No. 9

Aer Lingus Téoranta, DC-3 Dakota aircraft ("Saint Kevin") crashed near Lake Gwynant, Caernarvonshire on 10 January 1952

(The meteorological situation prior to and at the time of the flight is included in considerable detail as important technical information.)

Circumstances

At 1725 hours on 10 January the DC-3 (Saint Kevin) took off from Northolt Airport en route for Dublin, carrying a crew of three and twenty passengers. The flight was without incident as far as Welshpool. The intended course from this point onwards until the coast was reached at a point near Harlech, lay over the Welsh mountains with heights rising to about 3 000 feet.

At 1855 hours the "Saint Kevin", which throughout was flying under Instrument Flight Rules, asked and received permission from Preston Air Traffic Control to ascend from 4 500 feet which was the planned height of the flight, to 6 500 feet, being the next authorized level for westbound flights on this route. No reason was given for this request.

At about 1912 hours the aircraft reported its position to be over Nevin. At some time between 1912 and 1915 hours the "Saint Kevin", having changed to the Dublin frequency requested descent clearance. Dublin acknowledged this request and granted clearance which was not acknowledged. No further radio messages were received. At about 1915 hours the aircraft crashed approximately 18 nautical miles from Nevin Beacon in a northerly direction, at a point about 4 nautical miles E S E from the summit of Snowdon. All the occupants of the aircraft lost their lives.

Investigation and Evidence

The main problems for the Court were to discover:

i) Why the "Saint Kevin" was so far from the position in which the Captain believed it to be, and (the aircraft was neither over nor abeam on her course of Nevin at 1912 hours)

ii) What caused it to strike the ground.

The General Meteorological Situation. Prior to and at the time of the flight there was a broad, deep and rapid stream of air from the middle of the Atlantic across the whole of Ireland and across England south of a line approximately from Morecambe Bay to the Humber. The direction of the stream was from WNW to ESE. There was little variation in the direction up to heights of over 30 000 feet but the speed increased from about 60 knots at 6 000 feet to about 100 knots at 30 000 feet.

The air in this stream had come from the Western Atlantic between the Azores and Bermuda. On 8 and 9 January it had moved thence north about 1 500 miles. The lower layers were cooled as they moved over the colder ocean. These layers became very stable, i.e. resistant to vertical motion, in fact at this stage the temperature at 3 000 feet, 50°F., was higher than the temperature at sea level, about 45°F.

The stream turned gradually eastwards and from longitude 30° W moved at the great speeds already mentioned parallel to a stream of much colder air to the north of it, between latitudes 55° N and 65° N. This latter stream was moving more slowly at heights below 20 000 feet, but at equal or higher speeds at greater heights. In fact above 20 000 feet the two streams had practically the same temperature and could be regarded as merged into one great west to east current.

In the lower layers, however, the streams were separated by a transition zone or frontal surface sloping upwards from south to north with a gradient of about 1 in 50. Such a zone or front is a region where bad weather with extensive masses of cloud of cumulonimbus type is frequently, though not invariably, found. In such clouds dangerous icing is a recognized hazard and in winter it may occur at comparatively low altitudes. The position of this zone in relation to the "Saint Kevin's" route is therefore of prime importance. In the early morning of 10 January

the front, at sea level, ran westwards from the North of Ireland and during the forenoon it moved rather slowly northward and extended eastward. In the afternoon it began to move south and by 1800 hours had regained its early morning position in N W Ireland and ran from there just north of the Isle of Man and thence to the Humber. Subsequently it moved more rapidly southwards and reached Dublin at about 2100 hours and North Wales about an hour later or 3 hours after the time of the accident.

The bad weather associated with such a front is usually limited to a narrow band a few miles wide at the front itself and in advance of it, though in some cases the bad weather extends a substantial distance in advance of the front. A careful examination of the recorded observations of cloud and weather in advance of this front, as it moved south across the country, shows that it did not come into the latter category. The hail and snow reported by witnesses as occurring in the Welsh mountains after the accident but before the passage of the front cannot therefore be explained as due to an over-running of cold air from the north in advance of the front. The explanation must be sought in another direction and this will be indicated in the paragraphs immediately following.

Where the air-stream turned eastwards, between 300 and 600 miles south of Greenland, the freezing level on the afternoon of 9 January was at a height of 10 000 feet. It had fallen about 2 000 feet in the preceding 24 hours, through cooling by radiation as the air moved northwards. It was this section of the air-stream which reached England in the afternoon and evening of 10 January after travelling another 1 500 miles across the Atlantic Ocean and Ireland. Its temperature, at heights above 1 000 feet, was still so high that the cooling of the upper layers through radiation continued more slowly. Thus when 12 hours later, at 0300 hours on 10 January, this section of the air-stream reached a British Weather Ship ("Weather Watcher") in lat. 53°N., long. 18-1/2°W., the freezing level was still above 9 500 feet.

Gradually this air, originating from the eastern side of the original northward moving air-stream, was being followed in its track towards England by air, still from the same general stream, coming from further west. This latter air had followed a longer track over the ocean, over an area of ocean of much lower temperature. Consequently it had cooled appreciably more in the layers between 3 000 and 8 000 feet. It arrived earlier in the upper layers above 3 000 feet owing to the greater speed of the wind in these layers with the result that the freezing level at "Weather Watcher" fell after 0300 hours on 10 January at the rate of about 1 000 feet in 6 hours, although the temperature near sea-level showed no change.

