Special Report 16

AIRFIELDS ON SEA ICE

Practical recommendations, with ice thickness table for U. S. Navy planes: DHC-3, R4D, SA-16, P2V, R4Q, and R5D

The following recommendations, covering only practical field aspects, are based on theoretical work, field experiments, and practical experience of the Snow Ice and Permafrost Research Establishment, including ice surveys performed on the DEWline airlift. They follow chronologically the basic procedures necessary for the establishment and maintenance of airfields on ice. This report was prepared by Dr. Andrew Assur, Applied Research Branch, for use primarily by U. S. Navy Task Force 43.

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1. Preliminary choice of location.

Check map (scale at least 1:500,000) or aerial photograph of coast line configuration. Select location in a bay or behind a point of land so that airfield will not be subject to horizontal pressure, which causes extensive cracking. Unprotected airfields might be drifted away by currents. The direction of coastal currents, looking from the land, is usually to the right in the Arctic and to the left in the Antarctic. Shelf ice also forms protected bays in many cases. A shelf-ice bay has the added advantage that, during summer, ships can sometimes unload equipment directly on the sea ice left in the bay, and an airstrip can be established here also.

Active cracks (with ice movement) usually develop from points of land, in the direction of the current and towards the coast. Anticipate such cracks and choose a bay long enough to avoid them. When operating on minimum ice thickness, the width of the bay must be at least four times the basic load influence radius (see Table I), which depends on the ice thickness but not on the magnitude of the load.

Table I.

Sea Ice thickness (in.)	Basic load influence radius (ft.)
10	75
15	110
20	130
25	150
30	180
35	200
40	220
50	260

2. Exploratory field survey, for check of ice conditions and final location of sites. Use light aircraft for safe landing.

Circle above proposed site several times. Make sketch of coastal configuration, approaches, location of rafted ice, cracks, etc. Aerial inspection must be done from a higher elevation to get a general view of the area and from a lower altitude to check details. Snow drifts give some idea of the frequency of different wind directions, especially if combined with knowledge of general air circulation.

Land and decide on approximate location of air strip. The problem of adequate approaches, which always enters the survey at this phase, is not discussed here. Consult pilot on adequate approach and length of runway. One warning might be added. Never, except in emergency, locate an airstrip closely parallel to shore with high elevations, with the runway perpendicular to the prevailing wind. The local circulation pattern endangers smaller aircraft and causes trouble even for the heaviest ones.

As far as ice is concerned, the worst possible location is parallel to shore at the basic load influence distance (Table I) and with a water depth of some 20ft. Under these conditions, a maximum wave resonance effect will result when taxiing at 20mph. Avoid such a location if at all possible. This holds for minimum ice thicknesses. On thicker ice, resonance oscillations are less dangerous.

The best location is an airstrip with an angle of at least 45^{o} to the shore and nowhere closer to shore or shelf ice than twice the load influence distance. In many cases it will be difficult to find such an optimum location. Another solution, especially applicable for ice of doubtful safety, is to land on the water-supported ice and run out onto land-supported ice. A very careful ice survey is necessary in this case. The land-supported ice is bound to be or become rough, causing increased stresses in the landing gear. A tidal crack will usually be found or develop across the airfield between the water — and land — supported ice. When ice is sufficiently thick, do not locate airstrips on completely or partially land-supported ice. There is always the danger of failure due to air pockets under the ice, even with smaller loads.

Check ice thicknesses over the runway and especially on proposed parking areas. A minimum of four holes should be made if ice thickness substantially exceeds requirements, one in each of the two parking areas and two on the runway. If ice is close to minimum thickness, make more holes to make sure that there are no thin areas, particularly under large snow drifts, over shallow water, and near points of land. Be careful in measuring the ice thickness; careless and unreliable measurements are made more often than one would suspect.

Note average and maximum thickness of snow covering the ice. Measure ice surface temperature under the snow cover.

Make a reconnaissance on foot, sketching location of cracks over 1/2 in. wide. Note whether crack is dry or wet; record its width.

Decide on proper location of parking areas with a minimum amount of cracks. At least two parking and unloading areas are recommended for alternate use.

3. Decision on suitability of ice cover for an airstrip.

If the mean air temperature, averaged over the previous 5 days, was less than +10°F, or the ice surface temperature under about 1 ft of snow is less than +14°F, the criteria given in Table II can be used for safe landings, provided no wet active cracks and no dry cracks more than 1 in. wide were found on the runway and, especially, on the parking areas.

