PART 2 : SECTION 4

CHAPTER 9

FLYING IN ARCTIC CONDITIONS

Introduction

1. The operation of aircraft from polar areas in very low temperatures presents a difficult task. A thorough appreciation of the problems involved is vital if air operations are to be conducted safely. Most of the problems occur on the ground. This chapter has been prepared on the basis that aircraft can operate only from well-equipped bases, and that even at these bases it may be necessary to leave aircraft out in the open exposed to very low temperatures. Further, the chapter should be regarded only as a guide in which the broad aspects of the problem are highlighted. Detailed information is contained in other publications, and references to these are given in the appropriate paragraphs.

GENERAL INFORMATION

Land Areas

2. The land masses of the Western Hemisphere termed arctic areas include most of Greenland, the northern coasts of Canada and Alaska, the Canadian Arctic Archipelago, and northern Labrador. Sub-arctic areas include Newfoundland, Southern Labrador, the interior of Alaska, and most of the interior of Canada.

3. With few exceptions, the sub-arctic region is heavily forested. The arctic region does not contain trees although in some areas shrub willows, which grow a few feet high, are to be found. Large areas are composed of very poorly drained land which in summer is covered with lichens, grass, and moss ; and in winter with ice and snow. It is generally known as tundra. Practically all the tundra is permanently frozen a few feet below the surface. In the summer the surface layers thaw but owing to the underlying frozen ground the water cannot drain away. Permanently frozen ground (permafrost) is thus responsible for the marshy nature of the tundra and the numerous lakes which exist.

4. Glaciers are found in many areas. They can be divided into ice-cap and valley glaciers. As their name implies, ice caps cover areas of land without regard to the underlying topography. An outstanding example is the Greenland ice cap which is the largest in the Northern Hemisphere. It occupies more than three-quarters of the total land mass of Greenland, rises to 10,000 feet, and in places is probably 6,000 feet thick. Valley glaciers are essentially rivers of ice usually extending from inland ice caps and flowing outwards, often at tens of feet a day, to the coasts. The slow flowing movement of the ice over irregular terrain causes gaping cracks or crevasses to appear in the brittle surfaces of the glaciers. Because of crevasses, travel over glaciers is extremely hazardous and can only be safely undertaken by properly equipped parties.

Water Areas

5. The principal northern water areas of the Western Hemisphere are the Arctic Ocean, Greenland Sea, Bering Sea, Beaufort Sea, and Baffin Bay. Of these the first three are also common to the Eastern Hemisphere. The Arctic Ocean, with an area of nearly 4,250,000 square miles, is by far the largest of the northern seas. It fills the arctic basin which forms the central part of the polar region. The whole of the region is covered by the polar ice pack which has an average thickness of 10 feet in winter and 7 feet in summer. It is not a solid sheet of ice for, even in mid-winter, currents and winds cause the ice to crack apart and leave lanes of open water. Except in bays and inlets, tidal ranges are usually not more than 2 to 3 feet although wind effects can cause normal tides to be doubled.

CLIMATE AND WEATHER

General

6. During recent years there has been a great increase in the amount of information available regarding climate in the arctic region. However, there is still little information concerning weather at and near the north pole, and little is known about conditions in the upper atmosphere. It is difficult to generalize about weather in the arctic region because not only does the climate vary from place to place but it may vary a great deal from year to year.

7. The winter, which lasts five to six months, is very cold over most of the region and is marked by long nights or continuous darkness. The summer is much shorter, lasting about three months, and is marked by long days or continuous light. The transitional periods are short and during them weather, and lengths of day and night, vary rapidly.

8. The available evidence suggests that the north polar region is subject to the influence of depressions alternating with anticyclonic conditions more or less throughout the year. However, cyclonic activity over the north pole is least in winter and the depressions that affect the area at this time are usually well occluded. There is also some evidence that anticyclonic conditions tend to be rather persistent over the north pole and pack ice during the winter.

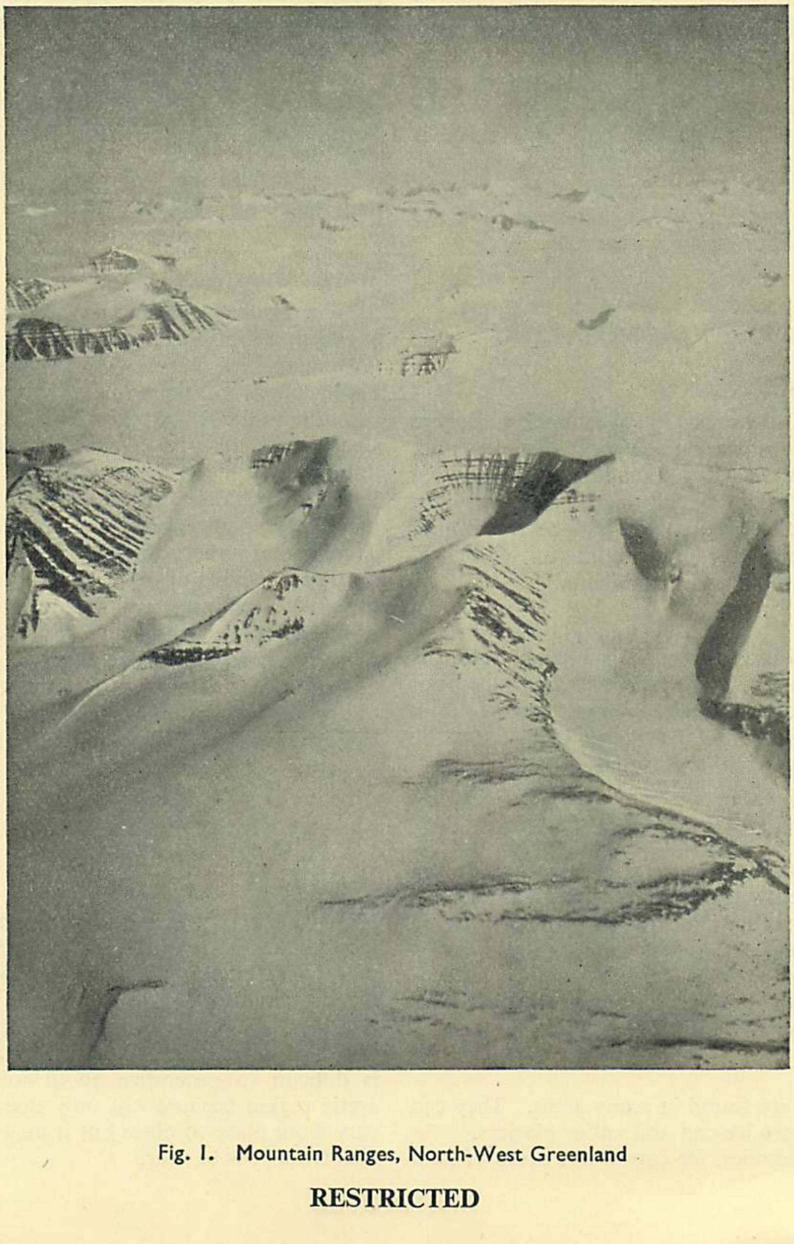

Fig. 1. Mountain Ranges, North-West Greenland

9. In the winter an almost continuous series of depressions move north-eastwards past Iceland and Bear Island to Novaya Zemlya. East of Novaya Zemlya, these depressions stagnate and fill up quite rapidly. Small depressions, which appear to form on the arctic front near the New Siberian Islands, move eastwards, but they usually fill up before reaching Alaska. The *arctic front* is the boundary between air masses that form close to the pole and those that form in sub-polar regions.

