beds in a straight line in a manner analogous with that which gives rise to fjords. Thus one often finds in the Alps valleys with vertical sides and even sometimes, in their upper sectors, the remnants of a glacier whose width corresponds with the gorge it has cut in the course of centuries. Examples of this are to found in many places, notably in the Lauterbrunnen valley in the Bernese Oberland and the Blindenthal in the Valais.

AIRCRAFT ICING

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Ice formation on aircraft in flight is still a considerable hazard. Much progress has been made in countering this danger, and we now know how to protect aircraft against the majority of atmospheric icing conditions likely to be encountered by a reasonably cautious pilot. But the best defence is to avoid serious icing conditions by flying over or round regions where icing is likely to occur. The prediction of such regions is a regular feature of the meteorological service, and skilled use of meteorological forecasts enables the pilot to vary his route and time-table so as to avoid areas where serious icing is likely to be encountered.

But this can only be accepted as a stop-gap measure. Civil air transport, in common with all other means of transport, must strive to achieve all-weather regularity throughout the year. This cannot be done so long as route and schedule are liable to be changed in order to take account of transient meteorological conditions.

For long-range flights the best policy is to fly "above the weather." At 30,000 ft. there is little likelihood of icing troubles. But this is not the complete answer. It is clearly impracticable to climb to Everest height on short flights, and there is always the chance that icing regions may have to be traversed on the ascent or descent. Hence aircraft must, so far as possible, be made immune to icing.

Ice can give trouble in many ways. It can stop the engines by blocking up the air intakes or carburettors; it can stick to the propeller, thereby reducing its efficiency and putting it out of balance; it can stop up the pitot head and static vent of the airspeed indicators and blind-flying instruments; it can penetrate into and jam the hinge gaps of ailerons, elevators and rudders; it can build up on wings and tail, thereby impairing their lifting properties and very considerably increasing the air drag; it can fasten on to the radio mast and radio aerials, causing them to break; and it can cause a multitude of other mishaps, such as obscuring the windscreen and jamming the retractable undercarriage.

There are many ways in which these troubles can be overcome. The most obvious is to heat any surface to which ice might adhere. Another method is to dislodge the ice by applying alcohol or other freezing-point depressant to the surface. This has been extensively used for clearing the windscreen. Yet another method is to break off the ice by deforming the surface to which it adheres. This is used in the well-known Goodrich method of wing de-icing. Something can be done by designing certain parts, for instances flying control surfaces and aerial insulators, so that they are protected from the impact of freezing water.

All these methods involve adding to the tare weight of the aeroplane. On a forty-seater aeroplane the weight equivalent of at least two passengers can easily be used up in de-icing equipment. This reduction in the aeroplane's revenue-earning capability may well make all the difference between commercial success and failure. The operator has to weigh up very carefully the relative sales value of all-weather regularity with reduced passenger capacity, and reduced regularity with increased passenger capacity.

This drives home the need for developing icing safeguards of the lightest possible weight. It is not good enough just to give protection; the protection must be given in the most economical way.

This consideration transfers the task from gadgets to scientific methods. Efficient protection is only possible if it is based, on the one hand, upon an accurate knowledge of the physics of ice accretion; and, on the other, upon statistical information of the frequency of atmospheric icing conditions of various measured degrees of severity.

Much progress, both in this country and in U.S.A., has been made in research into the physics of aircraft icing. One of the pioneers was Sir George Simpson, for many years Director of the Meteorological Office. His paper "Ice Accretion on Aircraft"* is one of the classics in this field. The latest addition to aircraft icing literature is a comprehensive report by J. K. Hardy.† This gives a full account of the results to date of aeronautical research here and in U.S.A.—research to which Mr. Hardy himself has made notable contributions.

Though much still remains to be discovered, the physics of ice accretion has now been put on a sound foundation. A much less encouraging situation obtains, however, in the complementary field of collecting statistical information about atmospheric icing. The aim here is to find out how often icing conditions of each of a series of defined severities occur along the air routes of the world. We know that icing conditions vary from those which are no hazard even to a completely unprotected aircraft to those which would be lethal to an aircraft protected to the highest practicable standard. The cost in weight of icing safeguards is roughly proportional to the standard of the protection given. Hence it would be unreasonable to require every air liner to be equipped to cope with icing conditions that would only be encountered, say, once in a million flying hours. Somewhere a line has to be drawn between the "average bad" conditions and freak conditions which may occur but once in a generation. That line can only be drawn with confidence if adequate statistics are available. But we cannot even begin to collect such statistics until precision has been given to the term "icing severity" and until an instrument has been devised to measure it.

This is one of the problems of the present day. It was recognized as such at a recent international conference of those concerned with aircraft safety. The report of this conference gives a number of items of research needing attention, one of them being:

> Research on methods of "calibrating" icing atmospheric conditions, i.e. measuring and recording the significant data, such as temperature, water-ice-vapour content, and drop size; the application of these methods to obtain statistical data on the frequency of occurrence of icing conditions of defined degrees of severity; the assessment of the behaviour and effectiveness of aircraft icing safeguards in icing conditions of measured severity; investigations of radio methods of giving warning of icing conditions.

Some research work is in hand aimed at developing a statistical instrument for measuring icing severity. But much remains to be done. The field is wide open to scientific ingenuity and imaginative research.

* Meteorological Office, Professional Notes No. 82, London: H.M. Stationery Office, 1942.

† See Glaciological Literature below.

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