C.A.P. 153

MINISTRY OF
TRANSPORT AND CIVIL AVIATION

CIVIL AIRCRAFT ACCIDENT

Report by the Federal Republic of Germany relating to the Inquiry into the Accident to G - ALZU AS 57 Ambassador (Elizabethan) on 6th February, 1958 at Munich - Riem Airport

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FEDERAL REPUBLIC OF GERMANY

R E P O R T

Relating to the

I n q u i r y

into the Accident to Aircraft G-ALZU

AS 57 Ambassador (Elizabethan) on

6th February, 1958, at Munich-Riem Airport

Luftfahrt-Bundesamt,

Brunswick Airport.

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Luftfahrt-Bundesamt

Az: 841 - V 12/58

Braunschweig (Brunswick) Airport,

Telephone: 30808, 30809, 30800
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31st January, 1959.

REPORT

relating to the Inquiry into the Accident to Aircraft G-ALZU AS 57 Ambassador (Elizabethan) on 6th February, 1958, at Munich-Riem Airport.

Circumstances of the Accident in Brief

The aircraft had carried out a special flight on 3rd February, 1958, from England to Belgrade, making an intermediate landing at Munich-Riem for refuelling purposes. On 6th February it flew back from Belgrade, bound for Manchester. As planned, it again made an intermediate landing at Munich to refuel, landing there at 1417 hours*). The take-off, at 1603 hr., was normal at the outset, but the aircraft did not become airborne. It overshot the boundary of the manoeuvring area (Rollfeldgrenze) and, when outside this area, struck a house and a wooden hut and was severely damaged by the fire which followed. Of the 44 occupants on board, 21 were killed instantly. The others received injuries of a more or less serious nature. Two died later in hospital as a result of their injuries. The house which was struck by the aircraft was badly damaged by fire. The hut was destroyed by fire.

A. Inquiry Procedure

The Inquiry into the accident was carried out by the Luftfahrt-Bundesamt in accordance with §2 of the Law relating to the Luftfahrt-Bundesamt dated 30th November, 1954 (BGBl. I, p. 354), in conformity with the Standards and Recommended Practices of Annex 13 to the Convention on International Civil Aviation (ICAO), and in accordance with the General Administrative Regulations governing Aircraft Accident Inquiry dated

*) All times quoted = local time.

4th March, 1958 (Bundesanzeiger No. 48), issued by the Ministry of Transport.

The proceedings of the Commission of Inquiry took place on:

29th-30th April and 1st May, 1958, in Munich, and
25th-26th June, 1958, in Frankfurt am Main.

The Commission of Inquiry consisted of:

STIMPEL,	Walter,	Landgerichtsrat,	Brunswick, Chairman.
REICHEL,	Hans-J.,	Flugkapitän,	Brunswick, Assessor, presenting the case (Berichterstatter).
BOCK,	Günter,	Prof. Dr-Ing.,	Darmstadt, Assessor.
UTTER,	Werner,	Flugkapitän,	Hamburg, Assessor.

The following were parties to the Inquiry:

The Federal Minister of Transport,

represented by Reg.-Baudir. STELLE (part-time)
and Reg. Rat. RANNERSMANN (part-time),

the Bavarian State Ministry of Economy and Transport,

represented by Min. Rat. Dr. NIBLER (part-time)
and Reg. Baurat ENDRASS,

the Bundesanstalt für Flugsicherung,*)

represented by Herr KOLBE,

the Ministry of Transport and Civil Aviation, London, (sic)

represented by Mr. G. M. KELLY, accredited representative of the United Kingdom, with Mr. R. F. JONES as meteorological expert.

The following were heard as experts:

Dr.-Ing. C.E. GERLACH,	Stuttgart,	on questions relating to aerodrome construction
Prof. Dr. H. SCHLICHTING,	Brunswick,	on aerodynamics,
Oberregierungsrat Dr. H.K. MÜLLER,	Munich,	on meteorology,

*) Federal Administration of Air Navigation Services

Dr.-Ing. E.W. PLEINES,	Frankfurt am Main,	on air traffic statistics, with reference to similar accidents,
Flugkapitän W. BLUME,	Hamburg,	on piloting of aircraft.

The following were also admitted to the oral proceedings:

Representatives of British European Airways Corporation, headed by Mr. H.E. MARKING,

Captain James THAIN, the person-in-command of the aircraft involved in the accident, assisted by Captain GILLMAN,

Captain KEY, representing the late Captain RAYMENT, who had died of injuries.

The two last-named appeared for the British Airline Pilots Association.

Throughout the proceedings the parties were entitled to express their views concerning every item of evidence brought before the Commission, to request the production of further evidence, to examine the witnesses and experts present, to lodge protests and to sum up their views on the results, both on individual points during the proceedings and on completion of the evidence.

Mr. J. BANFIELD, Civil Air Attache to the British Embassy, was present at the oral proceedings as observer.

B. Information regarding the Accident

1. General

a) Aircraft

Airspeed AS 57 Ambassador, Works No. 5217. Year of construction: 1952.

Owner and operator: British European Airways Corporation (BEA), Keyline House, South Ruislip, Middlesex.

Maker: Airspeed Ltd./de Havilland.

The Certificate of Registration and Certificate of Airworthiness, issued by the Ministry of Transport and Civil Aviation were valid on the day of the accident.

Engines: 2 x Bristol Centaurus 661:

	Port	Starboard
No.	89090	89068
Running time:		
Total	3662.05 hr.	4015.20 hr.
Since last overhaul	379.45 "	379.45 "

Permitted running time between overhauls: 1700 hr.

Propellers: de Havilland, fully automatic, four-bladed metal, Type CD/85/466/1

No.	4A 60090	4A 60073
Running time:		
Total	6339.27 hr.	6604.35 hr.
Since last overhaul	388.19 "	715.52 "

Permitted running time between overhauls: 1800 hr.

Weights:

Weight empty	17,181 kg.
Disposable load at time of take-off (beim Unfallstart):	
Fuel	3,198 "
Crew	500 "
Galley, etc.	438 "
Passengers	3,422 "
Take-off weight:	24,739 kg.
Maximum authorised take-off weight:	55,000 lb.
	= 24,948 kg.

During the period 1425 hr. to 1438 hr. the aircraft was refuelled with 3,300 litres of 100/130 Octane BP aviation fuel.

b) Crew

THAIN, James, person-in-command (Kommandant)*, born 7th February, 1921, domiciled at Mirande, Off Church Street (sic) - slightly injured.
Holder of British Airline Transport Pilot's Licence No. 24,827, which was valid on the day of the accident.

*Comment by U.K. accredited representative:
"Kommandant": In some parts of the German report this word is used to indicate "person-in-command" and elsewhere to indicate "pilot-in-charge". (Rank is omitted here.)

Experience:

1941-1946 Royal Air Force.
From October 1946: BEA, as First Officer, and from 1951 as Captain (Kommandant).

On 23rd March, 1955, he completed a conversion course on Elizabethan aircraft, since which he had flown 1,722 hr. on this type of aircraft. His last flight check was on 14th October, 1957.

His total flight time amounted to 7,337 hr. up to the day of the accident.

In the 30 days prior to 2nd February, 1958, he had flown about 26 hours and during the last three days prior to the accident 7 hr.

RAYMENT, Kenneth Gordon, First Officer (sic)*, born 11th March, 1921, in London, domiciled at Billinghurst, Sussex.

- Died in hospital from injuries on 15th March, 1958.

Holder of British Airline Transport Pilot's Licence No. 21,951, which was valid on the day of the accident.

Experience:

Began his flying training in 1940 in the Royal Air Force. In 1944 he was seconded to British Overseas Airways Corporation and joined BEA in March, 1946. In March, 1953, he completed a conversion course on Elizabethan aircraft and since then had flown 3,143 hr. in this type of aircraft.

His total flight time up to the day of the accident amounted to 8,463 hr.

During the 30 days prior to 2nd February, 1958, he had flown barely 6 hr. and during the last three days prior to the accident 7 hr.

RODGERS, George William, Radio Officer, born 14th September, 1922.

- Slightly injured.

Cabin personnel:

CABLE, William Thomas, steward, born 13th February, 1917.
- Killed.

BELLIS, Margret Ursula, stewardess, born 27th July, 1922.
- Slightly injured.

CHEVERTON, E. Rosemary, stewardess, born 31st May, 1932.
- Slightly injured.

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*Comment by U.K. accredited representative:

"First Officer": This appears to be an error in the German text. Rayment's rank was Captain and on this flight he was performing the duties of pilot-in-charge.

c) Passengers:

38 - including the Manchester United football team and journalists.

d) Weather Conditions

The Munich-Riem meteorological office of the German Meteorological Service issued the following report:

Time 1504 hr. - surface wind 300°/8 kt. - surface visibility 1.6 NM slight snowfall - 8/8 stratus at 600 ft. (precipitation ceiling) - QNH 1004.0 mb/29.65 inches - QFE 942.7 mb/27.84 inches - temperature 0°C. dew point -1.6°C.

On 6th February the following observations (QNY) were made:

Snow + rain (mixed).....	from	0420 - 0650 hr.
Rain only	"	0650 - 1120 "
Snow + rain (mixed)	"	1120 - 1150 "
Moderate snowfall	"	1150 - 1550 "
Slight snowfall	"	1550 - 1850 "
Moderate snowfall	"	1850 hr.

The following screen temperatures (height 2 m. above ground level) and relative humidities were measured:

At 1400 hr.	+ 0.1°C.	95%
" 1500 "	0.0°C.	96%
" 1600 "	- 0.2°C.	91%
" 1700 "	- 0.8°C.	89%
" 1800 "	- 0.9°C.	91%

e) Munich-Riem Airport

Geographical location:	48°07'54" N. 11°41'57" E.
Elevation:	528 m. = 1732 ft.
Density altitude:	884 m. = 2900 ft.
Runway (QFU) 249°	
Length	1908 m., concrete
Width	60 m.

Stopway available at end of concrete runway: 250 m. (grass surface).

The information in B.1, a)-c), was taken from BEA sources, from the aircraft documents and from a certificate from BP, who refuelled the aircraft. The weather conditions were obtained from the records of the Munich-Riem meteorological office of the German Meteorological Service. Data regarding Munich-Riem Airport is taken from the AIP for Federal Germany.

The Commission found no cause to doubt the accuracy of the data contained in these sections.

2. Accident Details

The aircraft, which landed at Munich at 1417 hr., made three attempts, from 1519 hr. onwards, to continue the flight to England. The crew twice abandoned take-off. The third /attempted/ take-off resulted in the accident. The following is a chronological record of R/T communication between the aircraft and Munich Aerodrome Control, taken from the tape-recording:

hr.m.s.

1519:00 Aircraft requested clearance to taxi to runway. This was given immediately, together with the meteorological information required for take-off, in the following words: "Wind 290/8 kt. - cleared to Runway 25 - QNH 1004".

1521:30 Taxi clearance was repeated with the words: "Cleared to line up and hold". Instructions for the flight (clearance) were then given.

1530:10 Aircraft reported: "I am ready to take-off". Clearance to take-off was given immediately, surface wind being repeated - 290/10 kt.

1530:40 Aircraft reported: "Rolling", and at -

1531:20 "We are abandoning the take-off".

This message regarding abandoning of take-off was repeated by the aircraft at the request of Air Traffic Control, and permission to taxi back along the runway to the initial position was requested. Permission was given and the aircraft taxied back to the beginning of the runway.

1534:40 The aircraft again reported: "Rolling", and at -

1535:20 reported abandoning of second take-off with the words: "We're abandoning this take-off as well". The aircraft continued its run to the end of the runway and then taxied to the terminal building.

1559:30 On request, the aircraft again received clearance to taxi to the runway and was given the surface wind.

1602:40 Aircraft reported that it was ready to take-off and immediately received clearance to take-off.

1603:06 Aircraft again reported: "Rolling".

1604:00 Aircraft called up, but the message was interrupted after the first identification letters had been given.

For details of R/T communication, see complete transcription of tape-recording, Appendix 1.

The following detailed picture is provided by Captain Thain's oral and written reports and by the witnesses' statements, which are thus far in agreement:

On the flight from England to Belgrade the aircraft was flown by Captain THAIN. It was agreed that on the return flight Captain RAYMENT should act as pilot-in-charge. For this reason, Captain RAYMENT was sitting in the left-hand seat. Captain THAIN was sitting on the right. In the aircraft documents, however, Captain THAIN was shown as person-in-command (verantwortlicher Kommandant) for the return flight as well.