10. During the summer depressions may penetrate any part of the arctic region. At this time of the year the arctic front is within, or quite close to, the polar basin. Thus the depressions that invade the north polar region in summer consist of both old occluded depressions, which formed on the polar front, and young unoccluded depressions, which formed on the arctic front. Even in summer, cyclonic activity is quite high in the region Iceland/Bear Island/Novaya Zemlya.

Fig. 2. Pack Ice off the Coast of North-West Greenland

Precipitation

11. The mean annual precipitation in the Arctic decreases rapidly northwards, and the amount near the north pole is only about a tenth of that in Southern Iceland. Over practically all of the arctic region, with the exceptions of the Greenland, Norwegian, and Barents Seas, precipitation is at a maximum in summer and a minimum in winter. Over the sea areas mentioned, precipitation is usually at a maximum in winter. The dominant period for snow is from November to April, but in the north it may occur at any time of the year, and near the north pole practically all precipitation falls as snow. Apart from the extreme south, thunderstorms and hail showers are practically unknown in the Arctic, and even in the south they are infrequent and usually occur only in summer.

Surface Winds

12. In the ice- or snow-covered regions of the Arctic, and over a great part of the region where the ice and snow persists throughout the year, topography plays a great part in determining the surface wind. Certainly, in places such as Greenland, the prevailing surface winds are controlled more by topography than by the prevailing pressure gradient. In such places katabatic ("ravine" or "fjord") winds are frequent, and the combination of the katabatic wind and "fjord" or funnel effect can produce winds of gale force. Such winds can be extremely unpleasant, especially in winter. The combination of a strong wind and falling or drifting snow results in the well-known blizzards, in which work in the open is highly unpleasant if not impossible.

Surface Temperature

13. In the winter, a surface temperature below freezing is common practically everywhere, except in those parts of the Greenland, Norwegian, and Barents Seas that are affected by the Gulf Stream. In the north polar region and over the pack ice, temperature continues to be near freezing even in summer. Elsewhere summer is mild and even warm over land. At inland places the seasonal variation in surface temperature may be considerable. Thus Verkhoyansk in North Siberia, which is reputed to be the cold north pole and which has recorded a minimum of −90°F., has also recorded a maximum of +94°F. The extreme temperatures in the case of Fairbanks, Alaska, are −66°F. and +99°F. Therefore ground crews working in the open in the Arctic may be troubled by frostbite in the winter and by mosquitoes and sunburn in the summer !

Wind Chill Factor

14. A very important phenomenon in the Arctic is the wind chill factor. This factor is a measure

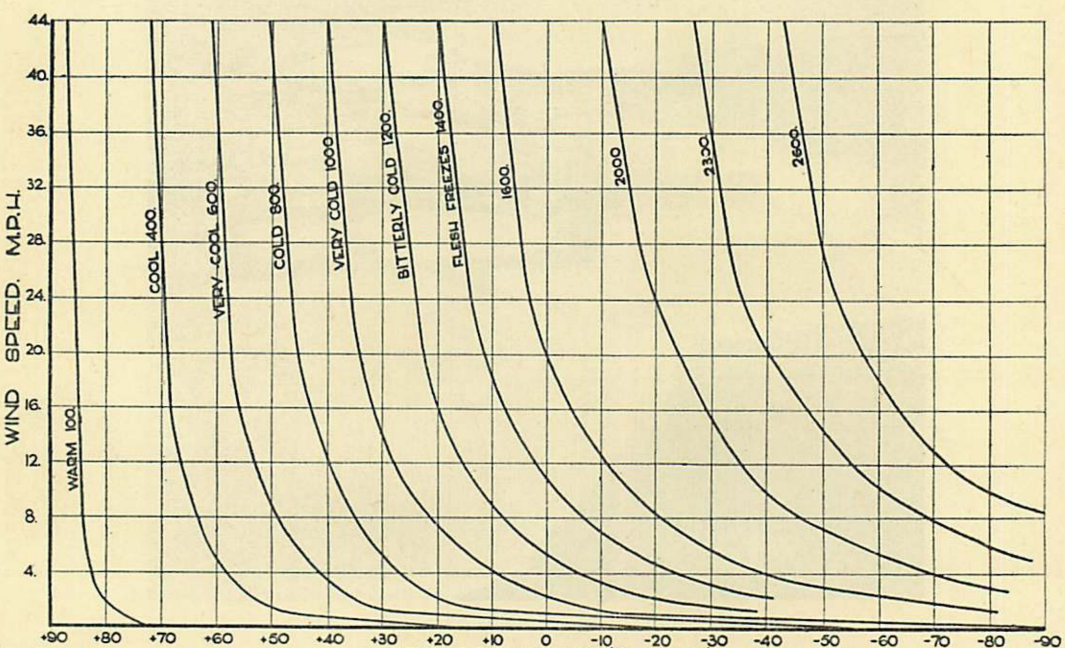

Fig. 3. Wind-Chill Factor Curves

of the quantity of heat that the atmosphere is capable of absorbing from an exposed part of the human body. It may be likened to the temperature that the human body feels as distinct from the actual temperature recorded by a thermometer. Thus a cold windy day feels more uncomfortable (*i.e.* colder) than an equally cold calm day. This is because the wind causes the natural rate of loss of heat by the human body to be speeded up by greater evaporation and a more rapid conduction of heat from the body.

15. The wind chill factor therefore depends on both temperature and wind. Fig. 3 shows the variation of wind chill factor with temperature and wind speed. The figures for wind chill factor are applicable to night-time or cloudy day-time. On sunny days the human body absorbs some of the sun's radiation. Therefore in sunny conditions the values given should be corrected by subtracting 100 during the morning and afternoon and 200 during the two hours around midday.

16. When the wind chill factor reaches 1,400, exposed human flesh begins to freeze, depending on the degree of activity, circulation, and condition of the skin. When the factor is 1,400 or more, work in the open, travel, and life in temporary shelter are disagreeable. When the wind chill factor reaches 2,000, exposed parts of the body of the average individual, such as the face, would freeze within less than one minute. Under such conditions, work in the open is impossible and travel and life in temporary shelter would be dangerous. If the factor increases to 2,300, exposed flesh would freeze in less than half a minute and travel and life in temporary shelter would be highly dangerous.