For a similar reason, the freezing level was lower in the stream 150 miles north of "Weather Watcher" than at "Weather Watcher" though this was still the warm air-stream as distinct from the cold stream mentioned in a previous paragraph. It was this section of the warm air-stream which reached North Wales.

While the temperature of the upper layers fell, the temperature of the lowest strata of the air-stream increased as the air moved eastwards from south of Greenland to Ireland. It rose from 45° F to over 50° F owing to the increase in the temperature of the ocean from west to east in the track of the air-stream. In labile air this increase of temperature would have lifted the freezing level about 1 000 feet. In fact it had no direct convective influence on the freezing level in this stable air, with its high freezing level, and the effect of the increase in radiation was insignificant.

The result of these different causes affecting the height level was a reduction from the 9 500 feet recorded at "Weather Watcher" to 7 500 feet in the section of the air-stream reaching N.W. Ireland near 1 500 hours on 10 January. This was the section of the stream which reached the Daventry-Nevin section of the route of the flight about 4 hours later when the "Saint Kevin" was in it.

When the air in this rapid stream reached Ireland a new factor of change began to operate on it, viz., large scale turbulence. Over the ocean the turbulence arising from the contact of air and water acts very slowly in changing the lapse-rate of a stable air-stream towards the labile rate. It takes many days for the effect of such turbulence to spread upwards 6 000 feet. This is the approximate height at which freezing level would be reached in the air-stream of 10 January if the stream were transformed by mechanical turbulence from a stable to a fully labile state up to that height. Over level or undulating country the process is still relatively slow and the time for the transformation would still be more than a day. But the large scale turbulence in a 60-knot stream crossing coastal cliffs and mountainous country extends the change of the lapse much more rapidly upwards and the process was assisted on the afternoon of 10 January by the reduction of temperature already mentioned in the layers between 3 000 and 8 000 feet.

When the air reached the Irish Sea it had already lost some of the stability it had possessed over the Atlantic. It underwent a further change when it was over the Welsh mountains. There, as it was lifted, it cooled at the full labile rate. This affected both the freezing level and the weather.

The temperature of the air at 4 500 feet, approaching the mountains from the Irish Sea, deduced from the considerations outlines and the radio-sonde observations, was 38° F, and the freezing level between 6 500 and 7 000 feet. Making the reasonable assumption that the air at 4 500 feet was lifted 1 500 feet, about half the height of the Snowdon range, its temperature on reaching the 6 000-feet level, as it crossed the range, would have fallen to freezing point, thus lowering the freezing level by more than 500 feet.

As the air-stream rose over the mountain range, a high percentage of the moisture in it was condensed and in the violent local upcurrents, to be expected when the 60-knot air-stream met the steep western face of the range, snow would be formed above the freezing level and possibly small hail, though not the usual hail of thunderstorms. The snow, as it fell through the cloud below freezing level, picked up water and melted, producing, as it must by established theory, the rain which fell in the mountains, in contra-distinction to the drizzle which characterized the weather of the nearby sea level meteorological station at the Royal Air Force Station, Valley, in Anglesey.

The rain so formed would be carried rapidly away from its source, but the possibility of its subsequently meeting another ascending current and being carried up again above the freezing level cannot be wholly excluded in the turbulent conditions prevailing over the extensive area of the Welsh mountains on the evening of the 10 January. The ascending current would need to be stronger than 1 000 feet per minute. If the raindrops were carried up, they would become super-cooled and would produce clear ice on an aircraft meeting them. But the cloud of such drops above the freezing level would necessarily be of small horizontal extent in the direction of the air-stream and an aircraft would be quickly through it - probably in less than a minute.

The violent local upcurrents mentioned would have their counterpart in intense local downcurrents on the lee side of the mountain range, and these downcurrents would not be confined to levels below the top of the mountain range. Observations, notably over the Rock of Gibraltar as well as in many other mountains, show that such currents may be found at heights at least double those of mountains of heights comparable with those of North Wales; and that the downward speeds may reach values of 1 000-2 000 feet per minute in winds half the strength of those on 10 January.

The Flight. The "Saint Kevin" took off from Northolt at 1725 hours on the 10 January 1952. According to the "flight plan" Daventry should have been reached at 1759 but the aircraft reported to Uxbridge (London Airways) at 1756 hours by R/T with the words "checked Daventry".

At Daventry up to which point the average ground speed was 97 nautical miles per hour (hereinafter referred to as "knots") the aircraft had to turn on to a course which brought the wind about dead ahead with a consequent reduction of about 8 knots in the ground speed. At 1800 hours the "Saint Kevin" reported to Uxbridge (South Eastern Flight Information Region) giving the time of passing Daventry as 1756 hours as in the previous message and estimating the time of passing over the point at which the course line cuts the third meridian west of Greenwich (hereinafter called "3° W") as 1841 hours implying an estimated ground speed of 96 knots.

At 1836 hours the aircraft reported to Uxbridge (SEFIR) with the words "Check three degrees west", and because on passing that point it entered the Northern Flight Information Region, at 1838 hours reported to Preston (NFIR) ". . . . check three west now estimate Nevin one zero (i.e. 1910 hours) and Dublin one nine five one (i.e. 1951 hours)".