Captain RAYMENT abandoned the first take-off, which had been preceded by an engine run-up. The reason for abandoning take-off was that the boost-pressure readings of both engines showed upward variations, rising 2 or 3 inches above the usual reading of 57.5 inches. The second attempt at take-off followed immediately after the aircraft had taxied back to the beginning of the runway. The engine run-up was not repeated.
Captain THAIN abandoned the second take-off because the boost-pressure reading (this time on the port engine only) again rose beyond the normal maximum value to 60 inches.

In each case the take-off was abandoned approximately half way down the runway. After the second attempt the aircraft continued rolling as far as the end of the runway and from there proceeded to the terminal building. The passengers disembarked. The two pilots remained on the flight deck. Mr. BLACK, the BEA Station Engineer, went on board to find out why the aircraft had returned. He then pointed out to the two pilots that the variations in boost pressure were connected with the elevation of Munich Airport. After a short discussion, the pilots decided to make a third /attempt at/ take-off and the passengers were told to board the aircraft again.

Before the fresh /attempt to/ take-off, a further engine run-up was carried out. After take-off had begun, the boost-pressure reading of the port engine again fluctuated somewhat, but this ceased after Captain THAIN had throttled back slightly for a short time (sic). After he had opened up the throttle fully again, no further fluctuations were observed.

The aircraft never became airborne in the course of the third attempt at take-off. It travelled on over the whole length of the runway and the adjoining grass-covered stopway (250 m.). At the end of the stopway it crashed through a wooden fence which marked the aerodrome boundary, cleared a secondary road and struck a house standing on the other side of the road.

The left wing was torn off outboard of the engine mounting. Parts of the tail unit were also torn off here. The house caught fire. The aircraft then crashed into a wooden hut standing on a concrete base about 100 m. further on, striking it with the right side of the rear section of the fuselage. The fuselage was torn away on a level with the trailing edge of the wing. The hut and the part of the fuselage which was torn away caught fire. The remainder of the aircraft wreckage slid on for a further 70 m.

The Luftfahrt-Bundesamt representative charged with carrying out the preliminary investigation arrived at Munich by air at 2200 hr. on the day of the accident. The scene of the accident presented the following appearance:

The scene of the accident was guarded by police. All the fires had been extinguished and the fire-fighting vehicles had departed. There was continuous snowfall at a temperature of -3°C. The main wreckage had been pulled apart in order to extricate the victims and extinguish the fire. The fuselage lay in a normal attitude, pointing to the right in relation to the direction of flight. On the port side the fuselage had been torn open throughout almost its entire length and towards the rear was increasingly compressed in the vertical plane. The port engine was torn away from its mounting and lay on the ground in a normal attitude, only a few metres from the remains of the wing. It had not somersaulted, and its accessories and their mountings appeared to be still intact. The nose of the aircraft (flight deck) was stove in on the left side. The deformation and the pieces of bark found showed that this indentation was caused by a tree standing beside the house which caught fire. As a result of this indentation the pilot in the left-hand seat had been trapped in his seat.

The right wing was only slightly damaged and the engine attached to it appeared to be completely undamaged. The blades of the two propellers

were only slightly deformed (see photographs 4 and 5). The main undercarriage was down at the time of the impact. It was torn off.

The landing flaps (split flaps) on both sides showed an equal angle of deflection, about 10°. They were locked in this position. The flight deck was only slightly damaged; but nothing definite could be determined from the position of the switches and levers, since during the extrication of the trapped pilot extensive changes had obviously been effected.

The whole wreckage was covered with a layer of snow about 8 cm. thick. Underneath this there was a rough layer of ice. Details concerning the deposit of snow and ice are dealt with under C.2, aa).

Traces of the powder from the fire-extinguishers showed that minor fires had broken out in the immediate vicinity of the forward fuselage section. There were no discernible effects of fire on the aircraft here.

Next to the house which the aircraft had struck first there were trees which had been snapped off at a height of 3 m. or knocked down. From the point at which the aircraft had broken through the fence its tracks could clearly be discerned, extending back to the runway. The double track of the right side of the undercarriage could be followed back to the runway without difficulty. The left-hand wheel-track was interrupted in places. Nowhere was there any nosewheel track to be seen.

From the end of the runway to the fence, in the direction of take-off, the wheel-tracks showed a slight swing to the right. Two days after the accident, when the snow had melted, the tracks were particularly clearly visible. On the runway, about 50 m. short of the end, a skid-mark began. It was clearly visible on the concrete and from the strewn sand which the wheels had pushed aside (see sketch map and photographs). This mark showed that at this point all four wheels of the main under-carriage were locked. This skid-mark continued for approximately a

further 30 m. beyond the end of the runway. It then stopped and there remained the impression of the free-running wheels on the grass surface. The track of the right-hand twin wheels was strongly marked; that of the left-hand wheels was fainter and at times interrupted. The track of the right-hand wheels was uniformly clear throughout the whole length (250 m.) of the stopway as far as the point at which the aircraft crashed through the fence. The left-hand wheels had at times left the ground. The skid-mark and wheel-marks were still clearly visible at the time of the survey of the scene of the accident by the Commission of Inquiry on 30th April, 1958.

C. Causes of the Accident

1. The Commission, with the agreement of all parties to the proceedings, was able to exclude at the outset a number of points which might have been taken into account as possible causes of the accident, viz:

a) There were no indications that the airport services, the air navigation services (Flugsicherung) or the German Meteorological Service had contributed to the accident through any defects in installations or functioning.

b) The presence of the house, 9.50 m. high, outside the aerodrome, beyond the runway, and of the hut, 3 m. high, did not contravene either the German regulations or the Standards and Recommended Practices of the International Civil Aviation Organisation (ICAO). The Commission arrived at this conclusion in agreement with the expert on aerodrome construction, Dr.-Ing. GERLACH of Stuttgart. The text of this expert's written opinion, to which the Commission subscribed, is attached to this Report as Appendix 3.

c) The members of the crew held valid licences. There were no manifest reasons for doubting their proficiency.

d) The aircraft documents were valid and in order.

e) It was not possible to establish that there had been any defects in the technical installations of the aircraft.

According to Captain THAIN's statement, the engines were working satisfactorily. The fact that take-off had been abandoned twice previously does not give cause for any conclusion to the contrary. The variations in boost pressure which, according to the credible depositions of Captain THAIN and of Mr. BLACK, the aircraft engineer, led to the abandoning of the two first take-offs, were occurrences which commonly arise at aerodromes at elevations such as that of Munich without implying engine trouble. The two engines, which were only slightly damaged, have been subjected to a test run by the manufacturer. The Commission has had before it a test report submitted by BEA. According to this, both engines showed the prescribed take-off power during the test run. No defects were found which could have been a contributory cause of the accident. The Commission saw no reason to doubt the accuracy of the test report.

In addition, there were no indications of defects in the other technical installations.

f) The loading of the aircraft lay within the permissible limits. See B.1, a), for information regarding permissible and actual take-off weight.

g) No objection could be raised with regard to the condition of the fuel with which the aircraft had been replenished. Samples of the fuel found in the aircraft after the accident have been tested in England at the instigation of BEA. BEA has notified the Commission of the result of the test. According to this, the chemical composition of the fuel corresponded to the relevant specifications. There are no reasons to doubt the accuracy of

this statement.

2. Since none of these factors comes into consideration as a cause of the accident, and since, on the other hand:

- it had snowed during the afternoon of 6th February, 1958,
- the aerodrome was covered with slush at the time of the accident, and
- the investigations in the evening showed a layer of ice on the wings of the aircraft,

the Commission considered itself primarily concerned with the question of whether the following explained the occurrence of the accident:

a) /Rolling/ friction (Reibungswiderstand) caused by snow on the runway,

b) The effect of slush on the free-running of the wheels, and

c) Alteration in aerodynamic efficiency caused by wing icing.

The following views were arrived at after detailed investigations and consultations:

a) /Rolling/ friction (Reibungswiderstand) caused by slush on the runway

It is obvious that snow or slush on the runway can increase the rolling friction (Rollreibungswiderstand) to such an extent that a take-off is impeded or even becomes impossible. The Commission has had before it numerous reports on experiences and accident reports concerning cases where slush has led to difficulties. Twenty-one reports from the collection of the German Institute for Air Traffic Statistics, the ICAO collection, publications of the Flight Safety Foundation, New York, and reports of Trans-Canada Airlines were utilised for purposes of comparison. In addition, BEA submitted, inter alia, the following reports for the study of incidents of this kind:

1. Captain T.M. GRIFFITHS, report dated 20th February, 1958, relating to an incident in Brussels on 20th February, 1957.

2. Captain P. SOUBY, report dated 20th March, 1958, relating to an incident in Manchester (no date).

3.	Captain A.E. BROWN,	report dated 17th February, 1958, relating to an incident in Düsseldorf on 14th January, 1955.
4.	Captain S.J.L. KEY,	report dated 6th February, 1958, relating to an incident in Cologne-Wahn on 14th January, 1955.
5.	Captain TARRAN-JONES, (Air Safety Report)	report relating to an incident on 20th December, 1956.
6.	Captain JENKINSON, (Air Safety Report)	report relating to an incident on 2nd February, 1953.

These reports may be summarised to the effect that the extent to which take-off is impeded depends on the thickness of the slush and the type of aircraft. Aircraft with nosewheels are affected to a greater extent than aircraft of tailwheel design, because, in slush, the nosewheel causes an increasing nose-heavy moment as the rolling speed increases and this must be overcome by the pilot by means of considerable force on the elevator control. All experience goes to show, however, that it may be assumed that take-offs can be made with nosewheel aircraft without danger up to a slush-depth of at least 5 cm.

At Munich-Riem on the afternoon of 6th February, 1958, the runway was first of all wet but free of snow and slush. From 1120 hr. onwards, mixed snow and rainfall set in, at 1150 hr. moderate snowfall and from 1550 hr. slight snowfall, temperatures being initially above zero but from 1500 hr. onwards dropping to 0° and later below 0°. Snowfall continued after the time of the accident. On the basis of the records of the [aerodrome] meteorological office, Oberregierungsrat Dr. H.K. MÜLLER, head of that office and serving on the Commission as meteorological expert, showed convincingly that on the basis of data concerning snowfall and temperature, established from the records, by 1600 hr. a total of 4-5 cm. of snow must have fallen, which, on the runway, would have subsided to form a layer of slush approximately $\frac{3}{4}$-1 cm. thick. This estimate tallies with the observations of the witness BARTZ. As Traffic

Manager (Verkehrsleiter) of the Flughafen München-Riem G.m.b.H. (Munich-Riem Airport Co. Ltd.), he had driven down the runway by motor vehicle during the period of the first two take-off attempts. In order to check up the conditions on the runway, he had left the vehicle several times to determine the depth of the slush as accurately as possible by inspection. He transmitted the following report on the state of the runway to the air traffic control tower by R/T: "Runway covered with thin layer of slush". In the course of his statements to the Commission he reported, inter alia, as follows:

> ".... We stopped in front of the position at which aircraft hold before they are cleared to the runway and there watched the first two attempts by the Elizabethan to take off. After these two attempts we received permission from the control tower to drive on to the runway. We always carry an R/T set with us for this purpose. We then drove on to the runway, left the vehicle and inspected the conditions. We found that the entire runway was covered with slush approximately $\frac{1}{2}$-$\frac{3}{4}$ cm. deep. None of it was snow, but it was a jellified, watery mass covering the entire runway. We began from the east and drove off the runway at the west end. We did not merely stop, but got out and established the fact that the tracks left by the aircraft consisted purely of water. ...."

As against this, Captain WRIGHT, who landed at Munich at 1558 hr. on 6th February, 1958, with the BEA Viscount 802, states that he estimated the slush-depth as 1-1.5 inches in places, but that in parts the runway was merely wet and was free of slush. This estimate must, however, be regarded as unreliable, since, as Captain WRIGHT was judging during the process of landing and was looking from the pilot's seat, he could not have obtained a precise impression of the deposit of slush. Moreover, his report to the control tower on the state of the runway was: "Braking action fair". All the other aircraft landing and taking off on scheduled services at the time made the same or similar reports.

According to the reliable statements of the personnel responsible for inspecting the runway, the deposit of slush on the runway cannot have amounted, on an average, to more than 1 cm. at the most.

