aircraft accident investigation (G.G. 27/A/56).
*1956	Nov.	20	
*1963			Amended by Royal Decree No. 377/1963 (G.G. No. 110/63/A).

GUATEMALA

1948	oct.	28	Decreto Núm. 563 - Ley de Aviación Civil: Capítulo X. - De los siniestros aeronáuticos (Art. 116-121).

HONDURAS

1957	sept.	3	Decreto Núm. 146 - Ley de Aeronáutica Civil: Título I. - Cap. II. - Dirección General de Aeronáutica Civil - (Art. 6 XIII). Cap. XIV. - Investigación de Accidentes Aéreos.

ICELAND

1964	May	9	Aviation Act - Chapter 11. - Flight Accidents Articles 141-147 - Investigation of Flight Accidents.

INDIA

1934	Aug.	19	The Indian Aircraft Act, 1934: Section 7. - Power of Central Government to make rules for investigation of accidents.
1937	March	23	The Indian Aircraft Rules, 1937, as amended: Part X. - Investigation of Accidents.

IRAQ

1939	Aug.	6	The Air Navigation Law No. 41: Article 5 (h).

IRELAND

1936			The Air Navigation and Transport Acts 1936 to 1959: No. 40/1936: Part VII. - Section 60 - Investigation of Accidents.
1957	Feb.	9	The Air Navigation (Investigation of Accidents) Regulations, S.I. No. 19/1957.

ITALY

1925	Jan.	11	Decree Law No. 356 - Rules for Air Navigation, as amended: Chapter VII.
1942	April	21	The Navigation Code, approved by Royal Decree No. 327 of 30 March 1942: Second Part - Air Navigation - Investigation of Accidents (Arts. 826-833).

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* The text does not exist in the files of ICAO.

IVORY COAST

1963 déc. 26 Loi nº 63-528 relative à l'aviation civile et commerciale: Livre Premier - Titre IV. - Des accidents.

JAMAICA

1953 The Air Navigation (Investigation of Accidents) Regulations No. 37/1953.

JAPAN

1952 July 15 Civil Aeronautics Law No. 231, as amended: Chapter 9 - Art. 132. - Investigation of Accidents.

JORDAN

1953 Law No. 55 on Civil Aviation: Investigation of Accidents (Article 106).

KOREA

1961 March 7 Aviation Law No. 591: Chapter IX. - Investigation of Accidents (Article 114).

LEBANON

1949 Jan. 11 Aviation Law: Chapter III. - Sub-Chapter 2 - Landing of Aircraft (Article 39).

LIBERIA

1962 Civil Aviation Regulations, effective July 1, 1963: Part VIII. - Aircraft Accident Investigation.

LIBYA

1956 The Civil Aviation Law No. 47: Part VI. - Accident Inquiry (Annex 13).

MALAYSIA (FEDERATION OF)

*1953 Nov. 1 Air Navigation (Investigation of Accidents) Regulations (L.N. 584/53).

MALI

1962 janv. 15 Loi nº 62-12 AN-RM relative à l'aviation civile et commerciale: 1ère Partie - Titre VI. - Des enquêtes sur les accidents d'aviation.

MALTA

*1956 Civil Aviation (Investigation of Accidents) Regulations.

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* The text does not exist in the files of ICAO.

MAURITANIA

1962	juil.	3	Loi n° 62-137 portant Code de l'Aviation civile: Article 9. - Enquêtes.
1962			Décret portant réglementation de la navigation aérienne: Première Partie - Titre VI. - Des enquêtes sur les accidents d'aviation.

MEXICO

1949	dic.	27	Ley de Aviación Civil (Libro IV de la Ley de Vías Generales de Comunicación): Cap. XIV. - De los Accidentes y de la Búsqueda y Salvamento (Art. 358-361).
1950	oct.	18	Reglamento para Búsqueda y Salvamento e Investigación de Accidentes Aéreos (en vigor a partir del 1° de enero de 1951).

MOROCCO

1962	juil.	10	Décret n° 2-61-161 (7 safar 1382) portant réglementation de l'aéronautique civile: Ière Partie - Titre VI. - Des enquêtes sur les accidents d'aviation (Art. 106-114).