Assuming that 1838 hours, when the words "check three west now" were used, was the time at which the Captain believed that he was at 3° W he could then have seen that his ground speed from Daventry to that point must have been 103 knots, 7 knots more than his estimate at Daventry and 18 knots more than indicated in the flight plan. This value is much too high in view of the undisputed value of airspeed and wind speed.

In view of the foregoing it is impossible for anyone to say where the "Saint Kevin" actually was at 1838 hours or at what time 3° W actually was reached.

The anticipated ground speeds implied by the 1838 hours report to Preston were 101 knots between 3° W and Nevin and 106 knots between Nevin and Dublin, respectively 6 knots and 11 knots higher than the speeds in the flight plan.

About sixteen minutes before the estimated time of reaching Nevin, i.e. at about 1854 hours, the "Saint Kevin" asked Preston for permission to ascend to 6 500 feet. Permission was given almost immediately and not later than 1855-1/2 hours the aircraft reported "leaving four five now" and at an unascertained moment between 1858 hours and 1902 hours reported "Check six five". According to the estimate made at the time when the Captain thought he was at 3° W he would, at 1858 hours, have been in a position about 8 nautical miles from the coast at Harlech, or about 16 nautical miles almost due south of the place of the crash. The next signal received from the "Saint Kevin" was "check Nevin": this was received by Preston before 1912 hours and was followed by an instruction from Preston to the aircraft to change frequency to Dublin. Before leaving the Preston frequency however, and still before 1912 hours, the "Saint Kevin" asked Preston "Have you any news of any outbound aircraft from Dublin on the London Route" and was told "Affirmative Easy Charlie Item departed Dublin at one eight four eight estimating Nevin at one two minutes past the hour (i.e. at 1912 hours)". A second message from Preston at or immediately before 1912 hours added the information that Charlie Item was at 5 500 feet and immediately afterwards the "Saint Kevin" called up Charlie Item and said "You'll find it pretty rough over the hills tonight we were at four five went up to six five it seems to be right through".

Shortly after 1912 hours and before 1915 hours the "Saint Kevin" having changed to the Dublin frequency reported "We checked over Nevin a minute ago flying six five IFR. We just passed Charlie Item. Request descent clearance please". This signal was acknowledged by Dublin and the desired clearance given. It is not known whether Dublin's signal was ever received by the "Saint Kevin" from which nothing further was heard by any receiving station.

It should be noted here that according to the flight plan Nevin should have been reached at 1924 hours while the "Saint Kevin's own ETA at Nevin given in the last signal which contained any such estimate (i.e. the 1838 hours message to Preston) was 1910 hours, a difference of 14 minutes. For the aircraft to have been where it was reported to be when the signal "check three degrees west" was sent it would have had to have gained 12 minutes on the flight plan estimate. The Court being satisfied that the wind speed was not less than 55 knots was forced to the conclusion that after leaving Daventry, which was probably reached at the time reported, the "Saint Kevin" was always well behind the points which the pilots believed they had reached.

The only evidence about the last moments of the flight comes from the recollection of witnesses on the ground. None of these had any duty to remember or record anything about the auditory sensations from which alone they could derive any impression of the behaviour of the aircraft. The Court is unwilling to base any finding upon the obviously honest but equally obviously inconclusive evidence of such witnesses. This caution is the more compelling upon the Court when it is remembered that it was a wild night of high and gusty winds which no doubt created much noise themselves and would have distorted other noises.

The aircraft struck the ground in a soft peat bog about 1-1/2 miles east of Lake Gwynant in Caernarvonshire at a height of about 1 200 feet above mean sea level. Most of the wreckage was swallowed up by the bog in which the engines completely disappeared. The main part of the wreckage was at the most westerly point at which any part of the debris was found, small fragments mainly of wing skin being found up to 1-1/4 miles to the eastward. The only detail of importance in this trail was the outer portion of the starboard wing which broke off about 26 feet from the wing tip and was found about 266 yards from the main wreckage.

The posture of what was left of the port wing and fuselage suggested that the aircraft struck the ground at a steep diving angle of 80° heading about north.

There was evidence of extensive disintegration upon impact and a fire had occurred in or about the main crater. The fragments lying to the eastward of the main crater showed no signs of burning.

The condition and location of the propeller blade fragments were consistent with the engines being under considerable power at the moment of impact.

The location of the largest detached fragment of the starboard wing together with a study of the fractures of the spars, indicated that the wing had broken shortly before the aircraft struck the ground and suggested that the breaking had been caused by over-stressing beyond the designed limits for upward and backward direction.

The control valve of the de-icing equipment was recovered broken away from the bulkhead to which it was attached and was found to be jammed in the "on" position.

The Weather. The sun had set at 1611 hours and civil twilight ended at about 1700 hours, well before the "Saint Kevin" took off from Northolt. There was, however, a nearly full moon which had risen just before 1400 hours. During the flight the moon was well up in the sky and at the time of the accident its altitude was about the same as the sun's mid-day altitude at the beginning of April. There would, therefore, not be complete darkness above the clouds or in the breaks between them. In fact the Captain of another aircraft flying along the route at 6 500 feet about 50 miles behind the "Saint Kevin" described the flight along the airways, prior to reaching the Welsh mountains, as "quite a pleasant trip": and a resident of Beddgelert who was asked immediately after the accident to look out for any fire which might help to locate the aircraft saw a reflection in the sky which he thought, correctly, might be the moonlight piercing the cloud.