The Commission is convinced that the /rolling/ friction caused by so thin a layer of slush cannot have been a cause of the accident. This would be contradictory to the experiences quoted above. No case is known in which this has caused take-off to be abandoned on concrete runways, let alone caused an accident. The expert, Prof. Dr. SCHLICHTING, moreover, in his report dated 13th June, 1958*) which will be dealt with later in detail, has put forward the view that, assuming a rolling-friction coefficient of /U = 0.06, the rolling distance required for a normal take-off may be increased by approximately 110 m. at the most. In actual fact, on 6th February, 1958, all scheduled operations at Munich-Riem were conducted without any hitch whatever, before and after the accident - and this is in spite of further snowfall. Sixteen aircraft landed and took off in the course of the afternoon. From the runway-condition reports (mentioned above) given by the persons-in-command (Kommandanten) of these aircraft it may be seen that none of them mentioned any impediment worthy of serious consideration. In addition, Captain THAIN, person-in-command of the aircraft involved in the accident, had already pointed out in his first statement on 8th February, 1958, that he was satisfied with the condition of the runway. He attached special importance to this statement and its inclusion in the Report. He also expressly stated at the time that he would otherwise not have made a third /attempt at/ take-off. From all this the Commission is convinced that the layer of slush on the runway did not increase the rolling friction to such an extent that the accident could be attributed to this.

b) Icing of the Undercarriage

Nor, in the opinion of the Commission, did the slush have such an effect on the free-running of the wheels as to be a cause of the accident.

*) Not reproduced.

The Commission considers that locking of the wheels owing to slush during the process of take-off is entirely ruled out. The wheel-tracks on the runway did indeed show that, at the end of the runway, both sides of the main undercarriage were locked at times. There must, however, have been other reasons for this, as will be explained later. At the V 1 speed of 117 kt. (= 216 km/h.), which was attained and, at times, exceeded, the wheels (tyre diameter 38" = 96.5 cm.) were rotating at about 1200 r.p.m. Added to this is the fact that, at the narrowest point between the tyres, the twin wheels are 28 cm. apart. Given such a considerable gap and such a high speed of rotation and corresponding force, there can be no question of the wheels having become locked owing to the watery slush on the runway [accumulating] either between the wheels or in the region of the oleo legs.

From the outset, the possibility that the snow could have become caught up and accumulated in the undercarriage of the aircraft during the take-off run to such an extent that the wheels would have been braked to a considerable degree also appeared to the Commission extremely remote, since not a single indication of this came to light. The Commission nevertheless went into this question with special care, since Captain THAIN did not consider it out of the question that this might provide an explanation of the accident. He too, however, was unable to put forward any actual facts which might have indicated any such braking action on the undercarriage in the case of the accident at Munich. He merely quoted parallel instances. The Commission has studied occurrences of this kind (see reports referred to under C.2, a)). In addition, Captain KEY, in person, gave evidence before the Commission regarding an incident of this nature which took place on 14th January, 1955, at Cologne-Wahn. He made, in particular, the following statements:

"We taxied out in darkness in order to take off for Berlin. We had been informed that the runway was in a serviceable condition. It had snowed practically all night, but the snow had turned to rain and the ground was rather slushy. We began the take-off and after a few seconds it was evident that the aircraft was not accelerating to the extent that it should have done. The engine readings were normal, but before I reached V 1 I decided to abandon take-off. A few hundred yards short of the end of the runway we came to a stop, and the runway is, as you know, exceptionally long.

"During the take-off run I had to apply extraordinarily high engine power in order to keep the aircraft rolling. During inspection after disembarking I found that the undercarriage was tightly packed with frozen snow which was effectively braking both the main wheels and the nosewheel.

"I myself have no doubt that had we continued take-off until reaching V 1 we would never have become airborne, even if both engines had continued to function normally. Nor would we have come to a standstill while still on the runway.

"I further recall that Captain BROWN had a similar experience in Düsseldorf the same day. In his case, take-off was continued and the aircraft left the ground at a very late stage. I believe that owing to the quantity of snow which had collected in the wheel-well the nosewheel did not retract properly."

Even if it is now no longer possible to clarify all the circumstances of this special case, the possibility, at any rate, cannot be excluded that, with the Elizabethan, in exceptional circumstances, snow and ice may pack the undercarriage and impair the smoothness of take-off when the manoeuvring area is covered with wet snow and temperatures around 0°C. prevail. There can be no doubt, however, that many very unusual factors would have to coincide in order to produce such an effect. All the time and all over the world aircraft are taking off and landing with the same or a similar type of undercarriage in snow and meteorological conditions such as prevailed at Munich on 6th February, 1958, without the occurrence of difficulties such as Captain KEY describes. All the facts established argue against the Munich incident's presenting a parallel case. The BEA Viscount 802 which landed from Vienna on the same day at 1558 hr. and took off again at 1721 hr. (i.e., after the accident to the Elizabethan), under still more unfavourable conditions, had an undercarriage similar to that of the aircraft involved in the accident. The

smaller gap between the twin wheels would make this undercarriage, if anything, appear still more vulnerable to becoming clogged with snow than the undercarriage of the Elizabethan. The take-off nevertheless took place without any difficulties whatever. In the Cologne incident Captain KEY noticed at an early stage that the aircraft failed to accelerate - possibly because snow which had previously collected while the aircraft was temporarily stationary had frozen. Captain THAIN, on the other hand, stated expressly that until just before the end of the runway he had had the impression of a normal take-off. The aircraft did indeed attain V1 without difficulty (as will be shown in greater detail below). In Cologne, dry snow assumed a damp condition owing to rising temperatures, so that probably a relatively firm "sticky" snow was present. At Munich, on the other hand, rain had turned to snow and the snow was still so wet that a watery track remained where the wheels of the aircraft had travelled. The witness BARTZ stated this categorically. Such a liquid slush would by no means have had the necessary density and adhesiveness to pack the undercarriage to such an extent as Captain KEY describes. Braking of the undercarriage main wheels by ice would probably have left traces in the rubber. On the only tyre still available, however, which has been examined by the makers and which the Commission inspected during the proceedings in Munich, no trace whatever of such damage was discernible. Finally, prior to the beginning of the third /attempted/ take-off, the accumulation of slush or ice in the undercarriage must have been somehow visible. Captain KEY, describing the Cologne incident, states that his undercarriage was packed with a wide "apron" of snow and ice up to the wings. In the case in point, at Munich, the aircraft had already made two attempts to take-off. It had covered the distance from the terminal building to the runway and back and had twice travelled over the greater part of the runway. There was no basic change in the runway conditions between the first, second and third /attempted/ take-offs. Nevertheless there was nothing discernible on the

undercarriage prior to the third take-off. Even if none of the other witnesses saw anything of it, Mr. BLACK, the Station Engineer, who, according to his own statement, walked round the aircraft again, shortly before the third take-off, looking for possible defects, would at any rate have been bound to have noticed anything. But, as he stated in reply to express questioning, he had noticed nothing. A photograph placed at the disposal of the Commission (see Appendix 7), taken before the third /attempted/ take-off, clearly showed that there were no traces whatever of any ice or snow packing. Thus, besides general experience and probability, so many important points argue against the assumption that the undercarriage was braked by slush that, in the opinion of the Commission, this cannot have constituted the cause of the accident.

c) Wing Icing

It remained for the Commission to investigate whether there was a deposit of ice on the wings of the aircraft at the time of the /attempted/ take-off and whether such a deposit led to the inability of the aircraft to take off within the take-off area available and constituted the cause of the accident.

aa) At the outset, the fact that there was indeed a deposit of ice on the wings of the aircraft at the time of the /attempted/ take-off did not appear to have been established with sufficient certainty, because exact observations concerning ice accretion were not made until 2200 hr. on the day of the accident, i.e., not until six hours after the accident, and because snow had continued to fall steadily after the accident until 2200 hr. The Commission, however, came to the conclusion that the wings were iced up at the time of the /attempted/ take-off.

At 2200 hr. on 6th February, the scene of the accident presented the following picture:

The wrecked aircraft, which lay 70 m. from the centre of the fire and to windward of the latter, was covered with a layer of snow 8 cm. deep.

This was powdery snow which could be pushed or blown off from the surface of the wings without difficulty. Underneath there was a very rough layer of ice. This had not blended with the snow lying on top. Its thickness amounted to about 5 mm. From numerous spot-checks it must be concluded that the entire surface was covered with this layer of ice and that it was interrupted only in the region of the two engines over the width of the propeller slipstream. These facts are based on the reports of the Chief Inspector of Accidents (Unfallreferent) of the Luftfahrt-Bundesamt, charged with the preliminary investigation, and the statements of the witnesses Graf zu CASTELL and Dipl.-Ing. GOETZ, which are in agreement. These two witnesses proceeded at once to the scene of the accident with the Chief Inspector, after he had landed at Munich at 2200 hr., and all arrived at the same results after investigations undertaken independently of one another. Their reports were not contradicted by the BEA representative who made a partial inspection of the crashed aircraft on the same evening.

Purely on the basis of calculation, this deposit of ice, the thickness of which was established as 5 mm., could have formed from the wet snow which had fallen in Munich during the period between the landing of the aircraft and the accident. Dr. H.K. MÜLLER, the meteorological expert, on the basis of the records of the /aerodrome/ meteorological office, stated that at 1400 hr. in Munich there was a thin layer of snow not yet of measurable dimensions, but that a further 4-5 cm. of snow fell prior to the time of the accident. In his opinion it is, moreover, not possible to say exactly what thickness will remain when a layer of snow has turned into ice. We may, however, regard it as possible that the thickness of the ice in such a case amounts to about one-seventh to one-tenth of the layer of snow from which it has formed. Thus we may at any rate proceed from the assumption that the observations regarding the ice deposit at 2200 hr., on the one hand, and regarding the snowfall between 1400 and 1600 hr., on the other, are not contradictory.

In point of fact, the /amount of/ precipitation which, by calculation, corresponds to the ice deposit noted had collected on the wing of the crashed aircraft prior to take-off. This is borne out by the fact that during the stay in Munich the deposit had not been cleared from the wings of the aircraft, in spite of the snowfall, and that the snow must consequently have remained lying there. The snow which fell directly after the aircraft landed may, indeed, partly have run off the wings at first, as observed by the witnesses WIGGERS and BLACK during refuelling. Snow which had fallen on the wings and perhaps melted at the outset must, however, very soon have begun to cling.

The aircraft flew from Belgrade to Munich at altitudes of 21,000-25,000 ft. at an air temperature of -21°C. - -25°C. From this it must be concluded that the outer skin of the wings was thus severely supercooled. The observation of the witness WIGGERS indicates that snow began to cling at an early stage; during refuelling he had already noticed, from the wingtips, the building-up of a layer of snow. Consequently, it is to be assumed that well before the first /attempted/ take-off at 1519 hr. the wings were already covered with snow and that later the layer which led to icing had formed, owing to the further snowfall. In the case of all the other aircraft which took off that afternoon snow had, in fact, collected on the wings and in each case it had been removed by personnel of the air transport undertakings. These a posteriori conclusions were clearly confirmed by the witnesses SCHOMBEL and WÖLLNER, who were twice heard by the Commission in order to give BEA the opportunity to put forward any protests. When the aircraft taxied out to the third /attempted/ take-off both these witnesses had been watching it for some time from rooms fairly high up in the terminal building and at a distance which permitted of making reliable observations. The witnesses stated that they saw the wings, <u>outboard</u> of the engines, covered with a thick, unbroken layer of wet

snow. In reply to the suggestion that they might have been deceived on account of the colour of the wing, they stated definitely that they were quite certain about the layer of snow. There is no reason at all to doubt the credibility of their statements. The Commission held the witness SCHOMBEL to be a particularly valuable and reliable witness as regards the observation concerned, because he had been employed at Hamburg-Fuhlsbüttel Airport for some time and had been engaged on the removal of ice from aircraft. His observations are therefore based on knowledge of a highly expert nature. The Commission is therefore convinced that complete confidence can be placed in his depositions and that of the witness WÖLLNER, which is in agreement with them.

The depositions of Captain THAIN and Station Engineer BLACK regarding this question do not detract from the conclusive nature of the evidence given by these witnesses. Captain THAIN did indeed declare that he had observed no layer of snow on the wings but saw only melted snow running off the trailing edge of the wings. He was also in agreement with Captain RAYMENT that nothing need be done about the snow. The pilots, however, as must be inferred from the evidence of Captain THAIN, had at no time such a view over the wing as would have permitted them to judge the condition of the upper surfaces of the wings reliably. Prior to re-embarkation they went direct from the terminal building to the aircraft and then never left it until the accident occurred. The upper surfaces of the wings, however, were not visible, either from that part of the apron over which they walked or from the flight deck, as the aircraft is a high-wing monoplane. From the pilot's seat, only the forward curve of the wing profile is visible (see photographs). From outside the aircraft the wing surfaces cannot be seen at all from the front unless one stands in a raised position and from the rear they can be seen only from quite a distance. It is therefore entirely possible that the crew, on their way to the aircraft, saw nothing of the layer of snow. Mr. BLACK can therefore also have seen

nothing when he walked round the aircraft again and inspected it thoroughly before it taxied away to make the third /attempted/ take-off. Captain THAIN's observation about melted snow running off the trailing edges of the wings is explained simply by the fact that engine gases are exhausted through two openings over the wing; the wing surfaces became heated at this point and it was there that the snow melted. Thus, from this angle, also, no doubts arise concerning the reliability of the statement that a considerable layer of snow had indeed formed on the wings of the aircraft during its stop at Munich. The question as to the time when this layer of snow turned into ice is not a decisive factor, since Prof. Dr. SCHLICHTING, the expert, when questioned, emphasised more than once that this is of no noteworthy importance to the aerodynamic assessment of the take-off and flying qualities of the aircraft. The freezing-up of the layer of slush by the time of the accident can, however, be explained. It is true that in the case of the first /attempted/ take-off at 1519 hr., at a temperature of approximately 0°, the humidity of the air still amounted to 96%. Cooling by evaporation will thus still have been slight at this juncture. Only a film of ice will have formed on the cooled wing, under the layer of snow observed. When the last /attempted/ take-off was initiated, however, the air temperature was already -0.2°C. and the humidity of the air was 91%. Thus there existed conditions which point to the fact that by the time the aircraft taxied out for the third /attempted/ take-off and during the first phase of take-off, the cooling by evaporation had become so highly effective that the wet snowy mixture turned into the rough sheet of ice which was observed in the late evening of the same day.