For rising mean air temperature above +10°F, the required ice thickness must be gradually increased by up to 50%, until operations, usually, have to be suspended due to surface deterioration. Slush thrown against control surfaces and into the wheel wells sometimes freezes after takeoff, creating a hazard.

The existence of cracks, old and new, often leads to unjustified concern. Uncracked ice is rare. Operations on cracked and cracking ice can be quite safe if the ice is sufficiently thick and under close observation and good maintenance (healing of open cracks with slush).

4. Establishment and maintenance of airstrip.

Even for ski-equipped aircraft, it is desirable to smooth out larger snowdrifts and check for cracks. Bush pilots have been known to cross open cracks up to 10 in. wide, but landing parallel to such cracks is dangerous, even if they are frozen (formation of deep ruts).

For wheeled aircraft, the snow must be cleared. If special snow-clearing equipment is not available, nothing smaller than a D-4 tractor should be used.

It is true that wheeled aircraft, such as the C-46, C-47, C-119, York, Lancaster, Bristol, have landed on unprepared or manually prepared surfaces on the DEWline, partly upon recommendation of SIPRE personnel. But these were emergency cases, mostly for the delivery of tractors for snow clearance. Although there were no accidents, such landings were considered hazardous. Wheeled aircraft should generally not land in snow deeper than 1/3 of the wheel diameters.

Snow-removal tractors (disassembled) were also delivered by ski-equipped C-47's, or air-dropped (with some losses).

A 2-3 in. snow layer should be left on the ice for good braking action. Even ski-equipped aircraft can operate better on snow, because the sea-ice surface itself has high friction with skis, owing to its high salt content.

Table II. SIPRE estimate of the thickness of sea ice for safe landing of aircraft

Condition: Mean air temperature, averaged over 5 days, less than 1°F or ice surface temperature under snow less than 14°F. No cracks, except dry hair cracks. Snow cleared, except for 2 - 3 in.

Type	Aircraft on wheels		Aircraft on skis	
	Gross weight (lb)	Minimum required thickness (in)	Gross weight (lb)	Minimum required thickness (in)
DHC-3 (UC-1)	6,540	13	6,870	12
R4D (C-47)	27,500	25	28,900	22
SA-16 (UF-1)	31,400	28	31,400	23
P2V	53,300	33	56,000	29
R4Q (C-119)	56,800	32	--	--
R5D (C-54)	61,900	34	--	--

Note: Do not use or quote the table without the following:

REMARKS

1. In spite of the greater weight, the required ice thickness is less for the R4Q than for the P2V because of more favorable gear configuration.
2. For aircraft on skis, a 5% weight allowance was made for ski and additional fuel.
3. Landing on thinner ice is known to have been safe under exceptionally favorable circumstances, but is not recommended for safe use.
4. If weight exceeds indicated gross weight, add 6% to ice thickness for 10% weight increase.
5. Increase required ice thickness gradually by up to 50% in case of higher temperatures.
6. Increase thickness by 10% for dry cracks with a width of 1.5in. and by 33% for wet active cracks, 2.5in. wide. Heal such cracks whenever possible.
7. Parking up to 1hr. Increase required thickness by 25% for 24hr. parking and move aircraft daily. At temperatures above 10°F, parking only up to 6hr. with 25% more thickness than required by table and point 5.

If this 2 - 3in. snow layer is well compacted, it will improve the bearing capacity in the spring by delaying deterioration of the ice. If the snow is loose, it must be removed when thawing starts. Slush thrown up against control surfaces is dangerous.

Snow piles on the sides of the runway weaken the ice underneath and form relatively deep ditches in the adjacent ice by slow plastic deformation. They should be flattened out if higher than some 3 1/2ft.

No, repeat no snow piles are permissible at the ends of the runways. It is important to enforce this rule rigidly in order to minimize accidents in case of short or long landings.

Because of the poor visibility of features on a snow-covered ground, especially under overcast sky, the runway must be properly marked. Large orange panels located perpendicular to the sides of the runway at the place of allowable touchdown are recommended. A short line of drums perpendicular to and outside of the runway at the place of touchdown is desirable in addition. Allow for an adequate overrun at the ends of the runway. The sides can be marked by empty oil drums. No solid markers are permissible across the runway at the ends.

Always keep an empty drum filled with dirt or rags and kerosene (or smoke bombs) about 1 mi. from the head of the runway and in line with it, to aid in locating the runway by smoke signals during adverse weather conditions.