The only direct evidence from the "Saint Kevin" itself of the weather actually experienced in the flight is the message to another aircraft at 1912 hours that it was rough over the hills both at 4 500 and 6 500 feet. The "Saint Kevin" was in communication from time to time with the control stations at London and Preston and at no time made mention of the weather or of any difficulty arising therefrom. The evidence of the weather met by the "Saint Kevin" is therefore mainly indirect. It can, however, be stated with certainty that the wind was about 60 knots and for most of the flight was nearly a direct head wind and that there was neither much turbulence nor bad cloud conditions along the route from Northolt to Wales. Only over the Welsh mountains did the aircraft meet the substantial turbulence implied in the message mentioned.

The value of 60 knots for the wind, derived from the meteorological observations and computations is confirmed by the value calculated from the times taken on six other flights along the Daventry-Nevin section of the route. The average value obtained from the records of these six flights at levels of 4 500, 5 500 and 6 500 feet between 1500 hours and 2200 hours on 10 January is 60 $\pm$ 6 knots.

Evidence was given by the pilots of four other Aer Lingus DC-3 aircraft which flew along the same route as the "Saint Kevin" in the afternoon and evening of the 10 January. The first of these aircraft, EI-ACI, flying from Dublin to Northolt, at 5 500 feet, passed the Nevin Beacon at the same time (i.e. 1912 hours) as the pilots of the "Saint Kevin" flying at 6 500 feet reported that they were passing it. This aircraft, EI-ACI, left Dublin at 1848 hours and had very smooth conditions over the Irish Sea. It received from the "Saint Kevin" the warning about rough conditions and shortly afterwards ran into quite rough turbulence near Barmouth but "not a bit different" from what the Captain had been led to expect from his briefing at Dublin. The aircraft also passed through fairly heavy rain at times and had occasionally a "very, very small amount of very wet ice on the wind screen but none at all sticking to the aircraft". The temperature reading was + 2° C except in cloud where it fell to — 1° C. After a period estimated at 10 to 12 minutes (clearly over-estimated, as will appear) the turbulence ceased, the cloud at and below 5 500 feet broke and the First Officer saw Welshpool as the aircraft passed near it.

The second aircraft, EI-ACT, was flying from Paris to Dublin at 6 500 feet. This was the aircraft which had had "quite a pleasant trip along the airways". It passed above the aircraft EI-ACI at 1922 hours and about 10 minutes later met turbulence which gradually increased in severity and was accompanied by icing, sufficient in quantity to cause eventually a substantial decrease of airspeed. One of the pilots said he saw hail but the other pilot saw no hail and was certain that if there had been hail he would have seen it. The turbulence and bad weather experienced by this aircraft appears certainly to have been the same as that through which the aircraft EI-ACI had flown just before in the opposite direction and at a level 1 000 feet lower. This bad weather was either a patch travelling within the 60-knot air-stream or it was a purely local effect produced in the air-stream by the mountains and restricted to the mountain region. An examination of the times, taken in conjunction with the known speed of the aircraft, shows that if the bad weather had been a travelling patch, the aircraft EI-ACI must have cleared it at about 1916 hours or 4 minutes after leaving Nevin. This was certainly not the case. The conclusion is that the bad weather was, in fact, a local effect and was left behind by EI-ACI between 1919 and 1920 hours. It extended inland only about 15 miles from the Welsh coast near Harlech. The aircraft EI-ACI was in it for about 4 minutes and the aircraft EI-ACT for about 10 minutes.

The aircraft EI-ACT, after reaching the Welsh coast at a point on its planned route about 10 miles from the Nevin Beacon descended, by permission from Preston, to 4 500 feet to escape the icing and then, owing to shortage of fuel (a circumstance which had been pre-occupying the pilots), diverted to Liverpool, flying at 5 000 feet along a route which took it within 5 miles of the wrecked "Saint Kevin" 40 minutes after the accident. On this part of its flight, EI-ACT

experienced no icing and less turbulence, so much less in fact that the Captain and the First Officer could, and did, interchange seats.

The aircraft EI-ACT had picked up some rime as it climbed to its flying level of 6 500 feet in France and this rime did not clear from the aircraft in the warmer air over England, for a reason which will appear later. The rime was believed to be a contributory cause of a reduction in the aircraft's airspeed from the 148 knots of the flight plan to 130 knots. But it seems clear from the times of the flight on the English section of the route that the true airspeed there was substantially in excess of 130 knots. The aircraft flew the 116 miles from Daventry to the point of diversion near Harlech in 84 minutes against a 60-knot head wind which implies an average airspeed of 143 knots.

A third aircraft EI-ACD flew from Northolt to Dublin earlier in the afternoon. It left Northolt at 1515 hours and flew at 4 500 feet all the way, passing Daventry at 1551 hours and the Nevin Beacon at 1706 hours. The weather experienced was "reasonable" until about 30 miles from Nevin when some cumulus cloud, heavy rain and moderate turbulence was met over the mountains.