Thus, even if all circumstances indicate that the ice accretion observed at 2200 hr. did indeed arise from the layer of slush on the wing observed by the witnesses, the Commission had nevertheless still to consider the question of (a) whether it might not have originated wholly or partly

from the precipitation which fell after the accident and, for this reason, (b) whether it had indeed been fully established that icing was a cause of the accident. It is true that the snow falling after the accident at temperatures of -0.2° (1600 hr.) to -3°C. (2200 hr.) was dry. Thus it could not have turned directly into ice. The question to be investigated, however, was whether, as a result of the fires caused by the accident, the snow (dry, in itself) had melted whilst still in the air or on falling on wings possibly heated by the fires to above 0° and had only solidified into ice when the fires were extinguished. The idea that the wings were perhaps warmed by the heat still remaining from the engines or by the fuel in the wing tanks was suggested during the proceedings. These and similar theories regarding subsequent ice formation all fail, however, to stand up to closer investigation. Arguing against the theory of subsequent ice formation is the fact that with such a process of melting and refreezing the snow would probably have become more firmly blended with the ice-layer proper in the transitional zone. According to the report of the Inspector making the investigation (Untersuchungs-führer) and the statements (agreeing with this report) of the witnesses Graf zu CASTELL and GOETZ, the lack of cohesion between the ice layer and the powdery snow on top was, however, extraordinarily marked. The snow could be "blown away", whereupon a sheet of ice immediately came to light. The fires which occurred would not have been sufficient to melt the snow in the air or on the wings. The minor outbreaks of fire in the immediate vicinity of the aircraft were soon extinguished and do not come into consideration as sources of heat. The hut, on the other hand, burned for a longer time, viz, to about 1700 hr., according to the report of the Munich Airport Administration. This centre of fire, which was certainly considerable, was situated, however, 70 m. from the wreckage (see attached sketch-map). Added to this is the fact that the wind was blowing away from the wreckage, in the opposite direction (see photograph, Appendix 1 (sic)). In these circumstances it is extremely

improbable that the radiant heat from any of the fires breaking out in the region of the aircraft wreckage had any effect on the snow. The remaining engine heat cannot have affected the entire wing to such an extent; it cannot have radiated thus far. Finally, it also appears out of the question that the fuel with which the aircraft had been replenished could have warmed up the whole wing again after the accident. Since it is established without a doubt from the statements by the witnesses SCHOMBEL and WÖLLNER that the fuel failed to cause the snow which fell prior to the accident to melt on the wings, it is quite out of the question that this should have happened after a further drop in outside temperatures and one and a half hours after refuelling. Furthermore, the fuel remaining in the aircraft prior to refuelling, after a flight at high altitudes, must have had a very low temperature. According to information from the firm which supplied the fuel, the temperature of the fuel taken on was not above about 0°C., because the tanker was parked in the open.

Even if all these points are not considered to be finally convincinf, however, there nevertheless remains as a decisive argument against any theories regarding subsequent ice formation the fact that, on the parts of the wing above the two engine nacelles, there was no ice deposit on the evening of the accident and no layer of snow before the accident, whereas elsewhere the wing upper surfaces were covered with snow or ice before and after the accident. Thus to this extent the observations of the state of the wings before and after the accident are in agreement. The parts of the wing above the engines would, however, have been iced up in the same way as the other parts of the upper surfaces had the ice actually originated from the precipitation which fell after 1600 hr., for there is no way of explaining why a subsequent snowfall over the engine nacelles should have been different from that on the other parts of the wing. Engine heat continuing to exert an effect on the wing upper surfaces for a while after the

accident could at any rate not entirely have prevented subsequent ice formation at these points. With the drop in temperature after 1600 hr., the engine heat would not have lasted as long as would be necessary for the formation of an ice layer 5 mm. thick. Above all, during the accident the port engine broke away from its mounting as a single unit (see Photograph No. 5) and lay 5 m. away from the wrecked aircraft, so that on this side there was no longer any heat-conserving element. Thus, in the case of subsequent ice formation the remains of the port wing ought, in any case, to have been uniformly iced up throughout, outboard and inboard of the engine. But this was not the case. Consequently, the engine zones on both sides could only have been cleared by the engine-heat, by the exhaust gases led over the upper wing surface and by the propeller slip-stream before the accident. Hence the deposit of ice cannot have originated as a result of precipitation which did not fall until after the accident.

bb) The Commission is convinced that the deposit of ice on the wings which, on the basis of all the foregoing, was undoubtedly present during /attempted/ take-off, prevented the aircraft from becoming airbone at any time. The fact that, under certain circumstances, wing icing can render an aircraft unable to fly, or at any rate considerably impair its take-off qualities, is well known in aviation. Although this would scarcely have required special proof, the Commission asked Dr.-Ing. PLEINES, the expert on air traffic statistics, to put forward a number of parallel cases. These do not, indeed, prove that such must have been the case at Munich on 6th February, 1958, but they do clearly illustrate the dangers of wing icing in principle. Other reports on similar incidents have also been referred to. In particular, the reports by the Flight Safety Foundation, New York, (Safety Suggestions), Trans-Canada Airlines, and the Department of National Defence, Ottawa, relating to ice accretion on aircraft on the ground, provide appropriate comparisons. Finally, the Commission of Inquiry

has had before it a number of instructions providing for de-icing in cases where the wings of aircraft on the ground are covered by snow, ice or hoar frost. Original texts and German translations of the following instructions, issued by the British, are attached to this Report as Appendices 4-6a:

(1) Air Registration Board "Notice to Licensed Aircraft Engineers and to Owners of Civil Aircraft", No. 14, dated 14th March, 1947: "The Effect of Hoar Frost, Snow and Ice on Take-Off".

(2) BEA Maintenance Instruction, General D-0-1, Issue 2, "Ground De-icing and De-frosting of Aircraft", dated 21st March, 1955.

(3) Reminder, issued on 7th February, 1958, that the Instruction referred to in (2) must be complied with.

These would, without doubt, not have been issued (and, in particular, would not have been so emphatic) had it not been established that any kind of accretion on the wings entails a risk of considerably impairing the flying characteristics of any aircraft. In order to check the general principle (founded on experience) that wing icing is highly detrimental to the flying qualities of aircraft, the Commission arranged for a scientific investigation relating to the crashed aircraft to be conducted. Prof. Dr. SCHLICHTING, the Director of the Institute of Flow Mechanics at the Technical University, Brunswick, was commissioned to undertake this investigation. Prof. Dr. SCHLICHTING is well known to the Commission as a recognised authority on aerodynamics. In compiling his report he has taken into account all available scientific material. The BEA representatives, assisted by an aerodynamics expert employed by the manufacturer, de Havilland, were afforded the opportunity of submitting to Prof. Dr. SCHLICHTING the material which they considered necessary for compiling the report, as well as the technical and aerodynamic data relating to the crashed aircraft, and of having a discussion with him at a joint meeting on 20th May, 1958, in Brunswick. The Commission also made available to Prof. Dr. SCHLICHTING the aerodynamic calculations put forward

orally by a BEA representative on 1st May, 1958, when the Professor was absent. All the BEA material referred to was taken into consideration when the report was being compiled. It was delivered orally during the proceedings and was discussed by all the parties. It is attached as a separate report.* Extensive reference is made to the contents. The error on page 22 of the report, according to which there were 2-4 cm. of slush on the runway, is of no account as far as the results are concerned, because the expert was referring to the quantity of snow that had fallen and at the desire of the Commission he had undertaken calculations based on various rolling-friction coefficients.

On the basis of the report the Commission arrived at the following conclusions:

As the main starting point it takes, on the one hand, the fact that, even assuming an extremely high rolling-friction coefficient (due to slush) of $/U = 0.10$, the aircraft would have been bound to become airborne after a rolling-distance of 1,080 m. at the latest. On the other hand, given this intensity of rolling friction, the expert's calculations show that with wing icing of about 5 mm. (the presence of which has been established) and a roughness height (based on this) of about 3 mm., the aircraft could not have attained the lift coefficient required for unsticking within a rolling distance of less than about 2,270 m. (i.e., at a point outside the aerodrome). There is, however, much to suggest that the rolling-friction coefficient was lower. Even if we proceed from the relatively low rolling-friction coefficient of $/U = 0.06$, however, the iced-up aircraft could still not have left the ground within a rolling distance of 1,900 m. (i.e., not before the end of the runway).

There may be some uncertainty in the exact determination of the thickness and roughness of the ice and in the determination of the rolling-friction coefficient. The Commission has been assured by the Inspector making the investigation, however, that a conservative estimate of ice

*Report not reproduced.

thickness and roughness has intentionally been given. The rolling-friction coefficient had to be set higher rather than lower. Consequently, everything suggests that owing to icing there was no question of the aircraft's unsticking before the end of the runway, even had it still been accelerating unhindered at this juncture. At this juncture, however, for other reasons (of which more will be said below), the aircraft was no longer accelerating. General flying experience and aerodynamic calculations are thus in agreement about the fact that an aircraft with such a degree of ice accretion as the aircraft involved in the accident would not, in the conditions obtaining at Munich on 6th February, be capable of taking off and flying within the take-off area available.

The increase, owing to icing, in the required take-off distance is due to two factors: the decrease in the maximum lift coefficient, as a result of which the necessary unstick speed was increased, and the rise in profile drag which reduced acceleration. The expert calculates the reduction in acceleration thus: the V 1 speed of 117 kt. was attained at about 1,680 m., given a rolling-friction coefficient of 0.10, or at about 1,400 m., given a rolling-friction coefficient of 0.06, assuming a roughness of 3 mm. This theoretical calculation corresponds approximately with the facts actually established, for in his description of the process of take-off Captain THAIN stated that the aircraft had accelerated normally. He could not indicate either the point along the runway at which he had made his observation regarding the decrease in the speed reading or the point at which V 1 was attained. Judging from the sequence of his whole account, however, the drop in speed can only have set in towards the end of the runway. Captain THAIN stated that during the process of take-off he at first only watched the instruments and did not look out of the aircraft. Only when he perceived a drop in speed did he look out. He then saw that they were in alarming proximity to the aerodrome boundary. Captain RAYMENT's exclamation, made at about the same moment, "We won't make it", would

naturally only have been made when they were already in a zone of the runway where catastrophe was seen to be unavoidable. There is therefore much to suggest that the drop in speed occurred approximately at or beyond the 1,800 m. mark. According to Captain THAIN's account, the aircraft first attained V 1, maintained, for a while, the speed it had reached, and only then lost speed appreciably. A certain interval must therefore have elapsed between the attaining of V 1 and the drop in speed. At 117 kt. a rolling distance of about 400 m. is covered in 6.5 seconds and a rolling distance of about 200 m. in 3.2 seconds. The interval during which V 1 was maintained would probably have lain within these values. If we proceed from this, and assuming that the drop in speed occurred within the zone beyond the 1800 m. mark, then it is highly probable that V 1 was indeed attained between 1400 m. and 1600 m., as the expert has calculated. Captain THAIN's statements thus provide a certain confirmation of the expert's calculations, as far as there can be any question of precise confirmation, considering the element of uncertainty in Captain THAIN's reconstruction of what happened. Under these circumstances the Commission considers it amply certain that V 1 was attained between 1400 m. and 1600 m. and was maintained or exceeded at any rate to within the region of the 1800 m. mark.

Nevertheless, although the nose was pulled up and the emergency tail bumper was at times on the ground, the aircraft could not be raised off the ground. For this, however, there is no explanation other than that given by the expert, viz, that owing to icing and the resultant decrease in lift coefficient, an unstick speed considerably higher than the normal one was required, and the fact that V 1 was not attained until a rolling distance of about 1400 m. had been covered could be attributed only to the increase in profile drag, which, likewise, could be accounted for only by icing. Thus icing was /a/ cause of the accident.

