No. 16

British European Airways Corporation, AS 57 Ambassador (Elizabethan), G-ALZU, accident at Munich-Riem Airport, Germany, 6 February 1958. Report released by the Federal Republic of Germany and also published by the Ministry of Transport and Civil Aviation, United Kingdom, as CAP 153.

Circumstances

The aircraft had carried out a special flight on 3 February 1958, from England to Belgrade, making an intermediate landing at Munich-Riem Airport for refuelling purposes. On 6 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 local time. A take-off was commenced at 1603 hours, but the aircraft did not become airborne. It overshot the boundary of the manoeuvring area 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 (6 crew and 38 passengers) 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.

Investigation and Evidence

Crew Information

The captain completed a conversion course on Ambassador aircraft on 23 March 1955. Since then he had flown 1 722 hours on this type of aircraft. His last flight check was on 14 October 1957. His total flight time amounted to 7 337 hours up to the day of the accident. In the 30 days prior to 2 February 1958 he had flown about 26 hours and during the three days prior to the accident - 7 hours.

The co-pilot completed a conversion course on Ambassador aircraft in March 1953. He was qualified as captain on the type and since then he had flown 3 143 hours on this type of aircraft. His total flight time up to the day of the accident amounted to 8 463 hours. During the 30 days prior to 2 February 1958 he had flown barely 6 hours and during the last three days prior to the accident - 7 hours.

On the flight from England to Belgrade the aircraft was flown by the captain, and it was to be flown by the co-pilot on the return flight. For this reason, at the time of the accident, the latter was sitting in the left-hand seat, and the captain was sitting on the right.

Weather

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

Time 1504 hours (the accident occurred shortly after 1604 hours) - 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 6 February the following observations (QNY) were made:

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

Munich-Riem Airport

Elevation:
528 metres (1 732 ft)
Density altitude:
884 metres (2 900 ft)
Length of Runway:
(249°), 1 908 m (6 260 ft)
Length of Stopway:
250 m (820 ft)

Accident Details

The aircraft made three attempts at take-off, two were abandoned, and the accident occurred during the third attempt.

The co-pilot abandoned the first take-off because 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 to take-off followed immediately after the aircraft had taxied back to the beginning of the runway. The engine run-up was not repeated. The captain 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, and the BEA station engineer went aboard. 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 the captain had throttled back slightly for a short time. 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.

Discussion of Possible Causes of the Accident

The Commission was able to exclude at the outset a number of points which might have been taken into account as possible causes of the accident.

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

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 Organization.

The members of the crew held valid licences, and the aircraft documents were valid and in order.

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

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 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, were subjected to a test run by the manufacturer. 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 fuel was tested and found satisfactory.

The loading of the aircraft lay within the permissible limits.

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 6 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 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) <u>(Rolling) friction caused by slush on the runway</u>

It is obvious that snow or slush on the runway can increase the rolling friction to such an extent that a take-off is impeded or even becomes impossible. The Commission had before it numerous reports on experiences and accident reports concerning cases where slush led to difficulties. In brief, 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 in the afternoon of 6 February the runway was first of all wet but free of snow and slush. From 1120 hours onwards snow fell. Temperatures were initially above zero but from 1500 hours onwards dropping to 0° and later below 0°. The records indicated that by 1600 hours 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 3/4 - 1 in thick. This estimate tallies with the observations of a witness, who examined the condition of the runway between the first two take-off attempts. He stated that he found that the entire runway was covered with slush approximately 1/2 - 3/4 in deep. None of it was snow, but it was a jellified, watery mass covering the entire runway.

As against this, another captain who landed at Munich at 1553 hours on 6 February stated 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 was regarded as unreliable, since as this captain 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".

According to the reliable statements of 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 was convinced that the (rolling) friction caused by so thin a layer of slush cannot have been a cause of the accident. No case is known in which this caused take-off to be abandoned on concrete runways, let alone caused an accident. An expert put forward the view that, assuming a rolling friction coefficient of $\mu = 0.06$, the rolling distance required for a normal take-off may be increased by approximately 110 m at the most. The captain of G-ALZU, who survived the accident, stated that he was satisfied with the condition of the runway, otherwise he would not have made a third (attempt at) take-off. The Commission was 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. Locking of the wheels owing to slush during the process of take-off was 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. At the V_1 speed of 117 kt (216 km/h), which was attained and, at times, exceeded, the wheels (tire diameter 38" = 96.5 cm) were rotating at about 1 200 rpm. Added to this is the fact that, at the narrowest point between the tires, 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 from 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. However, since the captain did not consider it out of the question that this might provide an explanation of the accident, the Commission went into this question with special care.

The possibility cannot be excluded that, with the Ambassador, 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. A photograph placed at the disposal of the Commission 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 argued 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.

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 hours 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 hours. The Commission, however, came to the conclusion that the wings were iced up at the time of the (attempted) take-off.

