ICAO CIRCULAR

CIRCULAR 43-AN/38

1955

ICE AND SNOW ON RUNWAYS

Published by authority of the Secretary General

INTERNATIONAL
CIVIL AVIATION
ORGANIZATION
MONTREAL • CANADA

This Publication is issued in English, French and Spanish.

Published in Montreal, Canada, by the International Civil Aviation Organization. Correspondence concerning publications should be addressed to the Secretary General of ICAO, International Aviation Building, 1080 University Street, Montreal, Canada.

Orders for ICAO publications should be sent, on payment:

In Canadian currency ($), to

Secretary General, ICAO,
International Aviation Building,
1080 University Street,
Montreal, Canada.
(Cable address: ICAO MONTREAL)

In Sterling or Irish currency (s/d), to

Her Majesty's Stationery Office,
P.O. Box 569,
London, S.E. 1,
England.
(Cable address:
WHOLECORN, SEDIST, LONDON)

In French currency (fr), to

ICAO Representative,
European and African Office,
60bis, avenue d'Iéna,
Paris (16e), France.
(Cable address: ICAOREP PARIS)

In Egyptian currency (L.E.), to

ICAO Representative,
Middle East Office,
Wadie Saad Building,
Sharia Salah el Dine,
Zamalek, Cairo, Egypt.
(Cable address: ICAOREP CAIRO)

In Peruvian currency (soles), to

ICAO Representative,
South American Office,
Apartado 680,
Lima, Perú.
(Cable address: ICAOREP LIMA)

In Thai currency (bahts), to

ICAO Representative,
Far East and Pacific Office,
Sala Santitham, Rajadamnoen Ave.,
Bangkok, Thailand.
(Cable address: ICAOREP BANGKOK)

In Australian currency (s/d), to

Robertson and Mullens,
107 Elizabeth Street,
Melbourne, C.1, Australia.

In Indian currency (Rs.), to

Oxford Book and Stationery Company,
Scindia House,
New Delhi, India.

In Argentine currency: from

Editorial Sudamericana S.A.,
Calle Alsina 500,
Buenos Aires, Argentina.
(Cable address: LIBRECOL)

TABLE OF CONTENTS

THIS PAGE INTENTIONALLY LEFT BLANK

INTRODUCTION

At the Third North Atlantic Regional Air Navigation Meeting, held in Montreal October 1954, the Aerodromes, Air Routes and Ground Aids Committee devoted one half-day to an exchange of technical views on the following part of its Agenda Item 2:

> Consideration of specific problems consequent upon the introduction of turbo-jet operations in the Region, with relation to:
>
> a) Icy runways;

This Circular, which is a summary of the discussions, will serve to supplement the information contained in the following ICAO's Circulars:

Circular 17 - AN/14	The effect of turbine-powered civil aircraft on the design, construction and equipment of land aerodromes.
Circular 23 - AN/20	Problems associated with the advent of turbine-engined airplanes.
Circular 36 - AN/31	Problems arising in AGA field as a result of the introduction of turbine-engined aircraft.

Time did not permit of discussion of the remaining parts of Agenda Item 2:

> b) Provision of taxiway holding or run-up areas;
>
> c) Handling of jet aircraft on aprons.

1.- CONDUCT OF THE MEETING

The meeting was convened under the chairmanship of Mr. A.L. Catudal of the United States and was conducted in an informal manner to enable all present to exchange freely their views and experience on the subject.

Two short papers, NAT III-WP/67, AGA-WP/5 by a Representative of Scandinavian Airlines System and NAT III-WP/93, AN-WP/7 by the Delegate of Belgium, were presented to the meeting. The contents of these papers and the discussions thereon are reflected in this Circular. Subsequent to the meeting, additional papers were received, one from Canada, two from France and one from Norway. As it was believed that these papers served to amplify the subject matter of the discussions and would be of interest to other States they have been included as Attachments "A", "B", and "C" to the Circular.