3. In spite of the foregoing facts, the Commission feels unable to declare with complete certainty that icing was the sole cause of the accident, owing to the fact that Captain THAIN's observation regarding the drop in speed towards the end of the runway can neither be refuted nor be explained with complete certainty. There may indeed be some uncertainty about the objective accuracy of the observation itself, since it is a generally acknowledged fact, based on experience, that, for subjective reasons, statements by witnesses are subject to error precisely when it is a question of giving an account of what happened in an unnerving catastrophe. On the other hand, it is entirely possible that the drop in speed of which Captain THAIN spoke so definitely did indeed occur. There is then the further doubt as to where it occurred and why it happened. There is much to suggest that the aircraft slowed down at the point on the runway at which the tracks of the locked wheels were visible after the accident. The loss of speed reported by Captain THAIN would then have the perfectly natural explanation that, in the final section of the runway, Captain RAYMENT saw disaster approaching and braked the landing wheels sharply. All four landing wheels were locked, as could still clearly be seen during the Commission's inspection in Munich. A simultaneous locking of all the wheels, however, can hardly have occurred except as a result of braking. But if this were the case it is not out of the question that a misunderstanding between the two pilots played a part at this juncture, for, whereas Captain RAYMENT (probably) applied the brakes, Captain THAIN, in the hope of averting the catastrophe at the last moment, did exactly the opposite, viz (as he stated during interrogation), pushed the throttle lever forward as far as possible. Thus the measures taken by the crew to avert the accident or make it less serious cancelled each other out. Whether it would have made any difference to the accident or the severity thereof if either the brakes had been applied and the throttle closed or the brakes had not been applied and the aircraft had

rolled on beyond the end of the aerodrome at full throttle cannot be stated with certainty. It is neither entirely out of the question that, if the aircraft had progressed unimpeded it would, before reaching the scene of the accident, have come within the limits of the required unstick speed (increased by icing); nor is it a sheer improbability that braking and closing of the throttle would have lessened the impact of the aircraft with the house and hut and could have made the results of the accident less serious. If the pilots did act in opposition in the manner outlined above, the Commission would regard this less as a pilot error (pardonable in these circumstances) than as faulty division of responsibility between pilot-in-charge (Kommandant) and second pilot.

As stated, it is not certain what actually happened at the point where the skid-mark was made on the runway. Even if we do not doubt that the brakes were applied, there remains the question of whether the drop in speed and the formation of the skid-mark really occurred at one and the same spot or whether the speed decreased just before, for other reasons. Captain THAIN's statement (the only source of information that can be considered) did not clarify this, because he noticed no braking. Aerodynamic explanations for such a loss of speed have been discussed with the experts. It is not out of the question that the pilot, after attaining V1, increased the angle of attack of the aircraft in order to initiate the unstick, with the result that the flow conditions over the iced-up wing changed and drag consequently increased. This, however, could not be proved by calculation. It is also possible that one of the pilots lowered the flaps just before the end of the runway; for, according to Captain THAIN's definite statement, the aircraft was taking off without flaps (as prescribed by BEA for Munich-Riem Airport). On the other hand, at the scene of the accident the flaps on both sides were found to be at take-off setting. Their design does not preclude the possibility that,

when the accident occurred, the flaps fell out of their own accord to an equal angle on either side, but this is not very probable. Flap-deflection, however, would also fail to account with sufficient certainty for a drop in speed of more than 10 kt. No indication of any other influences could be found.

After all this there still remains an element of uncertainty in the reconstruction of the course of the accident. This makes it appear not entirely out of the question that towards the end of the fatal take-off there arose, in addition to wing icing, a further circumstance which was a contributory cause of the accident. But this does not rule out icing as /the/ cause of the accident, for, even if a further circumstance affected the course of the accident in some way within a zone /of the runway/ lying beyond about the 1800 m. mark, this does not alter the fact that the aircraft would normally have become airborne long before this and that the accident would not have occurred if the aircraft had not been iced up.

Summary

The results of the Inquiry into the accident may thus be summarised as follows:

During the stop of almost two hours at Munich, a rough layer of ice formed on the upper surface of the wings as a result of snowfall. This layer of ice considerably impaired the aerodynamic efficiency of the aircraft, had a detrimental effect on the acceleration of the aircraft during the take-off process and increased the required unstick-speed.

Thus, under the conditions obtaining at the time of take-off, the aircraft was not able to attain this speed within the rolling distance available.

The decisive cause of the accident lay in this.

It is not out of the question that, in the final phase of the take-off process, further causes may also have had an effect on the accident.

(Signed) Stimpel Reichel G. Bock Utter

(Stamp)

LUFTFAHRT-BUNDESAMT

Certified true copy:

(Sd) Fritsch

Techn. Regierungsinspektor,

Brunswick, 31st January, 1959.

LIST OF APPENDICES

1. Transcription of tape-recording

*2. Statement by Captain J. Thain,

German translation.

2(a) Original English text.

3. Expert opinion of Dr.-Ing. C. E. Gerlach.

*4. Air Registration Board "Notice to Licensed Aircraft Engineers and to Owners of Civil Aircraft", No. 14, dated 14th March, 1947 : "The Effect of Hoar Frost, Snow and Ice on Take-Off",

German translation.

4(a) Original English text.

*5. BEA Maintenance Instruction, General D-O-1, Issue 2: "Ground De-Icing and Defrosting of Aircraft", dated 21st March, 1955,

German translation.

5(a) Original English text.

*6. Reminder, issued by BEA on 7th February, 1958, that the Instruction in Appendix 5 must be complied with,

German translation.

6(a) Original English text.

7. Photograph of the aircraft shortly before the fatal take-off.

8. Five pages of photographs.

9. Sketch-map of the scene of the accident.

*Report by Prof. Dr. Schlichting (separate item).

*Not reproduced here.

Appendix 1

C o p y

Bundesanstalt fur Flugsicherung,
Air Traffic Services Unit,
Munich

(Flugsicherungsleitstelle München)

FSK/B - AZ.0662

Munich,

8th February, 1958.

Tel. 470 186

TRANSCRIPTION OF TAPE RECORDING

(Subject: Accident to BEA Ambassador G-ALZU on 6th February 1958)

1. The following tape recording transcription contains all the R/T communication between BEA aircraft 609 (G-ALZU) and the Munich aerodrome control on frequency 118.7 mc/s during the period 1419 Z to 1504 Z on 6.2.58.

2. Radio stations participating:

(a) Munich aerodrome control (abbreviated TWR)

(b) BEA 609 (G-ALZU) (abbreviated 609)

3. Distorted or unintelligible parts are indicated by (.....); probable text is shown in small letters in brackets.

Time h m s	Station	Text
1419:00	609	MUNICH TOWER - B-LINE 609 ZULU UNIFORM - TAXI CLEARANCE PLEASE
	TWR	609 ZULU UNIFORM - MÜNCHEN TOWER - WIND TWO NINE ZERO - EIGHT KNOTS - CLEARED TO RUNWAY TWO FIVE - QNH ONE ZERO ZERO FOUR - TIME ONE NINE AND A QUARTER - OVER
:20	609	ROGER - THANK YOU
1421:30	TWR	B-LINE 609 - CLEARED TO LINE UP AND HOLD - AND HERE IS YOUR CLEARANCE - OVER
:40	609	609 UNDERSTAND - I GOT TO LINE UP AND HOLD AND I AM READY FOR THE CLEARANCE
:50	TWR	MUNICH CONTROL CLEARS B-LINE 609 ZULU UNIFORM TO THE MANCHESTER AIRPORT VIA AMBER AIRWAY ONE ZERO GREEN AIRWAY ONE AMBER TWO AMBER ONE AND ROUTE AS FILED - MAINTAIN ONE SEVEN THOUSAND FEET - RIGHT TURN AFTER TAKE-OFF - CLIMB ON THE SOUTH COURSE INBOUND TO THE FREISING RANGE - OVER

Time h m s	Station	Text
1422:10	609	AH - 609 ZULU UNIFORM - UNDERSTAND - IS CLEARED BY MUNICH ACC TO MANCHESTER VIA AMBER TEN - GREEN ONE - AMBER TWO - AH - TO MAINTAIN SEVENTEEN THOUSAND FEET - A RIGHT TURN OUT - SOUTHBOUND HEADING INBOUND TO THE FREISING RADIO RANGE - IS THAT AFFIRMATIVE - OVER
:50	TWR	609 - THAT IS NOT CORRECT - CLIMB ON THE SOUTH-COURSE OF THE FREISING RANGE INBOUND TO THE RANGE - OVER
	609	RIGHT TURN OUT - THE SOUTH COURSE INBOUND TO THE FREISING RADIO RANGE - OVER
1423:00	TWR	AH - THAT IS CORRECT
1429:30	TWR	B-LINE 609 - HOW LONG WILL IT TAKE FOR ENGINE RUN - OVER
:40	609	HALF A MINUTE
	TWR	AH - ROGER
1430:00	TWR	B-LINE 609 YOUR CLEARANCE EXPIRES AT THREE ONE - TIME NOW THREE ZERO - OVER
:10	609	AH - MUNICH - 609 ZULU UNIFORM - I AM READY TO TAKE-OFF
	TWR	609 ZULU UNIFORM - WIND TWO NINE ZERO - ONE ZERO KNOTS - CLEARED FOR TAKE-OFF - RIGHT TURN OUT
:20	609	THANK YOU
:40	609	ROLLING
	TWR	ROGER
1431:20	609	609 - WE ARE ABANDONING THE TAKE-OFF
	TWR	TOWER - PLEASE SAY AGAIN
:30	609	WE ARE ABANDONING THE TAKE-OFF - MAY WE BACKTRACK - OVER
	TWR	609 - CLEARED TO BACKTRACK
:40	609	THANK YOU
:50	TWR	609 - FOR YOUR INFORMATION - WE HAVE A CAR ON THE RUNWAY WHICH WILL BE REMOVED ANY SECOND
1432:00	609	HAVE A CAR ON THE RUNWAY ?
	TWR	DISREGARD - THE CAR IS LEAVING THE RUNWAY NOW - IT'S ON THE OTHER END
	609	... (roger)

Time h m s	Station	Text
1432:50	609	...MUNICH FROM 609 ZULU UNIFORM - WHEN WE GET TO THE END OF THE RUNWAY WE SHOULD LIKE TO TAKE-OFF AGAIN - IS THE CLEARANCE STILL VALID ?
1433:00	TWR	...NICH TOWER - ROGER - STAND BY
1434:00	TWR	609 - YOUR CLEARANCE IS STILL VALID - HOWEVER - MAINTAIN FIVE THOUSAND FEET UNTIL FURTHER ADVISED - THE WIND THREE ZERO ZERO - EIGHT KNOTS - CLEARED FOR TAKE-OFF
:10	609	THANK YOU - UNDERSTAND - MAINTAIN FIVE THOUSAND FEET UNTIL FURTHER ADVISED
:40	609	ROLLING
1435:20	609	MUNICH - 609 ZULU UNIFORM - WE'RE ABANDONING THIS TAKE-OFF AS WELL
	TWR	AH - ROGER - CLEARED TO BACKTRACK
:30	609	WE WOULD LIKE TO BE CLEARED BACK TO THE TARMAC - OVER
	TWR	ROGER - CLEARED TO THE RAMP
:40	609	UNDERSTAND - CLEARED TO BACKTRACK AND CLEARED TO THE TARMAC - AFFIRMATIVE ?
	TWR	YOU ARE CLEARED TO BACKTRACK OR CLEARED TO TAXI VIA CROSSWIND - AS DESIRED
:50	609	ROGER
1436:10	TWR	B-LINE 609 - DO YOU WISH TO MAKE ANOTHER TAKE-OFF RIGHT NOW OR DO YOU WISH TO WAIT AT THE RAMP - OVER
:30	609	609 ZULU UNIFORM - I AM RETURNING TO THE TARMAC - I AM RETURNING TO THE TARMAC - TO THE TERMINAL - OVER
	TWR	ROGER - THAT IS UNDERSTOOD
1439:00	609	609 ZULU UNIFORM AT THE ... (tarmac)
	TWR	AH - ROGER
1450:00	609	MUNICH B-LINE 609 ZULU UNIFORM
	TWR	609 ZULU UNIFORM - MÜNCHEN TOWER - GO AHEAD
:10	609	WOULD YOU HAVE MY CLEARANCE RENEWED - I AM ABOUT READY TO START
:20	TWR	MÜNCHEN TOWER - ROGER
1452:40	TWR	B-LINE 609 - CLEARED TO START UP ENGINES - YOUR FLIGHT PLAN HAS BEEN DELIVERED TO ATC