17. It is estimated that a wind chill factor of 2,000 occurs occasionally in the Arctic in mid-winter. In late winter the probable upper limit for the wind chill factor is estimated to be 2,600. When considering wind chill it must be remembered that it is a function of both temperature and wind speed. Extremely high wind chill factors can be set up locally in, for example, a propeller slipstream.

Upper Winds and Temperatures

18. Not a great deal is known about upper winds in the Arctic. They are expected to be mainly westerly and, on the average, not to be stronger than the upper winds at the same level in neighbouring temperate latitudes. The wind speed usually decreases towards the Pole. Jet streams may be encountered in the southern part of the arctic region.

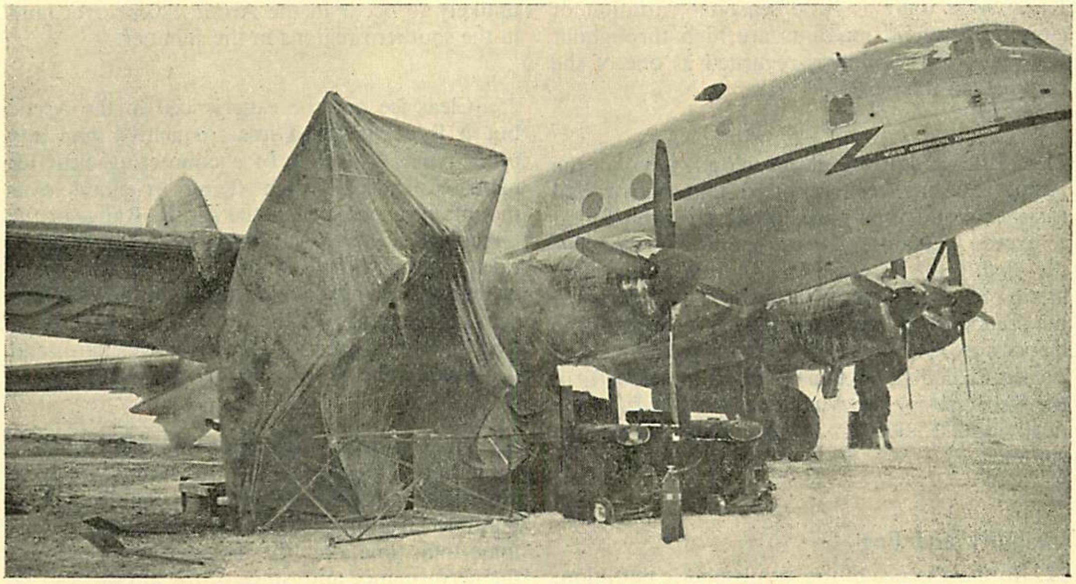

Fig. 4. Working Conditions

In high wind-chill conditions the first essential is to provide shelter for servicing personnel when work of a protracted nature is being done. Here the propeller is being used to support a tarpaulin shelter.

19. In winter, conditions in the troposphere over most of the region are usually considerably colder than the standard I.C.A.N. conditions. Because of the low tropopause the mean temperatures in the lower layers of the stratosphere in the Arctic in winter are only a little lower than the standard I.C.A.N. temperature. In the summer the mean temperatures in the troposphere in the Arctic are not very different from the standard arctic I.C.A.N. temperatures but, again mainly because of the comparatively low tropopause, the arctic stratosphere temperatures are usually appreciably higher than the standard arctic I.C.A.N. temperatures.

Cloud

20. With the exception of most of the region covered by the Greenland, Norwegian, Barents, and Kara Seas, conditions are usually much cloudier in summer than in winter. Overcast days are frequent in summer, often in the form of low stratus cloud, especially over the pack ice. This seasonal variation is very well marked in the north, over the pack ice, and over the northern parts of Alaska, Canada, and Siberia. There the average number of clear days per month may be as much as 10 to 15 in mid-winter, while the average number of overcast days per month may be as much as 15 to 25 in mid-summer. Over most of the Greenland, Norwegian, Barents, and Kara Seas, there is little seasonal variation of cloud, and cloud amounts are high throughout the year ; this region is regarded as one of the cloudiest in the world.

21. Little is known about cloud tops in the Arctic. It has been reported that during bad weather cloud tops have frequently been found to exceed 18,000 ft. There is some evidence that the depth of orographic cloud is very much greater than one would expect. The theoretical maximum cloud top is given by the height of the tropopause. Cloud tops are therefore unlikely to exceed 25,000 ft. in the north and 30,000 ft. in the south during the winter, and 30,000 ft. in the north and 35,000 ft. in the south during the summer.

Visibility and Fog

22. In the absence of fog, atmospheric pollution, or precipitation, visibility in the arctic region is usually exceptionally good. However, in areas where there is loose snow, even a moderate wind will raise sufficient snow to reduce visibility drastically ; and in blizzards the visibility is practically nil. In winter intense surface temperature inversions are common over land and to a lesser extent over the pack ice. These inversions are often accompanied by light winds, and under such conditions man-made pollution may reduce visibility below the fog limit.

23. Advection fog is the most common type occurring in the Arctic. Radiation fog does occur but is mainly confined to inland areas. Over the open sea, the pack ice, and in coastal districts, advection fog is very frequent in summer and infrequent in winter. Inland, away from water areas, radiation fog occurs most frequently during the autumn and winter.

Ice Formation

24. In the summer the freezing level is below 2,000 ft. in the north, rising to 6,000 to 8,000 ft. in the south, while in the winter the freezing level is at or near the surface over practically the whole area. Nevertheless it appears that ice formation is less of a problem in arctic flying than it is in flying in neighbouring temperate latitudes. The rate of ice formation in clouds in the Arctic is less than the rate in similar clouds in temperate zones. Cumulus and cumulonimbus, the clouds in which icing is liable to be most severe and rapid, are unlikely to occur in the Arctic except over land in the southern regions in the summer.

25. Clear ice may be experienced in the Arctic but it is encountered less frequently than any other type. This risk of encountering clear ice increases sharply when flying in cloud over mountain ranges such as the Alaska Range or the Greenland ice cap. It is possible for freezing rain to occur in the Arctic. In the north it is probably very infrequent and is confined to the summer months. In the south the frequency of freezing rain is greater, especially over land, and it probably occurs only during the winter.

26. Rime is by far the most common type of ice formation experienced in the Arctic. Severe airframe icing does not appear to occur frequently but, once airframe icing has formed, it can persist for a long time after the icing region is left and the performance and range of the aircraft can be seriously affected. There is some evidence that propeller icing may be one of the major icing problems in the Arctic. Under certain conditions ice may form on an aircraft parked in the open.

SPECIAL ARCTIC PHENOMENA

Sea Smoke Fog

27. One special type of fog that forms in the Arctic is called sea smoke fog or arctic fog. This type of fog occurs when cold air off the land or pack ice moves over the relatively warm water of the open seas. Evaporation takes place from the sea at a rate corresponding to its own temperature. The atmosphere, being at a very much lower temperature, is unable to hold all the water vapour. Some of the water vapour therefore condenses, forming a dense fog. However, the lower layers of the cold air are warmed by contact with the sea surface. Convection is therefore set up and the fog rises vertically giving it the appearance of smoke.