2. - SUMMARY OF THE DISCUSSIONS

2.1. - Scope

2.1.1 The discussions have been summarized under the following headings:

1) Specific problems

2) Methods of overcoming the problems

A - AIR

i) Anti-skid-brakes

ii) Special tires

iii) Braking parachutes

iv) Reverse thrust

B - GROUND

i) Special runway construction: concrete blocks, raised runways, heating

ii) Treatment: general, snow clearing, snow compaction and sanding

iii) Use of arrester gear (jet landing barrier)

3) Methods of evaluating the coefficient of friction

4) Methods of informing pilots of the state of the runway.

2.2. - Specific problems

2.2.1 It was generally agreed that icy runway conditions would introduce more acute problems with the advent of turbo-jet aircraft than with piston engined aircraft, at least until jet aircraft were equipped with a means for applying reverse thrust. Further problems with turbo-jet aircraft were that under certain conditions the jet blast melted any snow on the runway and on refreezing, created ice and, in the case of an icy runway that had been treated with sand, the jet blast tended to melt the ice and dislodge the sand. Experience had shown that the latter problem could, to some extent, be overcome by increasing the spacing in time between consecutive jet operations. This solution would not be acceptable, however, at busy aerodromes. The conditions under which the greatest difficulties could be expected were during and after freezing rain and when temperature fluctuations below and above freezing point caused thawing of snow followed by ice formation.

It was further pointed out that wet runways also created a problem due to slipperiness and that there was a danger of aircraft sliding sideways off the runways, particularly in conditions of strong cross-wind, as well as off the ends of runways. One solution to the problem of wet runways was discussed under the heading of "Special Runway Construction". The general conclusion reached was that the need for finding solutions to the problems of icy runways had become even more urgent with the advent of turbo-jet aircraft than with the piston engined aircraft. Included in these problems were: measuring the coefficient of friction of icy runways, developing the most efficient means of increasing the coefficient of friction and developing procedures by which pilots could be informed of the condition of the runway so that they may interpret it in terms of braking efficiency.

2.3. - Methods of overcoming the problems

2.3.1 Airborne devices

2.3.1.1 Anti-skid-brakes

Experience had shown the value of such devices, both in the take-off case and the landing case, particularly with slippery runway conditions.

2.3.1.2 Special tires

Mention was made of various types of special tires designed to increase the braking efficiency under various conditions including snow, mud, ice and water on runways. The devices used included special tire treads impregnated with gritty materials, metal spikes set in the treads and helical metal springs inlaid in the treads and serving a similar purpose to that of chains. The latter type of tire had proved very effective in winter conditions in the north of Canada and in the Arctic but were not quite as effective as some other types of tires on wet runways.

2.3.1.3 Braking parachutes

It was noted that such devices had proved to be effective on military aircraft but no one was prepared to discuss the possibilities of their use on civil aircraft.

2.3.1.4 Reverse thrust

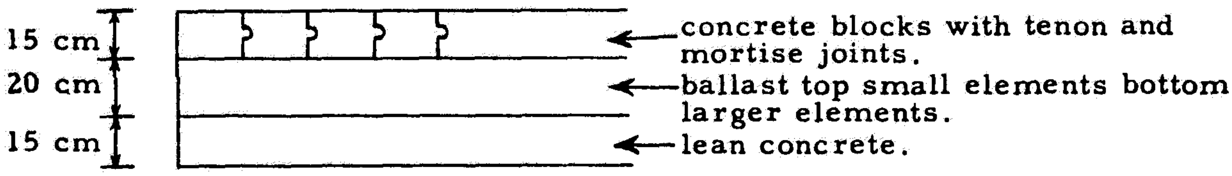
The meeting took note of the fact that considerable development was taking place in this field and that a number of devices for reversing thrust had been tested successfully in several States.