NEPAL

1959	April	22	Act No. 22 to control and regulate civil aviation: Section 5. - Power of His Majesty's Government to issue rules pertaining to investigation of accidents.

NETHERLANDS

1936			Act regulating the Investigation of Accidents to Civil Aircraft (St. B. 1936, 522).

NEW ZEALAND

1948	Aug.	26	The Civil Aviation Act, 1948, as amended: Article 8. - Power to provide for investigation of accidents.
1953	Nov.	11	The Civil Aviation (Investigation of Accidents) Regulations, Serial No. 152/1953 (made in accordance with ICAO Annex 13).

NICARAGUA

1956	mayo	18	Decreto Núm. 176 - Código de Aviación Civil: Título II. - Cap. V. De la Investigación de Accidentes Aéreos.

NIGER

1962	juil.	17	Loi n° 62-13 portant Code de l'Aviation civile: Livre Ier - Titre IV. - Des accidents (Art. 63-65).

NORWAY

1956	Sept.	21	Royal Decree establishing a permanent aircraft accident investigation Commission. (1)
1960	Dec.	16	The Civil Aviation Act. Came into force on 1 January 1962 with respect to civil aviation pursuant to Order of the King in Council dated 8 December 1961: Chapter XI, C. Investigation of Accidents (Paras. 164-168).

PAKISTAN

1937	March	23	The Aircraft Rules (corrected up to 24 February 1956): Part X. - Investigation of Accidents.

PANAMA

1963	agosto	3	Decreto-Ley Núm. 19 por el cual se reglamenta la Aviación Nacional: Título II. - Cap. VII. De la Investigación de Accidentes Aéreos.

PARAGUAY

1954	enero	15	Resolución Núm. 54 por la que se establece la definición "Accidentes de Aviación" y las normas a ser cumplidas en tales casos.
1957	sept.	30	Ley Núm. 469 - Código Aeronáutico: Título XVI. - Accidentes Aeronáuticos.

PERSIAN GULF TERRITORIES

BAHRAIN

1958	March	2	The Bahrain Aircraft Accident Regulation, Notice 2/1958.

QATAR

1957	Aug.	17	The Qatar Aircraft Accident Regulations.

TRUCIAL STATES

1958	March	2	Aircraft Accident Regulation, Notice No. 1/1958.

PERU

1963	Dic.	26	Decreto Supremo Núm. 22 - Reglamento de Aeronáutica Civil del Perú. Modificado por Decretos Supremos Núm. 9 y Núm. 15 del 16 de abril y del 26 de mayo de 1964: Título VI. Cap. I. - Accidentes.

(1) The substance of ICAO Annex 13 is used in principle at aircraft accident inquiries in Norway. The annex is partially implemented as regulations through that Decree.

PHILIPPINES

1946	May	9	The Civil Aviation Regulations: Chapter XVI. - Aircraft Accident Investigation.
1952	June	20	The Civil Aeronautics Act, No. 776: Chapter V. - Section 32 - Power and Duties of the Administrator: (11) Investigation of Accidents.

POLAND

1962			Civil Aviation Act: Part V. - Chapter Two - Articles 50. 2 and 55.

PORTUGAL

1930	Oct.	25	Decree No. 20.062 - Air Navigation Regulations: Chapter VIII.

ROMANIA

1953	Dec.	5	Decree No. 516 - The Air Code of the Romanian People's Republic. Amended by Decrees No. 204 of 11 May 1956 (B.O. No. 15) and No. 212 of 20 June 1959 (B.O. No. 17): Chapter VI. - Search and Rescue of Civil Aircraft in Distress - Handling of flight accidents and incidents.

SENEGAL

1963	Feb.	5	Law No. 63-19 - Code of Civil Aviation: Book IV. - Flight Personnel Title I. - General Provisions - Chapter II. Discipline (Articles 143-146).

SIERRA LEONE

*1953	Dec.	30	Civil Aviation (Investigation of Accidents) Regulations (P.N. 114/53).