At 2200 hours on 6 February, the scene of the accident was as follows:

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 was 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.

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. On the basis of records of the (aerodrome) meteorological office, at 1400 hours 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. It was not possible to say exactly what thickness will remain when a layer of snow has turned into ice. It is possible that the thickness of the ice in such a case amounts to about 1/7 to 1/10 of the layer of snow from which it has formed. Thus - the observations regarding the ice deposit at 2200 hours, on the one hand, and regarding the snowfall between 1400 and 1600 hours, 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 witnesses 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. to -25°C. From this it must be concluded that the outer skin of the wings was thus severely supercooled. One witness observed that snow began to cling at an early stage: during refuelling he had already noticed, from the wing tips, the building-up of a layer of snow. Consequently, it is to be assumed that well before the first (attempted) take-off at 1519 hours the wings were already covered with snow and that later the layer which led to icing had formed, owing to the further snowfall. When the aircraft taxied out to the third (attempted) take-off two witnesses who had been watching it for some time stated that they saw the wings, outboard of the engines, covered with a thick, unbroken layer of wet snow.

The freezing-up of the layer of slush by the time of the accident can be explained. It is true that in the case of the first (attempted) take-off at 1519 hours, 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 indicated that the ice accretion observed at 2200 hours 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 hours) to -3°C. (2200 hours) 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. These and similar theories regarding subsequent ice formation all failed, 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 and the statements of witnesses, 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, to about 1700 hours, 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. Added to this is the fact that the wind was blowing away from the wreckage, in the opposite direction. 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 was established without a doubt from statements of witnesses 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 0°C., because the tanker was parked in the open.

Even if all these points are not considered to be finally convincing, 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 hours, 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 hours, 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 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 slipstream before the accident. Hence the deposit of ice cannot have originated as a result of precipitation which did not fall until after the accident.

The Commission was 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 airborne 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.

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 and 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 $\mu = 0.10$, 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 $\mu = 0.06$, 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 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 (discussed 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 6 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 the captain 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. The captain 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. The co-pilot'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 the captain'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 1 800 m mark, then it is highly probable that V_1 was indeed attained between 1 400 m and 1 600 m, as the expert calculated. The captain'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 the captain's reconstruction of what happened. Under these circumstances the Commission considers it amply certain that V_1 was attained between 1 400 m and 1 600 m and was maintained or exceeded at any rate to within the region of the 1 800 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 - 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 1 400 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.

In spite of the foregoing facts, the Commission felt unable to declare with complete certainty that icing was the sole cause of the accident, owing to the fact that the captain'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 the captain 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 the captain would then have the perfectly natural explanation that, in the final section of the runway, the co-pilot 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 at 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 the co-pilot (probably) applied the brakes, the captain in the hope of averting the catastrophe at the last moment, did exactly the opposite, (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 captain and co-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 wheter 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. The captain'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 V_1, 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 the definite statement of the captain, 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 1 800 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.

Probable Cause

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.

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.