A fourth aircraft EI-ACL left Dublin at 1745 hours and reached Northolt at 1905 hours. It returned to Dublin, leaving Northolt at 2017 hours and arriving at Dublin at 2255 hours. On the first flight at 5 500 feet it was smooth over the Irish Sea. There was short and sharp turbulence around Barmouth and afterwards "nothing much". There was no icing and no precipitation. Temperature was + 2° C. On the return flight at 4 500 feet there was no icing and no precipitation but it was fairly turbulent, "no worse however over the mountains than it had been over England". The turbulence, though definite, was not sufficient to lift the Captain off his feet as he went to the passenger compartment to satisfy himself that all was well there. The temperature was + 4° C.

This evidence of the weather conditions at the levels of flight, based in the main on the recollections of pilots and not on records made at the time, is substantially in accord with the deductions of the meteorological experts from their charts of observations and records of upper air conditions obtained from radio-sondes. It may be supplemented with advantage by the observations recorded at the time by official meteorological stations near the route. At the Royal Air Force Aerodrome, Valley, in Anglesey, about 20 miles directly to windward of Snowdon there was slight drizzle, slight rain and slight mist in the period from 1500 hours to 2100 hours with a cloud base 1 700 at 18 hours. At the Royal Air Force Aerodrome at Shawbury about 60 miles directly to leeward of Snowdon and about 15 miles north of the route there was slight rain followed by intermittent moderate rain in the same period with a cloud base at 2 600 feet at 1800 hours. At Elmdon near Birmingham there was intermittent moderate rain, in the same period, with a cloud base at 3 100 feet at 1800 hours. At Cranfield, between Elmdon and London, there was no rain in the period and the cloud base was at 2 200 feet at 1800 hours, while at London there was slight intermittent drizzle and slight mist in the period with a cloud base at 2 000 feet at 1800 hours. At Collinstown near Dublin there was a slight drizzle with a cloud base at 1 500 feet at 1800 hours and there had been some rain during the day. At all these places the amount of rain was small. In the 12 hours from 0900 to 2100 it was 1/5th inch at Valley and Shawbury, 1/6th inch at Collinstown, 1/12th inch at Elmdon and 1/25th inch at Cranfield and London.

The evidence of the radio-sonde ascents indicates that at 4 000 to 6 000 feet the wind was from the direction 290° to 295° and its speed 55 to 60 knots and that the freezing level on the route was 7 000 feet falling after Daventry to 6 500 feet and over the mountains to 6 000 feet.

As mentioned previously the cold front reached North Wales at about 2200 hours and an aircraft carrying officials of Aer Lingus from Dublin flew thence to Valley in comparatively clear weather and full moonlight behind the front, landing at Valley at 2345 hours.

POSSIBLE CAUSES OF THE ACCIDENT - The "Saint Kevin" struck the ground not later than 1915 hours in a position about 18 nautical miles distant and bearing about 60° from Nevin Beacon. This position is about 14 nautical miles from the nearest point on the direct course from Daventry to Nevin.

It must be stated at once that except on an "airway" there is nothing inherently wrong about being knowingly a few miles one side or the other of a planned course without reporting the fact. The significance of these known facts, however, lies in the circumstance that the deviation of the "Saint Kevin" so far to the northward of the planned course brought the aircraft into the lee of Snowdon at a time when according to his signals the pilot must have thought he was clearing the last of the Welsh land and reaching the Irish Sea.

It seems likely that the beginning of the error which led the pilot to believe that he was at Nevin at a time when the distances recorded in the immediately preceding paragraph show conclusively that he could not have been there, must be looked for in the stage of the flight between Daventry and 3° W. The ground speed assumed by the pilot for this leg as indicated by his signal to Uxbridge (SEFIR) timed 1800 hours was 96 knots whereas the flight plan estimated a ground speed of 85 knots.

It must be a matter of speculation but it may be that the pilot was led to over-estimate his ground speed for the leg Daventry 3° W because his experience on the leg Beacon Hill-Daventry had shown him a ground speed of 98 knots against a flight plan estimate of 93 knots.

There is no means of telling where the "Saint Kevin" was when the report "check three west now" was made at 1838 hours but the aircraft could not in fact have been at 3° W without having made good a ground speed of 103 knots from Daventry or 18 knots better than the ground speed estimated in the flight plan.

There is no evidence from which the Court can say whether the pilots used any or, if any, what navigational aids on that night. All that can be said is that no signal from the "Saint Kevin" gave any hint or suggestion of anxiety, difficulty or confusion in the minds of those flying the aircraft. Their messages to Preston and Dublin announcing their position with reference to Nevin were clear and unequivocal. The request for permission to ascend to 6 500 feet was not explained, though inferentially it can be said to have been due to turbulence or anticipated turbulence: it was probably made at about the time the aircraft was approaching the lee side of the Berwyn Range. What may seem hard to understand is why, at a time when the "Saint Kevin" must in fact have been getting near the lee side of Snowdon, the pilots requested permission to descend. The probable explanation is that the Captain, believing in his own erroneously arrived at estimated time of arrival at Nevin and perhaps having experienced sufficient icing to lead him to switch on his de-icing boots, desired to come down to the first permitted quadrantal height (4 500 feet) above the safety height (3 000 feet) for the leg Nevin-Dublin as a first step in his run in to Dublin.