Ice Fog

28. A phenomenon peculiar to the Arctic is ice fog ; in this case the small fog particles are ice crystals. Ice fog appears to be confined mainly to the land areas but it may occur over the pack ice. It is reported that this type of fog is most prevalent and thickest in inhabited regions. According to reports it is comparatively shallow in depth but, while vertical visibility is usually reasonably good, horizontal visibility may be very poor. This fact is obviously of great importance to aircraft landing in ice fog conditions. Cases have occurred where aircraft running-up, taxying, or taking-off, have caused ice fog to form on an airfield (Fig. 5). Motor transport has at times produced ice fog, and it has been reported that signal mortars fired by air traffic control have induced the formation of the fog. It has been stated that ice fog dense enough and persistent enough to become a serious problem to aircraft operations rarely occurs at temperatures above −29°C. (−20°F.) and wind speeds above 3 knots.

Aurora

29. The Aurora Borealis, commonly called the northern lights, is of importance to aircraft operations in the Arctic for two reasons. First, the aurora could very well illuminate a target at night-time. When the aurora display is at its brightest it is quite possible to read large print with only the illumination supplied by the aurora. Secondly, aurora displays are almost invariably associated with heavy interference with radio communication. During displays of the aurora complete radio black-outs are common.

Contrails

30. During the winter the surface temperature over the land and pack ice may often fall below

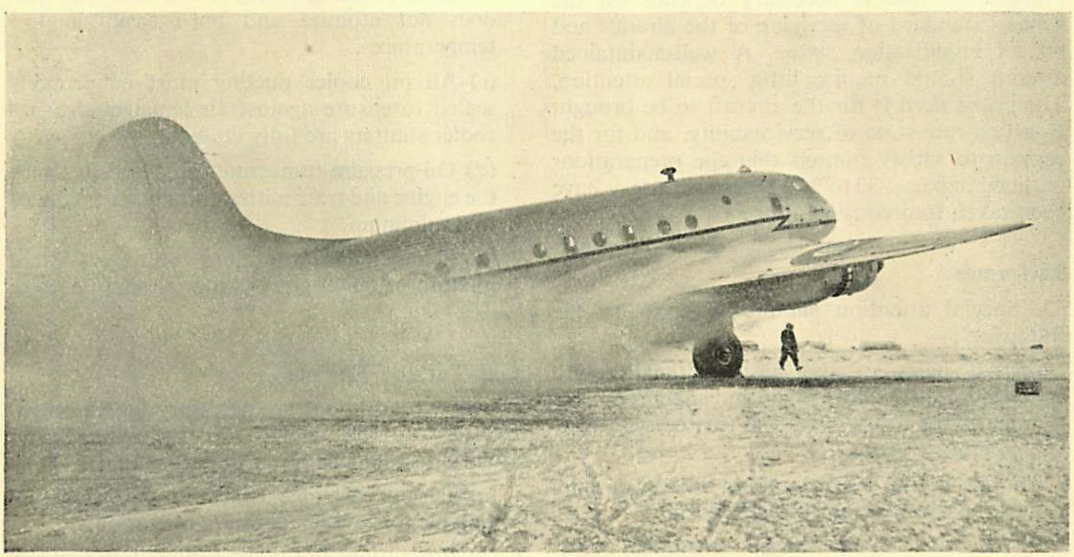

Fig. 5. Ice Fog

Condensed vapour from the exhausts creating a small local fog. One aircraft, running at high power at −50° F., can in certain circumstances cause a fog which will blanket the airfield.

the critical mintra temperature of −23°C.(−9°F.). On these occasions exhaust condensation trails may be formed on the ground and in the first few hundred feet above the ground. Under these conditions there is usually an inversion of temperature in the lower levels of the atmosphere. So, after climbing a few hundred feet, the aircraft would cease making trails until at a height of about 12,000 ft. when trail formation would usually start again.

Refraction

31. When abrupt changes of temperature occur with altitude, refraction effects cause many peculiar phenomena. The appearance in the sky or on the horizon of objects that are normally below the horizon is a common occurrence in the Arctic.

AIRCRAFT PREPARATION FOR FLIGHTS TO THE ARCTIC

Introduction

32. Aircraft design requirements call for the aircraft and its equipment to be capable of operation in all climatic conditions. Basically, therefore, an aircraft should be capable of proceeding to arctic areas with little special preparation. In practice the amount of special preparation that is necessary depends on the general standard of servicing of the aircraft and on its modification state. A well-maintained aircraft should require little special attention. The prime need is for the aircraft to be brought to a first-rate state of serviceability, and for the captain to satisfy himself that the preparations outlined in paras. 33 to 36 have been made or have been taken into consideration.

Airframes

33. Special attention should be given to the following :—

(*a*) All parts of the aircraft that require greasing, particularly flying and engine controls and flexible drives, must be treated with low-temperature grease.

(*b*) The flying control cables, if appropriate, must be checked for correct tension.

(*c*) An air drying device (methanol anti-freezer) should be fitted to the pneumatic system.

(*d*) De-icer pastes must be applied to all stub and whip aerials or similar projections.

(*e*) The cabin heating system must be capable of efficient operation at low temperatures.

(*f*) Aircraft with high landing speeds should be fitted with anti-skid type brakes.

(*g*) Sealing and draught proofing must be fully effective and cracks in transparent panels repaired.

(*h*) Oleo legs, fuel oil, coolant, and hydraulic systems must be completely free from leaks. All rubber pipes must be free from cracks, and clips and hose connections tightened fully.

(*j*) The amount of leakage from airspeed indicator, oxygen, and pneumatic systems must be reduced to an absolute minimum.

Piston Engines and Power Plants

34. Special attention must be given to the starting and lubrication of piston engines. Oil dilution is essential, and the captain of the aircraft must be thoroughly familiar with the operation of the oil dilution system and of its limitations as specified in the engine air publication. The following preparation of the engines and power plants is required :—

(*a*) Oil dilution must be initiated and the initial cleansing operations completed before departure.

(*b*) Provision must be made for the use of high volatility priming, owing to the fact that fuel does not atomize and burn easily at low temperatures.

(*c*) All oil cooler ducting must be properly sealed to ensure against air leakage when oil cooler shutters are fully closed.

(*d*) Oil pressure transmitter pipe lines between the engine and transmitter unit must be reduced to a minimum.

(*e*) If the engines are liquid cooled, a coolant mixture of 60/40 glycol/water should be used.

Gas-Turbine Engines

35. Few precautions are necessary before operating gas-turbine engines in the Arctic, but attention should be given to ensure that :—

(*a*) Turbo cartridge starters, if fitted, are suitable for low-temperature operation.