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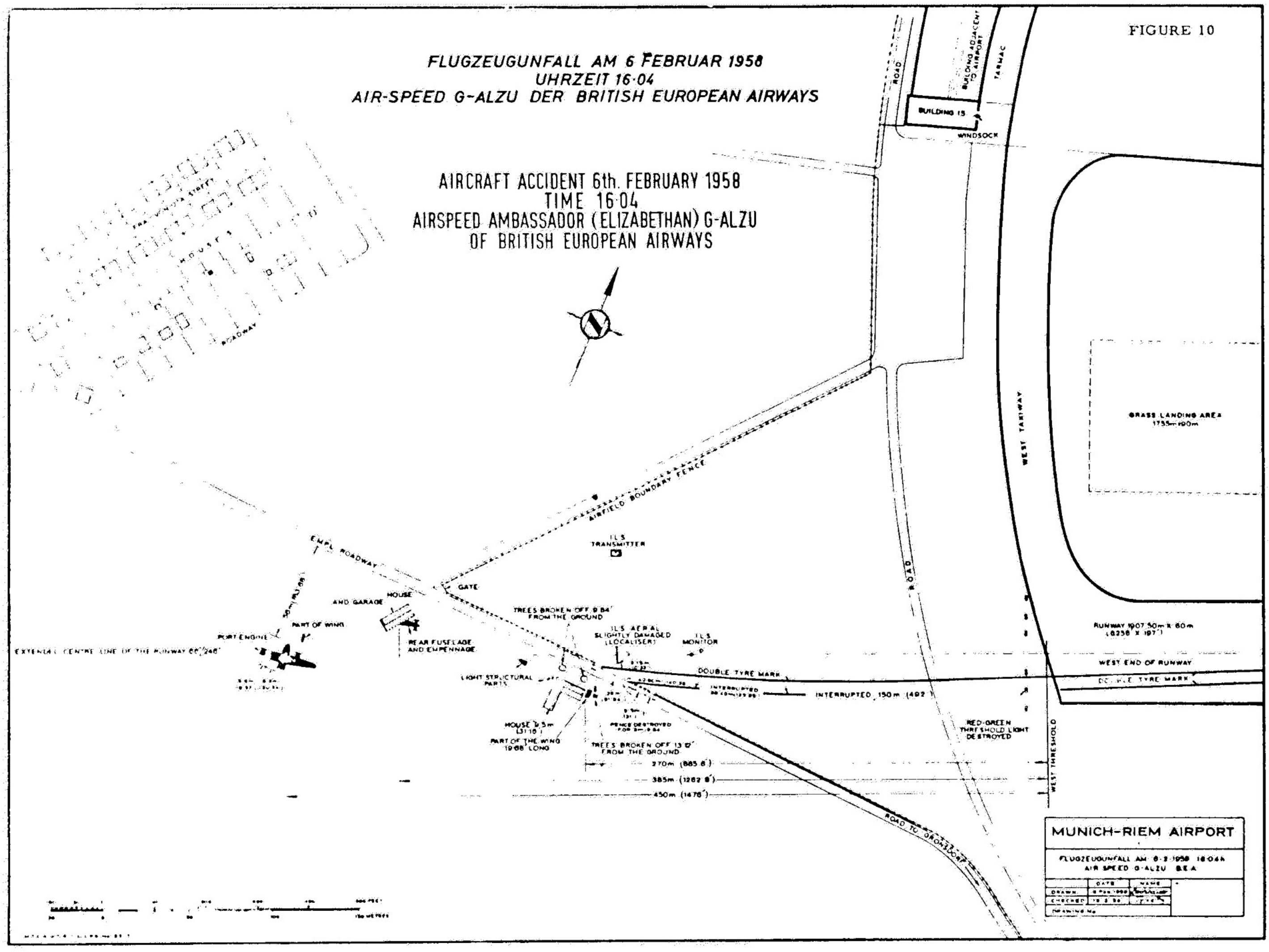
ICAO Ref: AR/565

FIGURE 10


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
BUILDING 15
WINDSOCK
TARMAC
ROAD
AIRFIELD BOUNDARY FENCE
I.L.S. TRANSMITTER
WEST TAXIWAY
GRASS LANDING AREA
GATE
HOUSE
AND GARAGE
PART OF WING
PORT ENGINE
REAR FUSELAGE AND EMPENNAGE
TREES BROKEN OFF 9.84' FROM THE GROUND
I.L.S. AERAL SLIGHTLY DAMAGED (LOCALISER)
I.L.S. MONITOR
DOUBLE TYRE MARK
WEST END OF RUNWAY
INTERRUPTED 150m (492')
LIGHT STRUCTURAL PARTS
HOUSE
PART OF THE WING
TREES BROKEN OFF 13.0' FROM THE GROUND
RED-GREEN THRESHOLD LIGHT DESTROYED
WEST THRESHOLD
270m (885.8')
385m (1262.8')
450m (1476')
ROAD TO GRONSDORF
MUNICH-RIEM AIRPORT
FLUGZEUGUNFALL AM 6-2-1958 16·04h
AIR SPEED G-ALZU B.E.A.

ACCIDENT TO BEA, AMBASSADOR AIRCRAFT, G-ALZU, AT MUNICH-RIEM

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

FIGURE 11

Left side of fuselage and port engine mounting.

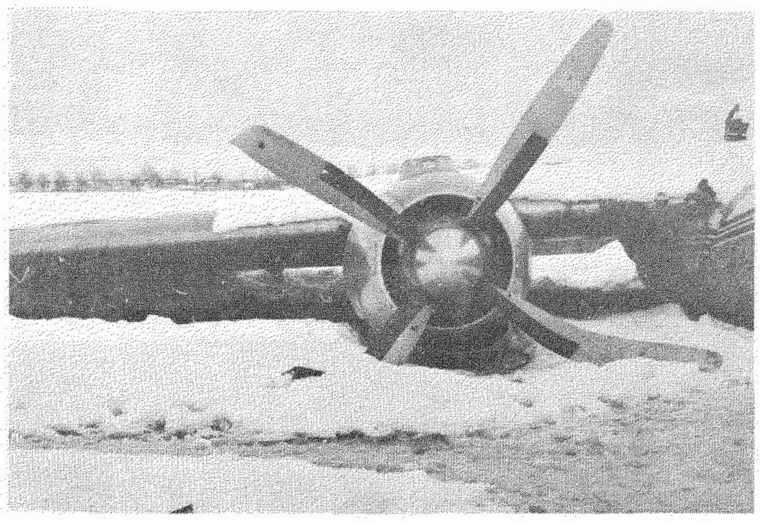


FIGURE 12

Starboard wing, with engine

FIGURE 13

Port engine