It is less easy to understand what led to the deviation to the northward of the track than to see what led to the Captain believing that he was further ahead than he was. In the absence of any fix after Daventry no one can say what compass course was being steered or what allowance was being made for lateral drift. It is possible that some mistake was made but there is no evidence of it. The most likely explanation is that the wind was not as far round to the northward as forecast and allowed for in the flight plan. The wind indicated in the flight plan was blowing from 300° at 60 knots whereas the actual wind was 290°/295° at 55/60 knots. Unless the pilots obtained at least one fix or correctly identified some ground lights after turning into the wind at Daventry they would have had no means of correcting by experience the wind estimated for them in the flight plan. It is also possible that the Captain may have glimpsed lights on the ground and, although a very experienced pilot on this route, misinterpreted them.

The Court is inclined to the view that the explanation of the fatality may be found under one or more of the following three heads:

a) The pilot, being in error as to his true position, began his descent from 6 500 feet to 4 500 feet and before he realized it ran into an unusually strong downward current in the lee of Snowdon. This downward current took him below the level of the crests of the mountains. In such a current an aircraft could lose 2 000 feet of height before any action for recovery of height could be effective. Once the aircraft reached a level below the crests of the mountains, it would in the conditions prevailing there at the time, be in a region of most chaotic turbulence from which in the darkness there would be the greatest difficulty in regaining control and recovering height. While the pilot was making an effort to do this, the aircraft encountered an unusually violent local gust which put the aircraft completely out of control and produced the stresses which broke off the starboard wing and plunged the aircraft into the bog.

b) The aircraft ran into a region of unusual violent turbulence which dislodged the pilot from the controls. Before he could recover control of the aircraft, it had got into an attitude from which control could not be regained before the aircraft hit the ground after losing a wing owing to the stresses set up.

c) The aircraft ran into a region of violent turbulence which dislodged moveable equipment in the cockpit which, in its turn, jammed the controls or injured the pilot and produced the same result as in b).

The Court has considered the possibility of the accident being caused by icing on the aircraft and has rejected it on the following grounds:

a) Icing takes time to build up. It could not have been deposited in sufficient amount to stall the aircraft in the interval between the warning of rough conditions to the aircraft EI-ACI and the accident.

b) If the icing had been appreciable before the warning mention of it, it would almost certainly have been included in the warning.

If the icing had been appreciable the pilot would not have waited until he was past Nevin (as he thought) before asking for permission to descend below the freezing level.

At the same time the possibility that icing was contributory to the difficulty of control in the conditions mentioned cannot be excluded.

Comments and Discussion - Frequency of High Winds - Winds at a height of 5 000 - 6 000 feet on any of the three routes between London and Dublin may exceed 50 knots in any month of the year. Winds of this speed blow mainly from a west or northwest direction. On the average in the winter months one day in four has such winds but in summer they do not occur more than once a month. Winds exceeding 60 knots occur about once in 20 days in winter and twice a year winds exceed 70 knots. The highest value measured at Liverpool at this height in the three years 1948-1950 was 84 knots from a direction 290°. It is clear therefore that gales from between west and northwest, as bad or worse than that of 10 January 1952, may be expected in the future.

Turbulence in High Winds over Mountains - It is clear from observations in manned balloons, in gliders and by pilots of aircraft, that the substantial vertical currents are produced even when an air-stream of moderate speed crosses a mountain range. Vertical currents of 800 feet per minute have been experienced on the lee side of mountains 1 500 feet high, in a transverse wind of only 20 knots. As already mentioned the investigation of vertical currents caused by the Rock of Gibraltar showed that the turbulence extended upwards to a height of more than 5 000 feet. Over a mountain range much higher than the Rock strong vertical currents may be expected up to heights of at least 3 000 or 4 000 feet above the crest of the range, especially in transverse air-streams of low stability. In such conditions the normal clearance of 1 000 feet does not give adequate protection against the hazards of turbulence. For air routes over mountainous regions, where an alternative route is not available or is excluded by other weather hazards, the specified safety level should be related to the meteorological conditions.

Height of Freezing Level - In regions covered by a satisfactory network of radio-sonde observations, the height of the freezing level can usually be specified with a higher degree of accuracy than $\pm$ 1 000 feet. The height can also be forecast with the same degree of accuracy for flights over the region, other than at times when changing conditions are being rapidly imported from regions where there is no satisfactory network. The degree of accuracy is not proportional to the height; it is, in such a region, substantially independent of the height. Consequently a percentage tolerance is not appropriate for specifying the degree of accuracy of the height of the freezing level.

Effect of Mountain Range on Height of Freezing Level - When a thermally stable air-stream crosses a mountain range transversely, the freezing level will be lowered owing to the lifting of the air and its consequent expansion and cooling. For example, if the air over Larkhill at 1500 hours on 10 January had been lifted just over 300 feet, the freezing level would have fallen from 7 500 feet to just over 6 000 feet. The change in the height of the freezing level due to this cause disappears when the air-stream again reaches lower ground unless the lifting has produced rain over the mountains, in which case the freezing level may be at a greater height after the air-stream has crossed the mountains than it was before. Although approximate estimates of the magnitude of the effect can be based on theoretical considerations, direct observations at different levels along stable air-streams crossing the mountains appear necessary to provide the data for the formulation of rules for the guidance of meteorological briefing officers.

Effect of Mechanical Turbulence on Height of Freezing Level - When an air-stream, thermally stable over the ocean, crossed land irregular enough in height to cause excessive turbulence, the height of the freezing level may be reduced. This effect, unlike that due to lifting over a mountain range, persists even when the air-stream reaches level or nearly level ground whose average level is not lower than that of the irregular land. The magnitude of the effect on lapse-rate which can be caused by mechanical turbulence arising in this way and the height to which it can appreciably extend can be obtained by direct observation at different levels along air-streams initially stable.