Time h m s	Station	Text
1456:30	609	MUNICH TOWER - B-LINE 609 ZULU UNIFORM - I AM READY TO TAXI - OVER
	TWR	609 ZULU UNIFORM - MÜNCHEN TOWER - WIND TWO NINE ZERO - EIGHT KNOTS - CLEARED TO RUNWAY TWO FIVE - QNH ONE ZERO ZERO FOUR - TIME FIVE SIX AND THREE QUARTERS - OVER
:50	609	THANK YOU
1459:30	609	MUNICH - 609 ZULU UNIFORM - ARE WE CLEARED TO LINE UP ?
	TWR	B-LINE 609 ZULU UNIFORM - CLEARED TO LINE UP AND HOLD - AND HERE IS YOUR CLEARANCE - OVER
	609	ROGER - GO AHEAD
:40	TWR	MÜNCHEN CONTROL CLEARS B-LINES 609 TO THE MANCHESTER AIRPORT VIA ROUTE AS FILED - MAINTAIN ONE SEVEN THOUSAND FEET - RIGHT TURN AFTER TAKE-OFF - CLIMB ON SOUTH COURSE INBOUND FREISING RANGE AND MAINTAIN FOUR THOUSAND FEET UNTIL FURTHER ADVISED - OVER
1500:00	609	ROGER - I UNDERSTAND - I AM CLEARED TO MANCHESTER VIA THE ADVISED ROUTE TO MAINTAIN SEVENTEEN THOUSAND FEET - A RIGHT TURN OUT - THE SOUTH COURSE INBOUND TO THE FREISING RANGE UP TO FOUR THOUSAND FEET - MAINTAIN FOUR UNTIL ADVISED - OVER
	TWR	ROGER - CLEARANCE CORRECT
:40	TWR	B-LINE 609 - WHAT IS YOUR RATE OF CLIMB - OVER
:50	609	SIX HUNDRED FEET A MINUTE
	TWR	AH - ROGER
1502:00	TWR	B-LINE 609 - YOUR CLEARANCE VOID IF NOT AIRBORNE BY ZERO FOUR - TIME NOW ZERO TWO
	609	ROGER - UNDERSTAND - VALID TILL ZERO FOUR
:40	609	AH - MUNICH - 609 ZULU UNIFORM IS READY FOR TAKE-OFF
	TWR	609 - THE WIND THREE ZERO ZERO - ONE ZERO KNOTS - CLEARED FOR TAKE-OFF
:50	609	ROGER - THANK YOU
1503:06	609	ROLLING
:10	TWR	...NICH TOWER - ROGER
1504:00	609	MUNICH - FROM B-LINE ZULU UNIF...

(Note: The last message starts with a howling-whistling noise and ends with loud background noise after the message was broken off.)

.....

The transcription of the text of the tape recording is certified as correct.

(Sgd.) HANS KOLLE

Head of FSK/B Munich

Copy

Accident at Munich 6.2.58

Statement by Captain J. Thain

G-ALZU

ALTP No. 24827
Elizabethan Flying Hours 1732 hrs.

On the 6th February, I was in command of Elizabethan aircraft G-ALZU which was chartered to fly from Belgrade to Manchester via Munich, and after landing at Munich, the engines were switched off at 13.11Z.

I proceeded to the Met. Office with Captain Rayment and Radio Officer Rodgers. It was snowing and the tarmac was covered with puddles of water and slush to a depth of about one inch. After the Met. briefing Captain Rayment and I completed the Flight Plan and extracted from the Operations Manual the V1 and V2 speeds for the flight. We left the Met. Office and I walked to the Air Traffic Control Office to file a Flight Plan. Captain Rayment did not accompany me, I believe he went to the BEA Office. Outside the Air Traffic Control Office I was met by Captain Rayment, and after taking the Operations Manual from me we discussed the snow which had fallen on the wings of the aircraft. He told me that he had looked at the wings of the aircraft and in his opinion it was not necessary to have them swept. I agreed with him and then left to sign the ship's papers in the BEA Office whilst he walked to the aircraft. After signing the papers I departed for the aircraft, and upon approaching it, studied the snow fall on the starboard wing. A thin film had formed but was not easily identified because it had thawed where it had fallen on the ribs of the aircraft wing, and I saw the thawed snow running off the trailing edge of the wing.

After the passengers had boarded the aircraft, the doors were closed, engines started, and the chocks were removed at 14.19Z.

Captain Rayment was occupying the left-hand seat and manipulating the flying controls, and I was sitting in the right-hand seat performing the duties of co-pilot - as we had done on the previous sector from Belgrade.

When all the cockpit checks had been completed and we had received clearance to take-off, Captain Rayment opened the throttles and we started to roll down the runway. I followed the advancing throttles with my left hand, and when they reached the maximum position I lightly tapped his hand which he removed and then held my hand behind the levers. Captain Rayment called "Full Power" and I confirmed saying "Full Power", then, monitoring the temperatures and pressures and warning lights, called "Temperatures and pressures OK, Warning Lights out". We continued to accelerate down the runway and when we achieved 90 knots I called "90", and then "100" when we reached 100 knots. At this point I heard an uneven note in the engine noise and glancing at the boost pressures I was just able to see both indicators fluctuating before Captain Rayment retarded the throttle levers. He called "Abandon take-off" and I immediately gripped the control column and assisted him in holding it fully forward whilst he applied the brakes. We slowed down and obtained permission to back-track in order to make another attempt to take-off. Before we reached the take-off point Captain Rayment said he wished to open the throttles a little before releasing the brakes and from that point he would open the throttles more slowly than he had done on the first attempt. We had both recognised that there had been boost surging which might have occurred through too fast a movement of the throttle levers. A power check was not considered necessary and after positioning the aircraft for the take-off, clearance was obtained to take-off.

Captain Rayment opened the throttles to about 28" of boost, released the brakes and we started to roll forward. He continued to open the throttles slowly but positively, and, with my left hand behind the levers I followed this movement until the levers were in the fully open position. I then tapped his hand which he removed. The starboard engine boost pressure was steady at 57 1/2", but the port pressure rapidly increased beyond the maximum figure of 60". I believe I said "The port is off the clock" and then pulled both throttle levers back to the closed position. We continued to roll towards

the end of the runway and I decided to return to the tarmac to consult the engineer. Whilst we were taxying down the runway I completed the cockpit checks and when we were clear of the runway Captain Rayment asked me to take over the taxying whilst he informed the passengers on the Public Address System the reasons for our return to the tarmac. I agreed and took over the controls. I recall that I could not see any other tyre marks in the snow and also that it was not possible to identify the edge of the perimeter track in between the markers. Captain Rayment then took over again and we parked the aircraft on the tarmac.

Engineer Black boarded the aircraft and inquired the reason for our return. I told him that we had abandoned two take-offs because of boost surging and he reminded us of the fact that surging had been a frequent occurrence at Munich in the past due to the height of the airfield. He continued that the technique adopted was to control the surge by manipulating the throttle lever. I acknowledged this and said that whilst I was aware of this remedy, if the movement of the throttle lever became out of synchronisation with the surge to any extent, it could develop into a snaking movement of the aircraft which with snow on the runway was undesirable. This aspect was discussed with Captain Rayment and recalling that we had found the landing run and nosewheel steering satisfactory on landing from Belgrade I decided to make a third attempt. Captain Rayment then asked Mr. Black if there was anything that could be checked and he said nothing apart from a complete re-tune of the engines. I confirmed my intention to depart and at that point learnt that the passengers had been off-loaded. I asked the engineer to tell the Traffic Officer to board the passengers as quickly as possible. Whilst we were waiting for this to be done I talked to Captain Rayment about the snow. We looked at the wings and agreed that we had lost the thin film which we had observed before our initial departure and again considered that there was no necessity to have the wings swept. By this time the passengers had boarded the aircraft but one was missing and after about 5 minutes he was found and then we departed.

The visibility had improved and there was less snow falling, we carried out a complete power check at the take-off point, and when the cockpit checks were completed I told Captain Rayment that I would control the throttles if surging was experienced on this run. Clearance was given to take-off and Captain Rayment opened the throttles to about 28" with the brakes on, the readings were quite steady, he released the brakes and we started to roll forward. He continued to open the throttles and with my left hand I followed this movement until the levers were in the fully open position. I tapped his hand which he removed and then Captain Rayment called "Full Power" and having checked the instrument readings replied "Full Power". I checked the temperatures, pressures and warning lights and then called "Temperatures and pressures OK, Warning Lights Out". At about 85 knots the port boost started to surge, I called "Port Surging slightly" and pulled the port throttle lever back until the surging was arrested, the reading was about 54" and then advanced the lever again until it was fully open and indicating 57 1/2". The starboard indication had remained at 57 1/2" throughout. I called "Full Power Again" and glanced at the temperatures and pressures. I then looked at the Air Speed Indicator, the speed was 105 knots and I called "105", the boost remained constant at 57 1/2". The needle of the ASI was flickering slightly and when it indicated 117 knots I called "V1" and waited for a positive indication of more speed. Captain Rayment was adjusting the trim of the aircraft. (Up to this point, whilst I had not looked out of the cockpit, I had not experienced any feeling that the acceleration had been other than normal under the circumstances.) The needle hovered at 117 knots and then dropped 4 or 5 knots, I was conscious of a lack of acceleration, the needle dropped further to about 105 knots and hovered at this reading. Suddenly, Captain Rayment called out "Christ, we won't make it!" I looked up for the first time and saw a house and a tree, all this time my left hand had been behind the throttle levers, I raised it and banged the throttles but they were fully forward. I believe Captain Rayment was pulling the control column back,

he called hurriedly, "Undercarriage up" and I selected up and then gripped the ledge in front with both hands and looked forward. The aircraft's passage was very smooth as if we had become airborne and it looked as if we were very slowly turning to starboard, I remember thinking that we couldn't possibly get between the house and the tree. I lowered my head and then the aircraft collided.

After the impact I glanced up and through the snow which had fallen on the windscreen I saw a vivid glow which appeared to extend round the nose of the aircraft. From this point we were subjected to many violent movements and the sound of the aircraft breaking up filled the air. I next looked up when we came to rest, we didn't appear to be on fire, I gave the order to evacuate the aircraft and at the same time released my safety belt. Captain Rayment made an effort to leave his seat but called out that he couldn't move because his foot was jammed, I remember saying "come on man, get out" but he could not move. I told him to hang on whilst I had a look at the outside, expecting fire to break out at any moment and then left the cockpit. Outside I ordered the crew to run away from the wreck because of the fire hazard, the Radio Officer remained and we quickly identified 5 or 6 small fires. Two were inboard of the starboard engine underneath the wing which was almost intact, and the others were at the end of what was left of the port wing. I returned to the cockpit and collected the two fire extinguishers pausing to tell Captain Rayment that it was necessary to put the fires out before I could assist him. We were unable to extinguish all the fires but the Airport Firemen were quickly on the scene and they eventually put the remaining fires out. The rescue work continued.

(Signed) J. Thain
Captain

Elizabethan Flight, BEA

6th March, 1958

Appendix to the statement by Captain J. Thain

Munich Accident 6.2.1958

In view of the preliminary reports made by the German Authorities in which they have stated that the accident is associated with ice formation on the aircraft wings, I am most anxious to ensure that all aspects of the accident are brought to the attention of the Court and thoroughly investigated.

In particular, from the evidence submitted two main facts have emerged; firstly, the aircraft speed did not exceed V1, secondly, the loss of speed could not have been caused by ice on the wings. From these facts therefore, it would appear that the cause of the accident had no connection whatsoever with ice accretion on the wings. Furthermore, the indications are that the cause is directly connected with a loss of speed which could only manifest itself by restricting the free rotation of the aircraft wheels.

(Signed) J. Thain
Captain

Elizabethan Flight, BEA

6th March, 1958

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Addendum to the Appendix of the statement of

Captain J. Thain

Elizabethan Accident, Munich, 6.2.58

As I am given to understand that the Variable Decision Take-off Technique as practised by BEA is not necessarily the same as that used by other Operators, I should like to take this opportunity of explaining it in detail for the purposes of clarity.

Within BEA the use of the variable decision speed (V1), selected to give the optimum benefits on take-off performance, is one of the basic principles used in calculating permitted take-off weights for Viscount and Elizabethan aircraft.

Group A standards to which these aircraft operate require the take-off weight to be so limited that should an engine fail at the decision speed (V1), the aircraft shall be capable of either:-

(a) continuing the take-off with one engine inoperative, reaching a height of 50 feet within the take-off distance available, and thereafter clearing all obstructions by a prescribed margin, or,

(b) being brought to a standstill within the emergency distance available.