The ice thickness should be checked at different points once a week when air temperatures are below +10°F, twice a week when temperatures are between +10 and +25°F, and daily when temperatures are above +25°F. A new hole must be made for each measurement.

Daily inspection of the runway is necessary, clearing new snow drifts and observing the development of cracks. With adequate ice thickness, cracks are permissible, but cracks over 1.5in. wide should be healed with slush if possible.

Special attention must be paid to cracks in the parking area. Aircraft may be allowed to roll perpendicularly over single cracks, but should not be parked on a crack. Do not allow aircraft to roll over places where several large cracks cross each other. Small flags put into such spots will help to guide aircraft to the proper parking place.

Alternate parking areas should be provided to give the ice an opportunity to heal and regain its strength.

Close parking of several aircraft is permitted only if the ice thickness substantially exceeds the requirements. For example, 40% more ice thickness is required if two airplanes park close together. If only the minimum ice thickness is available, loads must be separated by at least the "basic load influence distance," which depends on the ice thickness and is given in Table I. Open cracks and even a free ice edge are allowable at this distance from the load. However, such close loads should be stationary or move only very slowly.

5. Emergency landings and operations under marginal conditions.

Work on criteria for emergency landings, with increased risk to the aircraft for the purpose of saving the crew, is currently in progress at SIPRE.

Under most circumstances it is better to make an emergency landing on ice, even if thin, than on land.

Experience has shown that accidents on ice are far less serious than corresponding mishaps even on concrete runways. The shock is greatly absorbed by snow and the elastic resilience of the ice cover. There are very few cases of breaking through while moving on thin ice. Usually the gear breaks through after coming to a stop, and the aircraft sits on its belly or wings without sinking immediately, giving the crew enough time to escape.

It is essential for the man in the field to know how failure of the ice cover proceeds and what the danger signs are.

When operating on unsafe ice, the engines must be kept idling. One pilot should remain in his seat and one man should watch the behavior of the ice. Some cracking (often invisible but audible) can always be allowed, although it is a warning. With excessive loads, radial cracks proceed from one main gear towards the other and then in other directions. These cracks are hardly noticeable and at best appear on the snow cover as fine lines. But each crack is accompanied by a sharp sound, especially on colder ice. After considerable radial cracking, a circumferential crack forms suddenly several yards from the main gear, and the airplane sags noticeably. Breakthrough in most cases is not immediate, but is certain unless the aircraft is moved a distance at least equal to the basic load influence radius (Table I). Thus it is possible to unload an aircraft under marginal conditions by frequent moving before circumferential cracks occur.

If the aircraft is not moved, the ice will fail very close to the main wheels. The surrounding ice will crack but not break completely.

It is a good general practice, even on safer ice, to unload the aircraft as fast as possible and to avoid prolonged parking.

6. Ice airfield journal.

This journal is a document covering the establishment and maintenance of an airstrip on ice. It must be written and signed by a specially designated person, responsible for proper maintenance of the runway and delivery of messages on its condition. Experience has shown that, unless a designated person is responsible, maintenance is poor and accidents result.

The ice airfield journal should contain the following data:

a) Date and results of exploratory survey with sketch of general situation, cracks, pressure ridges, etc.

b) Date and procedure of first and all subsequent snow removals.

c) Height of snow piles.

d) Current data on ice thickness — noting total ice thickness, depth at which ice changes from light to dark color, ice surface temperature under the snow on the runway and depth of water.

e) Description of crack development — noting width (and approx. depth) of dry and wet cracks. Date and details of artificial healing.

f) Daily air temperatures. Thermometer must be located in shade. Daily mean can be derived from the following combinations:

   Mean of maximum and minimum; mean of measurements at 7, 13, and 21 hr. local time; mean of measurements at 0:30, 6:30, 12:30, and 18:30 Zebra time. The last combination is preferable, since weather observations for aviation purposes are taken at this time.

g) Landing and parking record. Type of aircraft, gross weight, time of landing, length of parking on the same spot. Record of cracking.

   Describe in detail whether cracking under aircraft was heard or seen during taxiing or parking; note whether cracking was occasional or frequent; describe whether sagging was observed. Any incidents or unusual occurrences, especially during emergency landings, should be described in detail.

h) During thawing weather, the depth of slush on the ice must be noted, as well as the formation of pit holes.

i) Radio all essential information to main base.

It is requested that a copy of the airfield journal be sent to the Snow Ice and Permafrost Research Establishment, 1215 Washington Avenue, Wilmette, Illinois, after completion of the operation. Such records are necessary for technical evaluation and continuing improvement of use of ice for airfields.