Temperature of the Air - A thermometer on an aeroplane is subject to heating owing to its speed through the air, and the temperature recorded is usually too high. For a thermometer under the wing or nose of an aircraft, properly shielded from radiation, the correction necessary to allow for this effect is approximately 2° C for an airspeed of 140 knots and 4° C for an airspeed of 200 knots. At the freezing level the recorded temperature would be + 2° C or + 4° C at these two speeds. The result might well be to give a pilot an unjustified sense of security against icing if, as appeared from the evidence in this case, no provision was made for ensuring that pilots knew the correction required to the actual readings to give the true temperature of the air. In view of the importance of icing as regards both performance and safety, it seems essential that pilots should know the correct temperature of the air through which they are flying especially when this is in the neighbourhood of the freezing point.

Melting of Rime or Ice on an Aircraft - The melting of rime or ice on an aircraft in flight depends upon the "wet-bulb" temperature. The effective "wet-bulb" temperature is that which would be recorded by a "wet-bulb" thermometer without correction for the speed of the aircraft and situated in the position where the rime exists. In dry air the "wet-bulb" temperature may be several degrees lower than the air temperature and if it is below freezing point, rime or ice will not melt, even if the air temperature is well above freezing point. In such a case the rime or ice would evaporate but this is a slow process. The non-clearance of the rime, collected over France by the aircraft EI-ACT, during the time the aircraft was flying over England in air at a temperature above freezing point appears to have been due to the fact that the "wet-bulb" temperature was below freezing point.

It is pertinent to add that snow or hail falling through air at a temperature above freezing point would not begin to melt unless the corrected "wet-bulb" temperature was also above freezing point.

Radio-Sonde Observations - The network of radio-sonde stations in the British Isles appears to be adequate to enable the meteorological briefing officers to meet the requirements of civil aviation in this respect except on those occasions when changes are occurring with unusual rapidity. On such occasions it is open for consideration whether intermediate observations could be made at key stations selected according to the actual meteorological situation and, in particular, an observation on such an occasion at 0900 hours or 2100 hours at Valentia when the meteorological situation indicated Valentia to be key station.

Consultation with Meteorological Briefing Officer - It emerged in the course of the Inquiry that there was, on occasions, insufficient time between the arrival at, and departure from, an airport for pilots to visit the meteorological officer and receive personal briefing on the meteorological situation. It appears desirable to make such amendment of schedules or instructions as may be necessary to avoid the recurrence of such occasions.

Notification of Meteorological Changes - It also emerged in the Inquiry that a change in the meteorological conditions affecting an air route might arise which (a) was not within the knowledge of, or foreseeable by, the meteorological briefing officer before the departure of an aircraft flying along the route; (b) did not constitute a recognized hazard but might nevertheless lead the pilot unwittingly into a situation of difficulty or into a region where a recognized hazard existed or was developing. Such a change would not, under existing arrangements, be communicated to the aircraft. It appears desirable to ensure that an actual or imminent change on any section of a route which the appropriate meteorological officer recognizes as an appreciable change in the conditions affecting the safety of aircraft should be notified on his authority to the aircraft, unless he is aware that the change has been specified in the forecast provided for the pilot before departure. This last proviso applies only when the appropriate meteorological officer is at a station other than the departure airport. A meteorological officer at the airport would be aware of the forecast provided.

It is no part of the duty of this Court to make specific recommendations as to the administrative measures (involving both the Air Ministry and the Ministry of Civil Aviation) necessary to be taken to give effect to what is here suggested.

Sufficiency of the Crew - It has already been made clear that no one will ever know what if any, use of the navigational aids at their disposal was made by the pilots of the "Saint Kevin" on their last flight. Apparently they were satisfied that they knew where they were although in fact they were somewhere else. It is therefore difficult to relate to the experience of this Inquiry a strongly-urged suggestion that aircraft of this type on this route carry an additional member of the crew in the person of a Radio Officer who would ensure that use could be made of the Gee radio navigational device at times when the two pilots were constrained to remain in their seats. There is no evidence that the Captain of the "Saint Kevin" took any step to obtain

a Gee fix, or that he wished to do so but could not because neither he nor his First Officer could leave his seat to go to the apparatus. The Court is not disposed to make any recommendation expressed in terms of the use or non-use of this device. Other suggestions directed to the more accurate ascertainment of position follow later in this Report.

The Sufficiency of Navigational Aids - It is, of course, obvious that there must be limits to the provision of costly devices such as radio ranges, fan markers and radio beacons. Not every route can be turned into an "airway". Risk of confusion as well as lack of money and free frequencies would preclude such a solution to the problems of navigators. At the same time it must be realized that the air traffic between England and Eire is important and growing and that the shortest route between London and Dublin passes over a difficult mountainous terrain and close to Snowdon. In the view of the Court, consideration should be given to the practicability of giving pilots a better lead over the part of the route which lies between 3° W and Nevin Beacon. Although use can be made of some or all of the aids available, there is between Daventry and Nevin no specifically located navigational aid. It is perhaps a fair inference from the few facts established in this Inquiry that, in practice, pilots tend to be content to do without recourse to aids which "take up time on the air" especially when such aids may be suspected of giving no greater accuracy on a short route or stage of a route than does dead-reckoning. It is for consideration whether on this route a specifically located aid in the form perhaps of an intermediate radio beacon ought to be provided.