It will be seen from the above that V1 (decision speed) actually represents a distance, but in the absence of a suitable way in which to measure the distance during a take-off run, the distance has been associated with a speed calculated for a hard dry runway. No figures are available for wet or snow covered runways.

The V1 speed then, represents a point beyond which the take-off cannot be abandoned with safety.

V2 Speed

A second speed is used in this method which is known as the take-off safety speed or V2. This takes into account the aircraft's gradient of climb with one engine inoperative, and also the difficulty of keeping the machine straight at slow speeds in the assymetric state.

The pilot is instructed not to attempt to fly the aeroplane off until the V2 is reached in order to ensure that (1), the machine will have the required gradient of climb to clear obstruction in the net flight path, and (2), that he will have sufficient rudder control to check the natural swing resulting from engine failure.

Operating Procedure

During the take-off, the pilot monitoring the instruments calls "V1" when that speed is attained. The pilot manipulating the flying controls then knows

that he is committed to continue the take-off. The pilot monitoring the instruments then calls "V2" when that speed is reached and the plane is flown off.

Conclusions

From the foregoing, the pilot's actions immediately prior to the accident may be more easily explained.

When our V1 speed of 117 knots was reached I called "V1". Captain Rayment then knew we were committed to the take-off. However, the aircraft failed to accelerate to the V2 speed for which he was waiting. He would have been wrong in attempting to fly under these conditions, and indeed, the fact that the tail bumper did not touch the ground, indicates that the aircraft was never at a sufficient angle of attack to fly.

(Signed) Captain J. Thain

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B.E.A. Flying Staff Technical Bulletin No. 81 and 132

Copy

Dr.-Ing. Carl E. Gerlach,
Construction Engineer,
Expert on Planning & Construction
of Aerodromes.
Lecturer at the Technical
University, Stuttgart.

Stuttgart-Feuerbach,
Elsenhansstrasse 13,
Telephone: 81582

18th June, 1958.

Subject: Accident to Aircraft G-ALZU at Munich on 6th February, 1958

Expert Opinion

on the Question of Freedom from Obstructions
in the immediate Vicinity of the Western
Approach Sector 1)

At the meeting on 29th April, 1958, in Munich, the under-signed gave a verbal opinion on the accident to aircraft G-ALZU. In a letter dated 6th June, 1958 (Az.: 841-V12/58/Tgb - No. 3342/58), the Luftfahrt-Bundesamt requested that the verbal opinion be put in writing for the Commission of Inquiry.

This opinion is confined, in the main, to answering the question of whether the presence of the house, 9.5 m. high and 270 m. from the end of the runway, was contrary to the German regulations and the international Standards and Recommended Practices of ICAO.

For the investigation of the present question, the following have been taken as a basis: (a) §§ 10a, et seq., of the Supplementary Law, dated 27th September, 1938, to the Air Navigation Law (Luftverkehrsgesetz) (LVG) and (b) ICAO Annex 14, together with supplements thereto.

The house concerned is located within the 1.5 km. radius specified under the LVG and is thus to be designated as an obstruction, both under this Law and in accordance with ICAO Recommended Practices.

Translator's Notes:

1) Anflugsektor: appears to be a three-dimensional concept combining the approach area and the approach surface.

The opinion is based on the following points:

1. Munich-Riem Airport is licensed by the Bavarian State Ministry of Economy & Transport as an aerodrome for use by international commercial air transport, and the relevant requirements are fulfilled.

2. The house concerned existed before the airport was constructed and approved. Its removal could therefore have been effected only by means of expropriation.

3. ICAO Annex 14, 2nd Edition, 3.1.1. recommends2) that, for reasons of safety, obstructions which should be removed shall, if not removed, be marked accordingly.

4. The requirement in 3 is fulfilled, as the house is marked by an obstruction light.

To this may be added the fact that reconstruction of the wrecked building on the same site will not be permitted. The building project, in this case, would, under §§ 10a, et seq., of the LVG, have to be submitted to the Luftamt for approval and would be rejected in view of its designation as an obstruction to air navigation. This requirement has been incorporated in the prospective revised version of §§ 10a, et seq., of the LVG and complies with the ICAO Standard 3) (Annex 14, 2nd Edition, 2.2.1) concerning the construction of new buildings, which shall be prohibited if they project above the obstruction-free approach surfaces.4)

To summarise: in view of the fact that the house was specially marked by a double obstruction light, its presence was not contrary either to German regulations or to ICAO International Standards and Recommended Practices.

(Signed) Gerlach

Certified true copy
Dipl.-Ing. Fritsch(?)
Brunswick
6th January, 1959.

Translator's Notes:

2) ICAO-Richtlinie: 3.1.1. contains a Recommendation.
3) " " : 2.2.1. contains a Standard.
4) Neigungslinie der Anflugsektoren: literally "sloping line of the approach sectors".

Appendix 4a

A b s c h r i f t

Air Registration Board

Notice to Licensed Aircraft Engineers and to Owners of Civil Aircraft

No. 14

Issue 1

14th March, 1947

The Effect of Hoar Frost, Snow and Ice on Take-off

1. As a result of a recent accident, it is necessary to draw the attention of all concerned to the dangers of the adherence of hoar frost, snow or ice to aerofoil surfaces, and to stress the vital importance of removing such deposits immediately prior to take-off.

2. When an aircraft has been standing in the open overnight or even for a period during the day at low temperatures, a deposit of hoar frost may be formed. This deposit will affect the aerodynamic characteristics of the aircraft to such an extent as to increase the drag and stalling speed, and decrease the rate of climb.

3. It is not sufficient to remove any snow which may have fallen because any hoar frost underneath will still remain. Snow will also adhere to hoar frost and will not be completely blown off when the aircraft commences to take off.

4. Glaze ice is caused by supercooled rain falling on aircraft surfaces which are at a temperature below freezing point. It is not easily visible at a distance and may have the same effect as hoar frost.

5. The de-icing of control surfaces alone is insufficient as the presence of hoar frost or glaze ice on the main planes will be sufficient to affect the take off to a dangerous degree.

By order of the Board,

gez. R. E. Hardingham

for Secretary

Brettenham House,
Strand,
London, W.C.2.

Copy

British European Airways

Maintenance Instruction

Distribution A

General D-O-1 Issue 2

General - De-icer System

Ground De-icing and De-frosting of Aircraft

INTRODUCTION

Several incidents have occurred where take-offs were affected by what appeared to be inadequate clearance of ice on the ground. Aircraft of the Elizabethan and Viscount classes will get super-cooled at altitude, and as a result can ice up on the ground at temperatures a little above freezing. Rain or sleet on such an aircraft can form into hard ice and the standard frost removers will not then be effective. In those cases the use of a concentrated fluid is required.

Two fluids will, therefore, be available. They will be Kilfrost G-17 for all normal uses and Kilfrost Arctic for the special conditions outlined above. It is important that the most economical use is made of these fluids and the following is therefore issued as a general guide and recommendation. Particular local conditions will, however, have to be assessed and dealt with individually by the Engineers concerned. Kilfrost Arctic fluid will be available from the same supply source as Kilfrost G-17 and TKS.R.328.

ACTION

1. General

Where frost or snow has formed on the wing or tail surfaces, G-17 should be sprayed on, and after the fluid has had time to be effective, the slush which will have formed should be swept off.

If ice has formed, Arctic should be applied locally by a controlled flow and brushed into the ice. Spraying will be ineffective and uneconomical in this case, as the fluid will not be retained long enough on the ice to melt it.

2. Typical Conditions and corresponding measures to be taken

(i) Aircraft landing after prolonged flight at low temperatures and standing in rain, sleet, snow, etc.

Spray with G-17 immediately. One hour before take-off, clear and re-spray with G-17. If ice is found to be adhering, apply Arctic locally to bad patches and check and clear again before take-off.

(ii) Aircraft out of hangar say 3 hours before take-off in frost or snow conditions:-

One hour before take-off spray with G-17 and clear and check just before take-off.

(iii) Aircraft parked all night in frost or snow

Two-three hours before take-off spray with G-17. Clear and inspect half an hour before take-off and re-spray if necessary. Apply Arctic locally if ice has formed.

3. Special Precaution

(i) Particular attention should be paid to ensuring that slush swept off wings, tail-planes, etc. is not allowed to remain in control surface shroud gaps. This is less likely to occur if the aileron or elevator is depressed while sweeping is going on.

(ii) The fact that an aircraft can ice up with ground temperatures just above freezing if it has been super-cooled on its previous flight, should be appreciated - especially on turn-around - and in these circumstances a specific check should be made prior to take-off.

(iii) To prevent soiling of cabin upholstery, ensure that all cockpit windows and fuselage doors are closed before spray is applied.

CANCELLATION OF INSTRUCTIONS

This Instruction supersedes Maintenance Instruction General D-O-1 dated 18.11.53 which is therefore cancelled.

(Sgd.)
Chief Inspector
for Chief Engineer

21.3.55

Appendix 6a

Copy

Notice to Flying Staff

All Flights No.

7th February, 1958.

Pre-flight precautions in Snow conditions

Chief Executive has requested that all pilots and engineers be reminded of the necessity to ensure that all aerofoil surfaces of aircraft are clear of ice and snow before take-off.

The relevant paragraphs from Flying Staff Standing Instructions are given below:

7.22.2.1. Ground engineers have been instructed to ensure that all aerofoil surfaces which can affect the performance of the aircraft are clear of all forms of ice and snow by spraying them with de-icing fluid as near as possible to time of departure of a Service. It is possible, however, under certain weather conditions, between the time an aircraft has been sprayed by the engineers and the time of take-off, for sufficient ice accretion, such as freezing rain or wet snow, to form on the wings and control surfaces as to affect adversely the performance of the aircraft.

7.33.2.2. Captains are, therefore, to make absolutely certain immediately before take-off, that lift and control surfaces of their aircraft are clear of ice or snow.

Signed: G. G. McLannahan

Duty Flight Manager

Aircraft G-ALZU on the apron at Munich-Riem Airport a few minutes before taxying out to the third [attempted] take-off (i.e. the fatal attempt). The photograph was taken from a window fairly high up in the terminal building.

Fig. 1 The scene of the accident and the wrecked aircraft.

Fig. 2 The wrecked aircraft and the port engine.

Taken on the day after the accident, after thaw had set in.

Fig. 3
Left side of fuselage and port engine mounting.

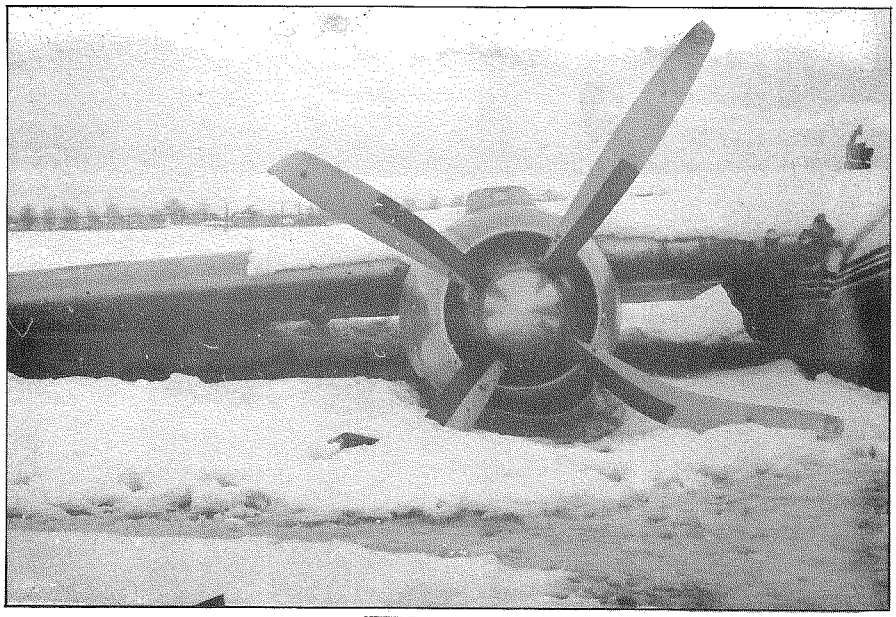


Fig. 4
Starboard wing, with engine.

Fig. 5
Port engine.