(*b*) Precautions are taken against low-pressure fuel filter icing, mainly due to precipitation of water in solution in the fuel. The use of filter heating or methanol injection into the fuel stream may be necessary.

Special Equipment

36. The following special equipment should be installed or carried :—

(*a*) An auxiliary power unit (A.P.U.) should be fitted if the size of the aircraft permits.

(*b*) Covers must be available for all aerofoil surfaces, for the wheels, cockpit, engines, and propellers. The engine covers for piston-engine aircraft should have provision for the attachment of heater pipes from external ground heaters. Covers or plugs must also be available for oil-cooler and radiator openings and for all other openings or orifices into which snow is likely to penetrate (Fig. 6).

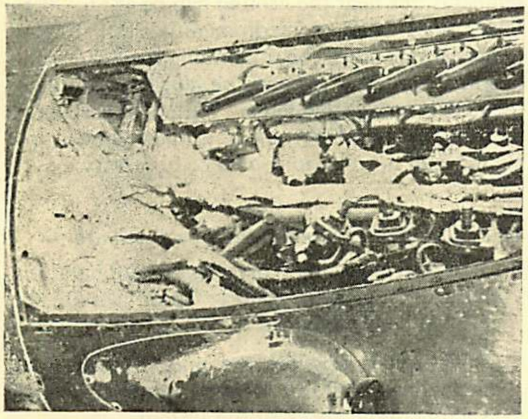

Fig. 6. Penetrating Action of Snow

The side engine cowling of a Lincoln removed to show snow which has entered an uncovered engine.

AIRCRAFT HANDLING

Introduction

37. The majority of aircraft handling problems occur on the ground and during take-off and landing. At high-latitude aerodromes it is the normal practice, during the winter months, to clear runways or taxy tracks of most of the snow by the use of snow ploughs and to pack the remaining snow by rolling. In some instances sand may be added to improve adhesion. This practice is not general, however, and is unlikely to be carried out where jet aircraft are operating, since the sand tends to coagulate and to cause compressor damage. Surfaces may therefore be slippery and treacherous, and extreme care is necessary to avoid accidents on the ground.

Taxying and Run-up

38. Before taxying, the condition of taxy-ways and runways must always be ascertained so that braking action can be assessed. It may be desirable to resort to towing as a routine procedure, particularly with jet aircraft. Obstructions and even taxy-ways are difficult to see, especially if fresh snow has fallen. Skids can easily be developed and are difficult to control, so that all taxying must be performed slowly. During thaw periods slush is an additional hazard and if thrown into wheel bays it may subsequently freeze and cause malfunctioning of undercarriage and door locks. If windscreen de-icers are fitted they should be operated during the taxying period ; alternatively the windscreen should be kept clear of frost by the use of rag and de-icing fluid.

39. Some special precautions are needed when running-up before take-off. Spiked type chocks are required to prevent skidding. The aircraft should be so aligned that blowing snow and slipstreams are not hazards to other aircraft or to personnel on the ground. If full-power checks are necessary they should be carried out in specially designated areas cleared of all snow and ice.

Take-Off

40. At low temperatures, because of improved engine efficiencies, the take-off performance of an aircraft should be better than that obtained in more temperate climates. However, the following factors, which in some instances offset this advantage, should be noted :—

(*a*) The combination of cross-wind and poor braking action can make it very difficult to keep the aircraft straight on the runway until adequate rudder control is obtained.

(*b*) If snow banks are present at the sides of the runway they are a serious hazard if a swing develops.

(*c*) Blowing snow can cause drifts to build up quickly on a runway. Even if the drifts are only a few inches deep they can cause a strong tendency to swing.

(*d*) The retarding effect of soft snow on a runway lengthens the take-off run.

(*e*) In certain conditions of cloud and light it may be difficult to judge height and distance after take-off.

(*f*) Blowing snow, condensation trails, or ice fog, caused by aircraft which have taken off previously, can seriously reduce visibility.

(*g*) After take-off the undercarriage should be raised and lowered two or three times to free any snow or slush which may have accumulated during the take-off and which could cause the undercarriage to freeze in the up position.

(*h*) In some coastal regions, where the humidity is relatively high and the temperature more moderate, carburettor icing can be a hazard during take-off and immediately afterwards.

(*j*) A final check, just before take-off, should be made to ensure that frost has not formed on lifting and control surfaces, and that the controls and trimmers are still free.

In Flight

41. During flight in arctic areas, navigation is the most difficult problem. In general, arctic areas are sparsely populated and airfields are few and far between. The network of meteorological observing stations is poor compared with neighbouring temperate latitudes, and unexpected weather deteriorations can take place rapidly. Very thorough flight planning is required and large fuel margins, to allow for possible long diversions, may be necessary. Equipment unserviceability, which elsewhere would only be regarded as a nuisance, may make it necessary in the Arctic to discontinue the flight.

42. Other points of which note should be taken are :—

(*a*) **White Out.** If low-level flight has to be undertaken under conditions of overcast or haze and when the surface is snow covered, the light may become so diffused that ground and sky merge into one surface. This condition, known as *white out*, can be extremely hazardous as there is no natural horizon.

(*b*) **Icing.** In flight, icing is no more of a problem, usually, than in more temperate latitudes. Hoar frost and rime are the most prevalent forms.

(*c*) **De-Icing.** Unless efficient de-icers are fitted it may not be possible to clear icing from the airframe. Even slight or moderate amounts of airframe ice may cause a serious reduction in range.

(*d*) **Engine Temperatures.** It may be necessary to use higher r.p.m. than normally, and possibly hot air to maintain adequate intake, engine, and oil temperatures. Such action will also reduce range.

(*e*) **Exercising Controls.** If the temperatures are very low, the throttle, pitch controls, and trimmers should be exercised at regular intervals to prevent them from freezing.

(*f*) **Clothing.** Adequate clothing for low-temperature survival should be worn or kept close to hand together with survival equipment.

Approach and Landing

43. Temperature inversions are often found in arctic regions. When letting down, the air temperatures near the ground can be 15° to 30°F. lower than those at medium altitudes. Engine temperatures must be maintained when losing height, if necessary by reducing speed and lowering the undercarriage and flaps. With piston-engined aircraft the use of hot air, and higher boost and r.p.m. than normal, may also be necessary.

44. Other points which should be noted are :—

(*a*) If airframe icing is present, aircraft handling characteristics and stalling speed should be checked before landing.

(*b*) Wherever possible the undercarriage and partial flap should be lowered at an early stage as a functional check of the systems.

(*c*) Before landing an estimate of the runway condition should be obtained from air traffic control.

(*d*) Provided the airfield is well known to the pilot, straight-in approaches are desirable if there is a risk of ice fog forming.

(*e*) Under "white out" conditions landing is hazardous unless the runway is clearly marked.

(*f*) It is difficult to judge height and distance when landing on a snow-covered runway. Extreme care is necessary on the approach and when rounding out. Experience shows that a flatter approach than normal, with power left on until touch-down, is the safest technique.