SOUTH AFRICA (REPUBLIC OF)

1950			The Air Navigation Regulations, G.N. 2762/1949, as amended up to 3 February 1961: Chapter 29 - Investigation of Accidents (Regs. 29.1 - 29.7).
1962	June	21	The Aviation Act No. 74: Section 12. - Investigation of Accidents.

SPAIN

1948	marzo	12	Decreto del Ministerio del Aire sobre investigación de accidentes y auxilio de aeronaves.
1960	julio	21	Ley Núm. 48 sobre Navegación Aérea: Cap. XVI. - De los accidentes, de la asistencia y salvamento y de los hallazgos.

* The text does not exist in the files of ICAO.

SUDAN

1960			The Air Act, No. 49/1960: Chapter V. - Accidents and Insurance.

SWEDEN

1957	June	6	The Swedish Air Act. No. 297. Came into force on 1 January 1962: Chapter 11 - Paras. 7-13 - Investigation of Accidents.
*1961	Nov.	24	Royal Decree relating to air navigation: Paras. 122-134 - Investigation of Accidents.

SWITZERLAND

1948	déc.	12	Loi fédérale sur la navigation aérienne (entrée en vigueur le 15 juin 1950): Articles 23-26.
1959	oct.	2	Loi fédérale concernant les enquêtes sur les accidents d'aéronefs, modifiant la loi fédérale sur la navigation aérienne de 1948.
1960	avril	1	Ordonnance sur les enquêtes en cas d'accidents d'aéronefs.

THAILAND

1954	Sept.	1	The Air Navigation Act, (B.E. 2497): Chapter 7. - Accidents (Sections 63 and 64).
1955	June	5	Civil Air Regulations No. 3 - Aircraft Accident Inquiry.

TRINIDAD AND TOBAGO

1954	Nov.	23	Air Navigation (Investigation of Accidents) Regulations, (G.N. 205/54).

UNITED ARAB REPUBLIC

1941	May	5	Decree - Air Navigation Regulations: Article 10.

UNITED KINGDOM

1949	Nov.	24	The Civil Aviation Act, 1949 (12 and 13 Geo. 6, Ch. 67): Part II. - Section 10 - Investigation of Accidents.
1951	Sept.	5	The Civil Aviation (Investigation of Accidents) Regulations, S.I. No. 1653. Came into operation on 1 October 1951.
1959	Aug.	6	The Air Navigation (Investigation of combined military and civil air accidents) Regulations S.I. 1959, No. 1388. Amended by S.I. 1960, No. 1526.

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* The text does not exist in the files of ICAO

UNITED KINGDOM COLONIES

Article 76 of the Colonial Air Navigation Order, 1961, and Section 10 of the Civil Aviation Act, 1949, apply /the latter by virtue of the Colonial Civil Aviation (Application of Act) Order, 1952, as amended/ to the undermentioned Colonies:

Aden (Colony and Protectorate)
Bahamas
Barbados
Bechuanaland Protectorate
Bermuda
British Guiana
British Honduras
British Solomon Islands Protectorate
Central and Southern Line Islands - Malden
Starbuck
Vostock
Caroline
Flint

Falkland Islands and Dependencies
Fiji
Gibraltar
Gilbert and Ellice Islands Colony
Hong Kong
Leeward Islands - Antigua
Montserrat
St. Christopher and Nevis
Virgin Islands
Mauritius
St. Helena and Ascension
Seychelles
Southern Rhodesia
Swaziland
Tonga Islands
Windward Islands - Dominica
Grenada
St. Lucia
St. Vincent

ADEN

*1954			The Civil Aviation (Investigation of Accidents) Regulations (G.N. 125/54).

BAHAMAS

*1952	Aug.	1	Air Navigation (Investigation of Accidents) Regulations.

BARBADOS

*1952	April	29	Air Navigation (Investigation of Accidents) Regulations.

* The text does not exist in the files of ICAO.

UNITED KINGDOM COLONIES (Cont'd)

BERMUDA

*1948 Dec. 18 Air Navigation (Investigation of Accidents) Regulations.

BRITISH GUIANA

*1952 Aug. 18 Air Navigation (Investigation of Accidents) Regulations, No. 19/1952.

BRITISH HONDURAS

*1953 Dec. 19 Air Navigation (Investigation of Accidents) Regulations, (S.I. 1/54).