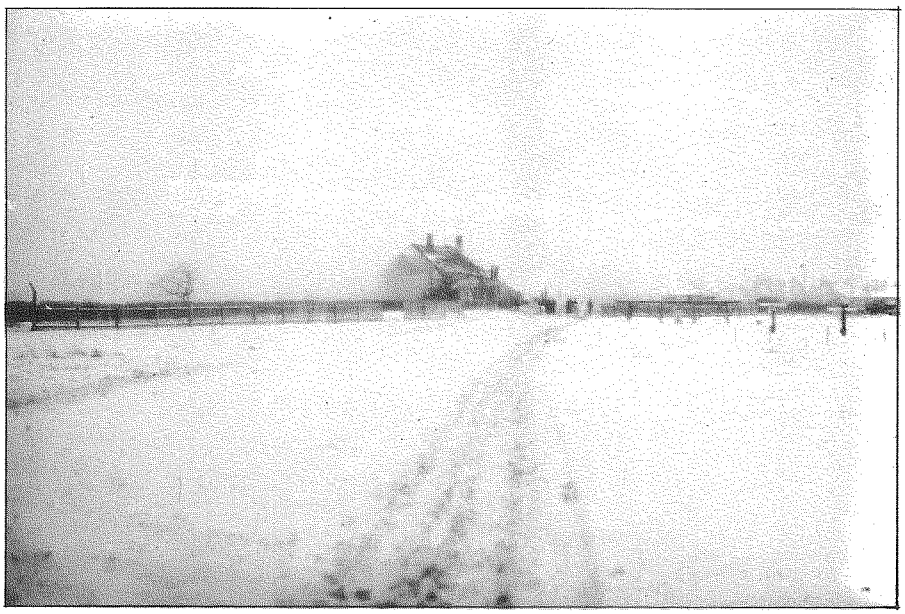


Fig. 6
Photograph taken shortly after the accident. Wheel tracks (facing in the direction of take-off).

Fig. 7
Photograph taken on day after the accident, during thaw. (Opposite direction.) Runway in the background. (Footmarks)

Fig. 8
Photograph taken four days after the accident, when the snow had melted. (Direction as in 7). Runway in background.

Photographs taken four days after the accident.

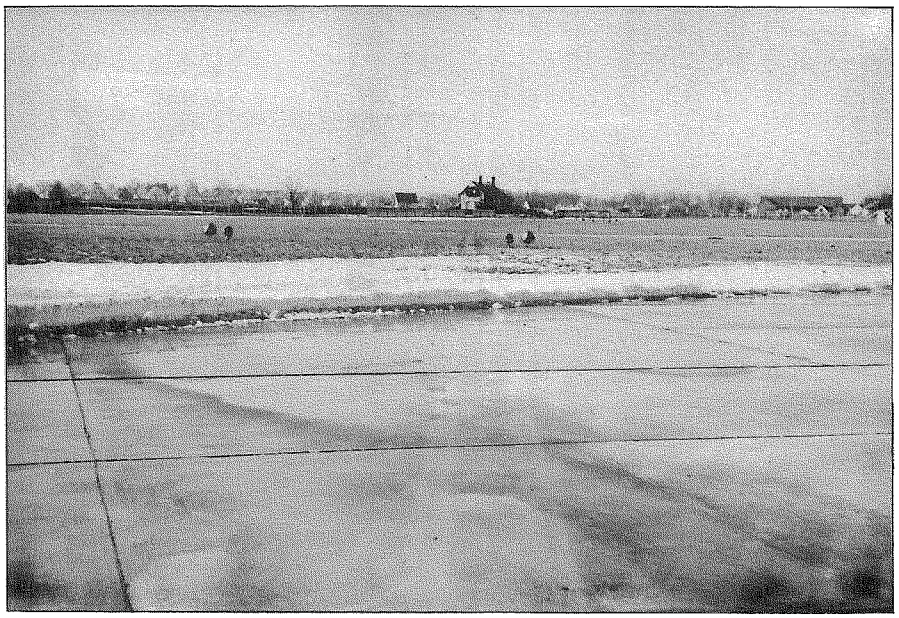


Fig. 9 Skid-marks left by right-hand undercarriage wheels at end of concrete runway.

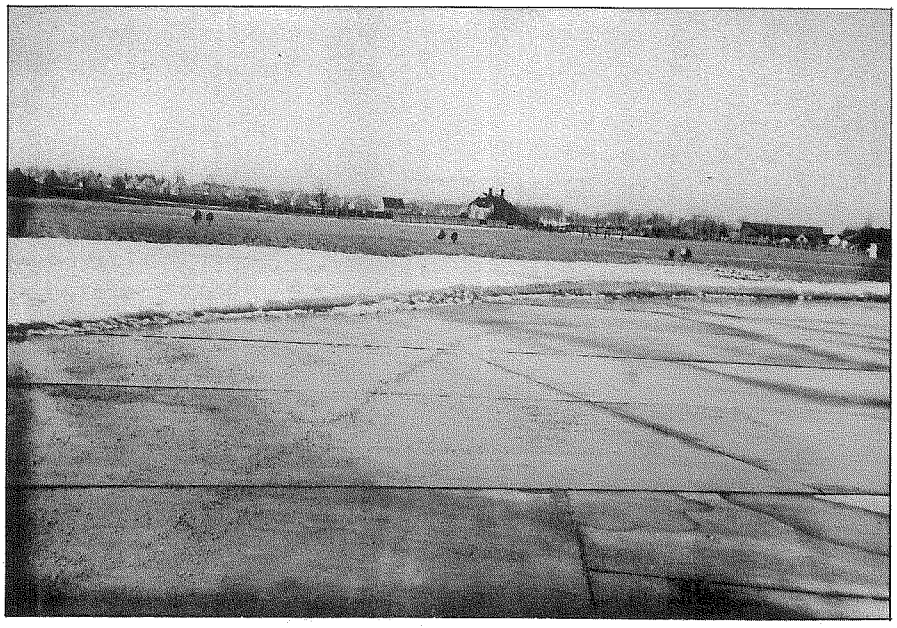


Fig. 10 Skid-marks left by left-hand undercarriage wheels at end of concrete runway.

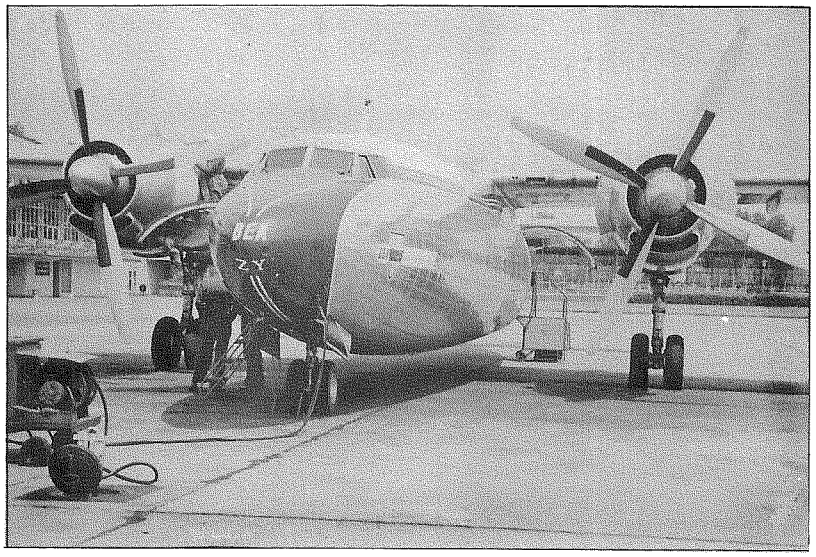


Fig. 11
An "Elizabethan" aircraft.

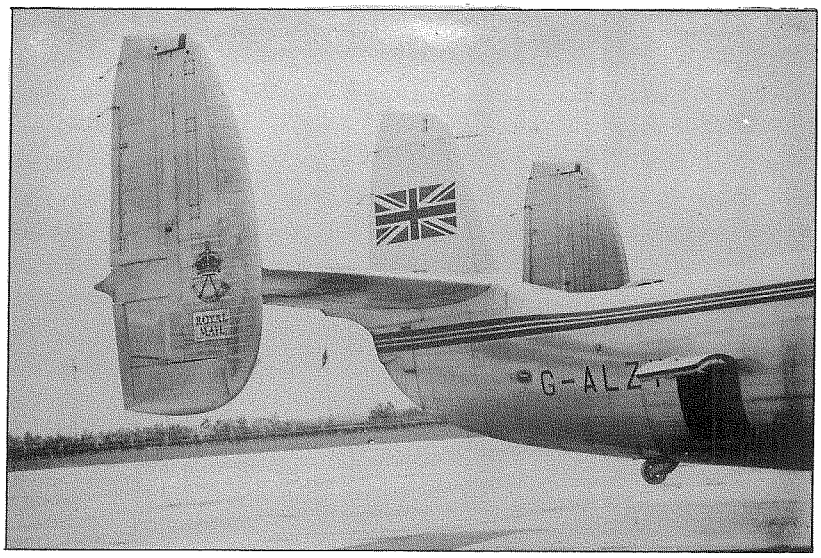


Fig. 12
The (emergency) tailwheel.

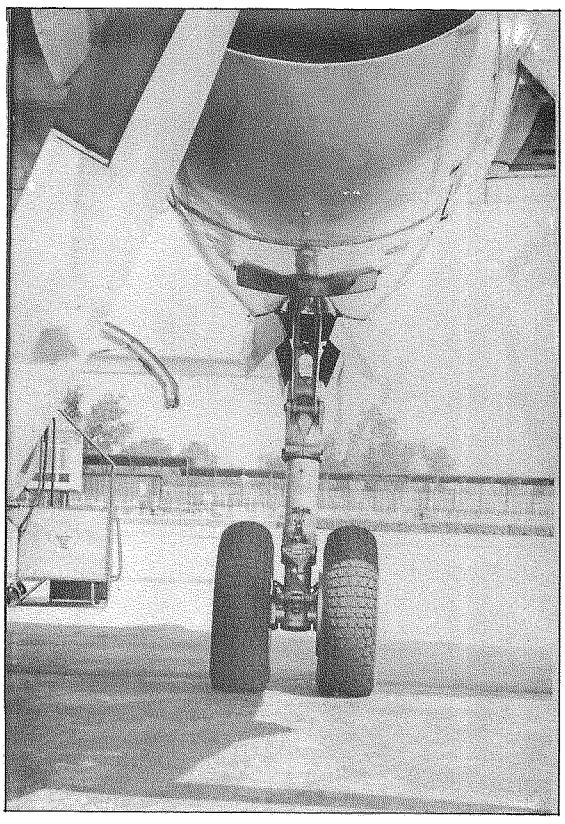
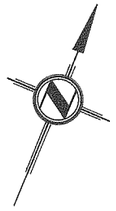


Fig. 13
Front view of main undercarriage.

APPENDIX 9

FLUGZEUGUNFALL AM 6 FEBRUAR 1958
UHRZEIT 16·04
AIR-SPEED G-ALZU DER BRITISH EUROPEAN AIRWAYS

AIRCRAFT ACCIDENT 6th. FEBRUARY 1958
TIME 16·04
AIRSPEED AMBASSADOR (ELIZABETHAN) G-ALZU
OF BRITISH EUROPEAN AIRWAYS



FRAU VON UTA STREET
HOUSES
ROADWAY
ROAD
BUILDING ADJACENT TO AIRPORT
TARMAC
BUILDING 15
WINDSOCK
GRASS LANDING AREA 1755m x 90m
WEST TAXI WAY
AIRFIELD BOUNDARY FENCE
EMPL ROADWAY
I.L.S. TRANSMITTER
GATE
56m (183·68')
Mr. WINKLER'S HOUSE AND GARAGE
TREES BROKEN OFF 9·84' FROM THE GROUND
PART OF WING
PORT ENGINE
I.L.S. AERIAL SLIGHTLY DAMAGED (LOCALISER)
I.L.S. MONITOR
EXTENDED CENTRE LINE OF THE RUNWAY 66'/246°
REAR FUSELAGE AND EMPENNAGE
3·15m (10·33')
42·80m (140·38')
DOUBLE TYRE MARK
INTERRUPTED 38·40m (125·95')
INTERRUPTED 150m (492')
WEST END OF RUNWAY
DOUBLE TYRE MARK
RUNWAY 1907·50m X 60m (6258' X 197')
LIGHT STRUCTURAL PARTS
5·6m (18·37') 6·2m (20·34')
28m (91·84')
9·5m (31')
FENCE DESTROYED FOR 3m (9·84')
Mr. BERGER'S HOUSE 9·5m (31·16')
PART OF THE WING 19·68' LONG
TREES BROKEN OFF 13·12' FROM THE GROUND
RED-GREEN THRESHOLD LIGHT DESTROYED
WEST THRESHOLD
270m (885·6')
385m (1262·8')
450m (1476')
ROAD TO GRONSDORF
100 50 0 100 200 300 400 500 FEET
30 0 50 100 150 METRES

M.T.C.A., A.T. 6.(D.O.)DRG. No. 2317

MUNICH-RIEM AIRPORT

FLUGZEUGUNFALL AM 6-2-1958 16·04h.
AIR SPEED G-ALZU B.E.A.

	DATE	NAME
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CHECKED	10-2-58	Goetz
DRAWING No.		

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