(*g*) When there is slush on the runway, and its length permits, landings should be made with the minimum of flap to prevent damage by slush thrown back by the wheels.

(*h*) Cross-wind landings on icy runways are difficult and require very good timing and judgment.

(*j*) Brakes must be used with extreme caution.

SERVICING AND GROUND CHECKS

Introduction

45. The principles of the servicing of aircraft in arctic and sub-arctic areas are given in A.P. 1441B, Vol. 1 (The Servicing of Aircraft and Associated Equipment in Low-Temperature Conditions). Captains and pilots of aircraft proceeding to arctic regions should be familiar with the contents of that publication, as satisfactory operation in cold weather depends to a large extent on pilots having a thorough knowledge of the servicing problems likely to be encountered. Some of the more important servicing precautions are outlined in the following paragraphs, but reference should also be made to Vol. 1 of the air publications covering the aircraft and engine.

Pre-Flight Procedures

46. In addition to a thorough normal pre-flight inspection, the following additional precautions are necessary when working under low-temperature conditions ; their application in individual instances depends on the weather and on whether the aircraft is parked in the open or under cover.

47. **Airframe.**

(*a*) Aircraft covers must be removed with care. All snow, ice, and frost must be cleared off the surfaces of the aircraft. This should be done by brushing, if possible, and applying heat, and followed by a thorough drying of the surface. Defrosting fluid may also be applied, but de-icing fluid should only be used as a last resort as it tends to remove the grease from control bearings and hinges. Particular attention must be paid to the surfaces around turbine engines, as any snow or ice in this area will melt on starting up and may subsequently freeze again.

(*b*) All control-operating devices and hinges must be checked for freedom from ice, and full movement of each control obtained. Fuel vents must be free of ice ; all oleo leg pistons, hydraulic jack rams, undercarriage locks, and micro-switches must also be cleared of ice, snow, or slush. Pre-heating should be used if necessary to remove snow or ice, but all traces of water must be dried off after pre-heating.

(*c*) The canopy or hood must be examined for signs of cracking.

(*d*) If the aircraft has been parked on ice, the tyres must be checked to ensure that they have not frozen to the ground. If not free, the tyres should be inflated to one and a half times normal pressure to break the ice, or the ice should be melted.

48. **Engines.**

(*a*) No difficulty should be experienced in starting gas-turbine engines down to a temperature of −30°C. ; below this temperature pre-heating may be necessary. Turbo-starter cartridges must be kept in a warm storage if the temperature is below 0°C., and precautions to ensure engagement of the starter may be necessary.

(*b*) Piston engines must be hand-turned before starting, and a check made of the air temperature to determine whether it is below that for which :—

(i) Normal engine priming is satisfactory (as stated in the air publication). If so, high volatility priming must be used or the engine pre-heated.

(ii) The engine oil was diluted. If so, pre-heating of the oil system, as well as the engine itself, is essential. The pre-heating period depends on temperature and wind speed and may be between one and three hours.

(*c*) Starting and warm-up procedures are given in the engine publication. Special care is necessary with piston-engined aircraft to ensure that the oil is thoroughly warm and is circulating fully through the oil cooler, thus giving oil temperature control, before boil-off of the diluent is started. The oil tanks must be topped up if necessary after boil-off.

(*d*) An external power supply must be used for starting, to avoid overloading the aircraft batteries. The starting loads are very high in low temperatures, and starters must not be kept turning for lengthy periods.

Post-Flight Procedures

49. The importance of careful post-flight procedures is stressed. A little time spent on ensuring that the aircraft is adequately protected against the weather will save endless difficulty. Carelessness may well involve serious damage to the aircraft or engines. Some of the more important aspects are :—

(*a*) The aircraft should be completely covered when parked in the open, but the prevailing wind strength may determine whether it is practicable to fit covers. If they can be fitted the covers must be tightly fitting and secure. All pitot heads, static vents, and any orifices through which snow could penetrate must be covered. Oil cooler and coolant radiators should have blanks fitted. Exposed rams of electrically-operated controls must be left in the closed position and all control surfaces securely locked. The aircraft must be picketed if high winds are expected.

(*b*) If the aircraft has to be parked on ice, or if the temperature is likely to alternate between freezing and thawing, the aircraft should be parked with the tyres resting on some material that prevents adhesion.

(*c*) All oleo leg and exposed hydraulic jack rams should be cleaned and protected with a film of hydraulic fluid.

(*d*) The aircraft must be chocked as soon as possible (preferably with spiked chocks) and the brakes released.

(*e*) All aircraft using AVGAS should be refuelled as soon as possible and the tanks kept as full as possible, consistent with the flights planned, to prevent the condensation of water and subsequent formation of ice in the fuel system. It may be preferable to leave the tanks of aircraft using AVTUR or AVTAG fuels empty until immediately before flight, as the use of heated fuel may be required. This will be necessary in the absence of any system on the aircraft to safeguard against low-pressure filter icing, caused by the separation of water in solution as the fuel becomes cold soaked.

(*f*) If the aircraft is to be parked in the open for more than four hours, and the temperature is below −5°C., the batteries must be removed and stored in a heated hangar, preferably on charge.

(*g*) Before oil dilution the oil tanks of piston-engined aircraft must be topped up to the level recommended. It may be necessary to heat the oil for ease of pouring. After oil dilution, undiluted oil must not be added to the oil tanks. The degree of oil dilution should be based on that required for a temperature of at least 10°C. below the expected air temperature at the time of restarting. Accumulated condensed water must be boiled off or drained from the oil system as recommended in the engine air publication.

Servicing in General

50. Servicing principles are the same in arctic or temperate climates, although additional precautions are necessary in the Arctic. Personnel servicing aircraft must be thoroughly familiar with A.P. 1441B. The following points should be noted by all pilots :—

(*a*) Heated hangars are a very great aid to servicing and serviceability ; however, certain aspects of the use of heated hangars should be known. Rapid changes in temperature on movement in or out of heated hangars cause differential expansion and contraction, and may cause fuel and/or other leaks and a tendency for canopies to crack. The aircraft also tends to sweat when placed in a heated hangar. Moisture caused in this way must be removed before the aircraft is moved into the open again, otherwise ice forms. The effect of temperature change must also be allowed for when changing oleo legs and hydraulic accumulators, and when inflating tyres.

(*b*) Servicing in the open is quite feasible provided that adequate clothing is worn. The use of shelters or wind breaks, and heaters is essential, except for work of a minor character. The time to do a specific job, however, unavoidably increases. Gloves must be worn except when working in awkward parts of the aircraft ; if gloves are removed the items being serviced must be continuously warmed. The use of heat is also necessary when fitting or removing flexible pipes.

(*c*) Care must be taken not to overtighten bolts, nuts, or control cables.

(*d*) All filters must be checked regularly for presence of ice.

(*e*) The use of specially made-up wing mats (canvas with wooden slats) is recommended to minimize the danger of personnel slipping from the wings.