Detection of Icing in Darkness - It emerged in the course of the Inquiry that on DC-3 aircraft no light is fitted by which the parts of the airframe liable to receive a build-up of icing can be seen from the cockpit. Pilots must either use a hand or resort to switching the landing lights on and off and observing the amount of the build-up on the glass of the lights in the dying glow. Neither of these methods can be regarded as satisfactory. In certain DC-3 aircraft adapted for service on commercial air lines a special light is fitted so as to illumine the leading edges of the wings and this might well be made a standard practice for all aircraft.

The Importance of "de-briefing" - The meteorological service provided for the benefit of aviators is like any other intelligence service dependent upon the reading of data obtained from a large variety of sources. One of the most valuable sources is the experience of persons having just come in from a flight on the same route. This giving of information by pilots to the meteorological officers is known as "de-briefing" and it is the opinion of the Court that pilots should be encouraged to attend at the "Met Office" for "de-briefing" within some specified period (say 30 minutes) of landing from any flight under instrument flight rules or where any unexpected weather phenomenon has been experienced.

Recommendations - The safety height for stages of an air route which cross mountain ranges should be related to meteorological as well as to orographical data. This means that on occasions when the meteorological forecast indicates that strong winds will be encountered at the approaches to and over the range, the safety height (which is usually 1 000 feet above the contours) should be increased and so shown on the flight plan. The following clearances are provisionally suggested for flights under IFR pending the results of the investigation proposed in the next paragraph Wind speed at height of crest

	Clearance
26-35 knots	2 000 feet
36-45 "	2 500 "
46-55 "	3 000 "
56-65 "	4 000 "

It is recognized that such clearances might, on some occasions, force an aircraft above the freezing level and that with slow-climbing aircraft the duration of a flight on a short route might be unduly prolonged. Such matters would have to be brought into calculation before any mandatory regulations could be made.

Investigations should be made of the vertical currents in air-streams of high velocity and differing degrees of stability crossing mountain ranges so that the resulting data may be applied to the establishment of safety heights on regular air routes crossing such ranges.

An investigation should be made of the reduction in the height of the freezing level in a stable air-stream crossing a mountain range and meteorological officers should indicate the allowance, based on the investigation, in their forecasts and briefing.

An investigation should be made of the effect of turbulence over the land in changing a thermally stable air-stream towards a labile state in order to determine the resulting change in the height of the freezing level when this lies within the layer affected.

Consideration should be given to the desirability of making more frequent radio-sonde observations at one or more of the stations in key positions when the meteorological situation is changing exceptionally rapidly.

Consideration should be given to the desirability of discontinuing the use of a percentage tolerance in the forecast height of the freezing level. It is probable that the layout of the conventional form for route forecasts is in itself an invitation to forecasters to be less explicit than they might be about the limits between which the freezing level is expected to lie. In the opinion of the Court those limits should be explicitly stated.

Air crews should be provided with the corrections necessary to obtain the true air temperature from the reading of the thermometer on the aircraft. They should also receive instruction as to the significance of "wet-bulb" temperature in relation to freezing and melting.

Consideration should be given to improving the system of collaboration between the Air Ministry (Meteorological Office), the Ministry of Civil Aviation (Air Traffic Control) and Operators of Civil Aircraft whereby it can be ensured that substantial actual or imminent changes in the meteorological conditions along an air route are notified by controllers to aircraft on the route.

The framers of schedules and those responsible for rostering pilots as well as the pilots themselves should always keep in mind the importance of allowing sufficient time at airport to permit direct personal briefing of pilots by meteorological officers. The location of the meteorological office may be an influence in encouraging or discouraging pilots to or from making a personal visit to the forecaster, and a too rapid "turn-round" may be a real discouragement. The value of direct personal briefing in marginal weather conditions is too great to be sacrificed to the other concerns which may engage the attention of pilots during quick "turn-rounds".

Consideration should be given to devising a discipline which will minimize the risk of moveable objects, e.g. computers, Verey pistol, articles of clothing and crews' effects getting adrift in the cockpit in turbulent conditions. Articles of this kind, unless properly stowed, may easily slip down into the mechanism of the control system and lead to the jamming of controls. It may be that the provision of better stowage facilities ought to precede the formulation of disciplinary rules.

Careful thought should be given to the question as to whether or not pilots are actually encouraged to rely too much upon dead-reckoning through the absence of sufficiently strict instructions from their employers on the subject of entries in the aircraft navigational log. The Court leans to the view that it might lead to better all-around navigation if it were made mandatory upon Captains to record in the log a definite "fix" of position every so many (depending upon the length and/or nature of the route) minutes of flight with an annotation showing the method used to obtain such "fix". It is further for consideration whether such "fixes" ought to be reported by R/T to the appropriate FIR when a fix shows that the aircraft is materially off-course: such consideration will, of course, have due regard to the importance of securing a prudent economy in the use of busy communication channels.

Consideration should be given to the question of providing a specifically located aid to navigation between Daventry and Nevin.

Study should be given to the problem of designing a means whereby the build-up of icing can be watched during darkness. It is for consideration whether the provision of such means ought to be made compulsory and its continuous use in icing conditions be prescribed in the disciplinary code of operators.