FIJI

*1952 May 1 Civil Aviation (Investigation of Accidents) Regulations, (L.N. 90/1952).

GIBRALTAR

1952 Jan. 3 Air Navigation (Investigation of Accidents) Regulations.

HONG KONG

*1957 Air Navigation (Investigation of Accidents) Regulations.

LEEWARD ISLANDS

*1952 July 31 Civil Aviation (Investigation of Accidents) Regulations, (S.R.O. 18/52).

MAURITIUS

*1952 Sept. 4 Civil Aviation (Investigation of Accidents) Regulations, (G.N. 200/52).

ST. LUCIA

1948 Nov. 27 Air Navigation (Investigation of Accidents) Regulations, (S.R.O. No. 40/48).

ST. VINCENT

*1953 Jan. 8 Air Navigation (Investigation of Accidents) Regulations, (S.R.O. No. 6/53).

SOUTHERN RHODESIA

1954 March 26 Aviation Act No. 10/1954: Section 4(s), (t), Section 13 - Enquiries.

1954 [illegible] 18 Air Navigation Regulations (F.G.N. No. 246/1954): Part 18. - Accidents.

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* The text does not exist in the files of ICAO.

UNITED STATES OF AMERICA

1958 The Federal Aviation Act of 1958, as amended (Public Law 85-726, 85th Congress, 2nd Session; 72 Stat. 731; 49 U.S. Code): Title II. - General Powers and Duties of the Civil Aeronautics Board - 204(a) General Powers; Title III. - Organization of Agency and Powers and Duties of Administrator - Sec. 313(c) Power to Conduct Hearings and Investigations; Title VII. - Aircraft Accident Investigation; Title IX. - Penalties - Sec. 902.(o) - Interference with aircraft accident investigation.

The Federal Aviation Act of 1958, Annotated; Title VII

U.S. Code of Federal Regulations

Title 14 - Aeronautics and Space (Chapter II. - Civil Aeronautics Board Regulations)

1950 Sept. 15 Procedural Regulations - Part 303 - Rules of practice in aircraft accident investigation hearings, (as issued September 15, 1950, 15 F.R. 6440); revised effective February 15, 1957, 22 F.R. 1026; Part revised by Reg. PR-35, effective March 21, 1959, 24 F.R. 2224).

1950 Sept. 15 Procedural Regulations - Part 311 - Disclosure of aircraft accident investigation information. (As issued September 15, 1950, 15 F.R. 6441; reissued effective April 1, 1963, 28 F.R. 582)

1963 Safety Investigation Regulations - Part 320 - Rules pertaining to aircraft accidents, inflight hazards, overdue aircraft and safety investigations. (As reissued by Regulation No. SIR-4, effective April 1, 1963, 28 F.R. 583)

1964 Organization Regulations - Part 386 - Delegation and review of action under delegation; Determination of the probable cause of aircraft accidents. (As issued, effective April 7, 1964, 29 F.R. 5033)

1955 Policy Statements - Part 399 - Statements of General Policy (as issued, effective May 25, 1955, F.R. 4117; amended and codified, effective January 29, 1964, 29 F.R. 1454): Subpart F - Policies relating to aircraft accident investigations: 399.70 - Investigation of accidents involving foreign aircraft.

1958 Public Notice PN-13 - Request to Administrator of Federal Aviation Agency to investigate certain aircraft accidents for a temporary period. (As issued, effective December 31, 1958, 23 F.R. 10492)

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 ICAO 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 comprised 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.

PROCEDURES FOR AIR NAVIGATION SERVICES (PANS) are approved by the Council for world-wide application. They comprise, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome. As in the case of Recommended Practices, the Council has invited Contracting States to notify any differences between their national practices and the PANS when the knowledge of such differences is important for the safety of air navigation.

REGIONAL SUPPLEMENTARY PROCEDURES (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

ICAO FIELD MANUALS derive their status from the International Standards, Recommended Practices and PANS from which they are compiled. They are prepared primarily for the use of personnel engaged in operations in the field, as a service to those Contracting States who do not find it practicable, for various reasons, to prepare them for their own use.