(*f*) The need for special care of batteries, both alkaline and lead acid, is stressed. Low temperature causes a loss of capacity and a decrease in the ability to accept recharging. Starter trolleys and aircraft batteries must be stored in warm buildings and kept on charge when possible. They should only be brought out into the open or installed in aircraft immediately before use. Where possible, batteries should be transported between the storage room and the aircraft in a heat-insulated container.

Servicing of Equipment

51. Special care is necessary in the maintenance of all aircraft and ground equipment to ensure its maximum serviceability in low temperatures. The care of such items as aircraft covers, electrically-operated equipment, and heaters, is particularly important. Points for especial care are :—

(*a*) In low temperatures the serviceability of heaters is of paramount importance. Operating personnel must be thoroughly familiar with their operation, and service them regularly. Stringent observation of safety precautions to minimize danger of fires when using heaters must also be stressed.

(*b*) The crankcases on all piston engines used for ground equipment must be filled with a thin oil, diluted by the addition of kerosene if temperatures are below −25°C. Heaters should invariably be used to assist starting.

(*c*) The addition of 1 per cent. alcohol to the fuel of internal combustion engines is recommended to prevent icing troubles.

(*d*) Ground equipment not in use should, if possible, be housed in a shelter or heated building.

NAVIGATION

Introduction

52. Navigational methods are fundamentally similar in any undeveloped, ill-mapped part of the world. In high latitudes, however, special attention must be paid to the following features:—

(*a*) Definition of direction.

(*b*) Compass performance.

(*c*) Flight illumination.

Definition of Direction

53. True North is a thoroughly unsuitable datum of direction in latitudes above 70°N., owing to the convergence of the meridians. Rhumb line tracks are impracticable because of their curvature, and great circle steering is inconvenient because of the constantly changing heading. To avoid these difficulties the grid navigation technique detailed in A.P. 1234A, Section 2, Chapter 3, is used.

Compass Performance

54. The magnetic compass is an unsuitable steering instrument in high latitudes owing to :—

(*a*) Reduction in strength of the horizontal component of the earth's magnetic field.

(*b*) Imperfect knowledge of magnetic variation.

55. Unstabilized needle compasses of the P.10 type cease to function satisfactorily in a field strength of less than 0·06 gauss; gyro-stabilized inductor compasses, such as the G.4 series, are reputed to function correctly down to 0·03 gauss. Fig. 7 shows the areas affected by the above limitations and it will be seen that the geographic pole and most of the Canadian Arctic are included.

56. The values of magnetic variation are high and the positions of the isogonals are not accurately known. The isogonals converge on both the magnetic and geographic poles, so that a comparatively small error in the assumed position produces a large error in variation. In addition, magnetic storms cause temporary changes in variation, the effects of which are significant as far afield as the east coast of Greenland. Thus, even if the magnetic compass functioned satisfactorily, its indications could not be converted to true headings with any degree of accuracy.

57. In areas where the above difficulties are encountered, the magnetic compass must be discarded and the aircraft steered on a directional gyro. The actual grid heading of the aircraft is checked by astro compass at regular intervals (20 or 30 minutes). The gyro is not reset since this would upset its wander rate ; instead the navigator calculates the required alteration in gyro heading to make good the intended grid heading.

58. The gyro log also provides for the calculation of the wander rate. This is essential in case the sky becomes obscured and astro-compass heading checks cannot be made ; the aircraft must then be steered on the assumption that the previously observed wander rate continues to hold good. Any action that would prejudice this assumption (*e.g.* large alterations of heading) should be avoided.

Flight Illumination

59. Astro observations for position fixing and heading checks are not possible during twilight periods, unless the moon or a planet happens to be available. The duration of twilight in high latitudes is very sensitive to the aircraft's flight path so that, unless great care is taken in selecting the time of take-off, it is possible to fly for long periods in unfavourable conditions of flight illumination, *i.e.* the aircraft keeps pace with the twilight band.

Navigation Aids

60. **Astro.** Astro fixing is not possible during the summer season of total daylight, except for the few days each month when the moon is

favourably placed relative to the sun. Total daylight lasts from 21st March to 22nd September at the North Pole, and from 20th May to 23rd July at Lat. 70°N. Single position lines are available in summer but it is often necessary to observe bodies at very low and even negative altitudes ; special care is then required in the calculation and application of corrections for atmospheric refraction.

61. **Radio Aids.** The immense logistic problems act against the deployment of radio aids except at bases developed for other purposes. Thus, whilst homing aids are provided at most airstrips, long-range fixing cover is not generally available. Long-range aids are subjected to heavy interference from auroral activity, resulting in gross inaccuracies and sometimes complete radio blackouts.

62. **Map Reading.** The quality of mapping of the Arctic is improving rapidly, but great care is still necessary when map reading. Coastal regions are fairly accurately depicted in general outline, but detail is often insufficient to allow pinpointing or even localization unless a large stretch of coast is visible. Inland, both ground detail and vertical features are generally unreliable. Even where the outlines of features are accurately mapped their geographical positions may be in error by several miles. Map reading is made more difficult by snow cover, by variable coastal ice, and by seasonal freezing of bays, inlets, rivers, and lakes.

63. **Radar.** All the factors in para. 62 affect the reliability of fixing by search radar of the H_2S type. P.P.I. interpretation is made particularly difficult by the camouflaging effects of ice and snow and the seasonal changes in those effects.

64. **Dead Reckoning.** The limitations on fixing emphasize the need for accurate dead reckoning supported by frequent wind finding. Multiple drift winds are not favoured because the required alterations in heading may affect the wander rate

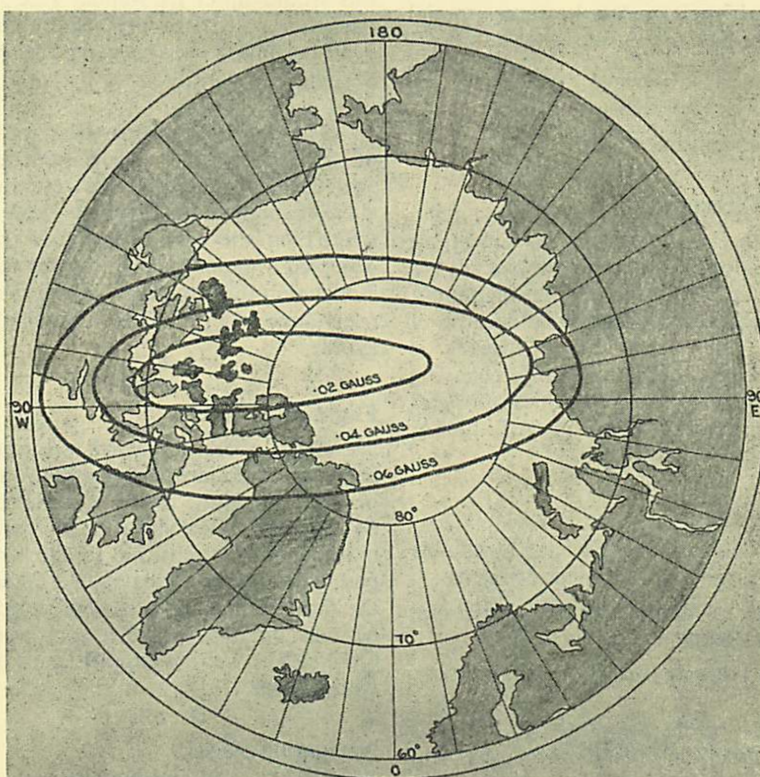

Fig. 7. North Polar Horizontal Magnetic Field

of the steering gyro. Wind finding is therefore confined, in the main, to the following methods:—

(*a*) By drift recorder, using a radar altimeter to obtain the aircraft's true height so that a groundspeed as well as a drift can be determined.