TECHNICAL MANUALS provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

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.

ICAO CIRCULARS make available specialized information of interest to Contracting States. This includes studies on technical subjects as well as texts of Provisional Acceptable Means of Compliance.

EXTRACT FROM THE CATALOGUE
ICAO SALABLE PUBLICATIONS

ANNEX

Annex 13 — Aircraft accident inquiry.
2nd edition, March 1966. 16 pp. $0.50

MANUAL

Manual of aircraft accident investigation.
(Doc 6920-AN/855/3). 3rd edition, 1959. 257 pp. $4.00

ICAO CIRCULARS

18-AN/15 — Aircraft Accident Digest No. 1.
June 1951. 116 pp. $2.00

24-AN/21 — Aircraft Accident Digest No. 2.
1952. 170 pp. $0.85

31-AN/26 — Aircraft Accident Digest No. 3.
1952. 190 pp. $1.00

38-AN/33 — Aircraft Accident Digest No. 4.
1954. 186 pp. $3.00

39-AN/34 — Aircraft Accident Digest No. 5.
1955. 186 pp. $2.00

47-AN/42 — Aircraft Accident Digest No. 6.
1956. 237 pp. $2.50

50-AN/45 — Aircraft Accident Digest No. 7.
1957. 245 pp. $2.50

54-AN/49 — Aircraft Accident Digest No. 8.
1958. 212 pp. $2.25

56-AN/51 — Aircraft Accident Digest No. 9.
1959. 290 pp. $3.00

59-AN/54 — Aircraft Accident Digest No. 10.
1961. 286 pp. $3.00

62-AN/57 — Aircraft Accident Digest No. 11.
1961. 266 pp. $4.25

64-AN/58 — Aircraft Accident Digest No. 12.
1963. 376 pp. $5.75

69-AN/61 — Aircraft Accident Digest No. 13.
1964. 359 pp. $5.50

71-AN/63 — Aircraft Accident Digest No. 14.
Volume I. 1965. 115 pp. $2.00
Volume II. 1966. 202 pp. $3.25

78-AN/66 — Aircraft Accident Digest No. 15.
Volume I. 1966. 156 pp. $2.50

N.B.—*Cash remittance should accompany each order.*
Catalogue sent free on request.

PRICE: U.S. $4.00
(or equivalent in other currencies)

UNITED STATES OF AMERICA (Cont'd)

1961			Public Notice PN-15 - Statement of Organization and Delegations of Final Authority. Effective July 3, 1961, 26 F.R. 7231: Section 1.2 - Functions of the Civil Aeronautics Board - (c) Safety Activities; Bureau of Safety - Sections 5.1 - 5.9; Section 7.2 - Functions of the General Counsel; Section 7.3 - Delegated Authority; Section 7.6 - Redelegation of Authority to Associate General Counsel, Rules and Legislation. (26 F.R. 7231)

U.S. Code of Federal Regulations

Title 22 - Foreign Relations

1952			Part 102 - Civil Aviation - Subchapter K - Economic, Commercial and Civil Aviation Functions: U.S. Aircraft Accidents Abroad; Foreign Aircraft Accidents involving U.S. Persons or Property. (As issued in Department Regulations 108.164, effective October 1, 1952, 17 F.R. 8207; Part 102 as republished, effective December 23, 1957, 22 F.R. 10871)

URUGUAY

1955	feb.	2	Decreto Núm. 23.826 - Reglamento para la investigación de Accidentes de Aviación de Carácter Civil.

VENEZUELA

1955	abril	1	Ley de Aviación Civil: Cap. X. - De los accidentes y de la búsqueda y rescate.

WESTERN SAMOA

1963	Aug.	1	Civil Aviation Act. No. 6/1963: Part VIII. - Accident Inquiry.

YUGOSLAVIA

1949	June	1	Decree on Air Navigation, as amended on 19 December 1951: IV. Flight (Article 28).

ZAMBIA

1954	March	26	Aviation Act No. 10/1954: Section 4(a), (t), Section 13 - Enquiries.
1954	June	18	Air Navigation Regulations (F.G.N. No. 246/1954): Part 18. - Accidents.

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