(*b*) By H_2S, tracking a suitable echo across the P.P.I.

(*c*) By pressure pattern soundings, again using the radar altimeter to obtain the aircraft's true height. Only the cross-track component of wind velocity is determined, but this enables a pressure pattern position line to be plotted.

Flight Planning

65. Flight planning considerations are the same as those for long-range flying in lower latitudes, but with greater emphasis on the following :—

(*a*) Fuel reserves to cater for unforecast weather conditions. The density of reporting stations in the Arctic is insufficient to allow detailed forecasts to be made, and the radio links between stations are often interrupted by auroral activity.

(*b*) Flight illumination conditions, for the reasons outlined in para. 59.

(*c*) *Safety Heights.* In the present state of mapping, all elevations indicated on maps should be regarded as approximate.

(*d*) *Crew Co-Operation.* Gyro steering imposes a set pattern of activity that must continue regularly and without interruption. Other activities in the aircraft must therefore be dovetailed into this pattern.

66. Blown snow can reduce the visibility to zero and forecasts should be carefully checked for wind velocity and snow conditions. Thick fog can form very quickly in winter, especially near coasts. The trend of any wind shift should be noted, since shifts of 45° can change the visibility from unlimited to zero within minutes.

RADIO

General

67. Arctic weather conditions present considerable problems to designers and operators of aircraft radio installations. The intense cold and formation of ice adversely affect aerial insulators, control cables, torsional drives, and rubber insulation. The danger of aerial insulators being short-circuited by ice can be reduced by the use of an arctic grease, while the control cables and torsional drives will not freeze up provided the correct anti-freeze lubricant is used. Little can be done, however, to prevent the crystallization of rubber insulation ; care should be taken to avoid bending cables while they are cold, and they should be inspected carefully before flight for signs of disintegration.

Frequency Creep

68. Another design problem is *frequency creep*. This phenomenon is likely to occur in all equipment operating on preset frequencies if the master oscillator control unit frequency has been set up under normal conditions. The reason for this creep is that the wide temperature variations cause expansion or contraction of wiring and condenser plates, and so the master oscillator creeps off the desired frequency. This can be obviated if crystal control is used, and is unlikely to cause trouble if the radio equipment has been set up and is operated in an adequately heated cabin.

Limitations of Equipment

69. The operational usefulness of radio equipment is considerably reduced in the Arctic, the main causes of this being :—

(*a*) Unusually high levels of precipitation static may occur, making reception difficult.

(*b*) Sky-wave propagation may be erratic owing to the effects of the aurora borealis on the ionosphere.

(*c*) Frequency selection for long-range communication proves difficult because of the variation of the hours of daylight and darkness between the transmitting and receiving stations. It will often be easier to establish reliable communications over North-South links than over East-West links.

(*d*) Large errors in D/F bearings due to refraction may occur where the coastlines are irregular or precipitous.

(*e*) Primary radar systems are affected by the poor conductivity of glacier formations which may give misleading responses.

(*f*) The presence of areas of pure fresh water from melting snow may result in the radio altimeter losing its effectiveness.

THE HUMAN PROBLEM

Morale

70. The human problem is one of living and working, possibly in a lonely and isolated place,

under conditions of intense cold, and with long periods of darkness. The maintenance of morale is all-important. It may be necessary to stay within the bounds of the camp and a good corporate spirit must be fostered. Every effort should be made to fill leisure time with hobbies, games, competitions, and similar activities. With suitable safeguards, participation in survival exercises, hunting trips, and winter sports will familiarize men with their surroundings.

Food and Drink

71. A generous diet is needed to maintain both health and morale. It must include plenty of meat and fat, fruit juices, vegetables, and the protective foods—butter and vitaminized margarine. It will probably also be necessary to give vitamin pills separately. Alcoholic drinks may be available, but it should be remembered that they raise the rate of heat loss from the body and greatly increase the risks of exposure.

Clothing

72. Suitable ranges of clothing have been developed for ground and air crews. They are described in A.P. 1182E, Vol. 1, and consist of wind-proof outer garments and multi-layer inner garments which can be worn or left off as the need arises. The outer garments are hooded and particular attention is given to the protection of hands and feet. It is extremely important to have the proper sizes. In particular, socks must be large enough. Clothing must be treated carefully and kept free from moisture and oil since these destroy the insulating properties of the material. Torn items should be mended as soon as possible. Bedding material must be kept dry and should be aired when not in use.

73. Whilst in flight, clothing that is adequate for survival purposes should be worn at all times. Parachutes should not be allowed to become cold-soaked or they may become too stiff to open. Emergency equipment adequate for low-temperature survival must be carried in the aircraft.

Frost-Bite

74. Liability to frost-bite increases as the temperature falls and increases much more rapidly as the wind speed rises. Further information on wind chill factor is given in paras. 14 to 17 and Fig. 3.

75. Most likely to be affected by frost-bite are the exposed parts of the face and the extremities. The symptoms are numbness, stiffness, and a greyish discoloration. As a safeguard, men working in the open should periodically check one another's faces for the appearance of frost-bite. The treatment is to thaw the affected parts slowly, using body heat. Rubbing or rough handling, which will break the skin, must be avoided.

76. If very cold metal is touched with the bare skin, freezing will occur immediately and the skin will stick to the metal. Forcible separation is to be avoided. Where possible moderate heat should be applied before separation otherwise skin tissues may be torn resulting in painful wounds. If fuel or other volatile liquids are poured on flesh, the temperature drop caused by evaporation may cause frost-bite.

Care of Eyes and Skin

77. In daylight there is a risk of snow blindness both when flying and on the ground. Protective snow goggles must be worn whenever the glare is in the least unpleasant. The use of cold cream or lanoline will reduce the risk of painful chapping of the face and hands.

Working in the Open

78. If heavy work is done in full clothing it is easy to become overheated, even in extremely low temperatures. Should garments become sweat-soaked, rapid chilling occurs when the work is completed. To avoid this, outer clothes should be discarded whilst working and ankle, wrist, and neck fastenings loosened to allow free ventilation. The aim should be to maintain normal body temperatures and this of necessity means accepting a slower working tempo.


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