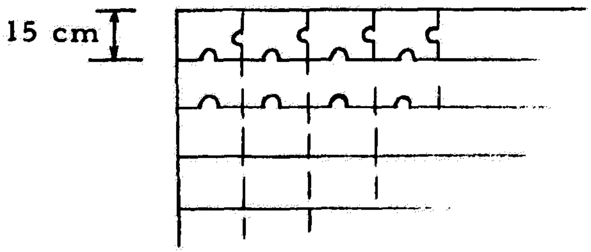
2.3.2 Ground devices

2.3.2.1 Special runway construction

a) Concrete blocks

In Belgium a special type of runway construction has been adopted for 200 to 300 metres (660 to 1000 ft) at both ends of runways and results had justified its continued use in the future. It consists of interlocking concrete blocks arranged as indicated in the sketch hereunder.





It was stated that, in Belgium, ice was formed on runways as a result of glazed frost and when melting snow freezes again. In the case of glazed frost, runway surfaces with joints are less slippery than continuous surfaces; in the case of melted snow, the water penetrates immediately into the base course and thus does not freeze if frost follows

Furthermore, should jet exhaust gases cause deterioration of the end of the runway, repairs to this surface can be effected rapidly and at low cost. For a runway designed for an equivalent single isolated wheel load of 45 tons, the cost of such a surface is one and a half times that of a concrete surface.

Although this type of construction may not provide any great advantages in colder countries where, for long periods, the frost does not thaw, it may still be of value during other times of the year in reducing the slipperiness of runway surfaces in wet conditions.

b) Raised runways

In Canada many roads and some runways have been constructed with the surface elevated approximately .45 metres (1.5 ft) above the surrounding country. This facilitated snow removal since most of the snow was blown off by the wind.

c) Heating

In Belgium tests had been made with heated pavement surfaces. This method had proved to be very effective but costly. It was thought that it might be applicable to certain selected areas such as the apron immediately adjoining a terminal building. One difficulty seen with this method was that of getting rid of the water since it might tend to refreeze and block the drainage system, particularly if large areas such as runway surfaces were heated.

2.3.2.2 Treatment of snow and icy conditions

a) General

A considerable amount of the discussion was on the question of snow removal and snow compaction prior to treatment for icy conditions. The most widely adopted practice was to clear the snow down to the bare runway wherever practicable and to treat icy surfaces with sand. It was generally agreed that, in most cases, it was simpler and cheaper to compact the snow than to clear it. Objections to snow compaction included: the difficulties created by melted snow and slush during periods of thawing and with ice on refreezing, the long period of unserviceability during the thawing of deeply compacted snow, the problem of slush during the thaw even with compaction controlled down to a few inches and the difficulties of height perception over compacted snow runways in blowing snow conditions. As indicated hereunder various methods can be used to help overcome some of these difficulties.

b) Snow clearing

The method adopted in Canada and Sweden was to start plowing with high speed plows as soon as two inches of snow had fallen and to continue plowing throughout the storm. The snow was usually plowed from the centre of the runway outwards and from the sides inwards and then blown clear of the runway by means of snow blowers. In Canada a special machine was used to clear the last 1/4 - 1/2 inch of snow. It consisted of a high speed drag towed behind a 3 ton truck at not less than 35 miles per hour. It stirred up the remaining snow and the wind generally blew it away. In some places, with raised runways and prevailing windy conditions, it had been found that this machine alone would get rid of the snow and no snow plows were needed. In order not to damage fixed light fittings during snow clearing operations, special snow plows fitted to small agricultural tractors were used but, in many cases, lights with extension cords and "lily pad" bases were used. These lights could be lifted out of the way of the snow plows and then replaced on top of any remaining snow. In order to combat the problem of drifting snow the Canadian authorities adopted the practice of compacting the snow on the outer areas of the runway system and removing the snow from the inner areas.

c) Snow compaction

In parts of Northern Canada, Sweden and Norway it was not practical to remove the snow or at least to remove it completely. In these places, runways were formed by rolling and compacting the snow. In Canada three methods were used:

i) compacting the snow as it falls on the runways. This was a simple method and it was easy to maintain breaking action on such a runway. The snow compacted from one foot down to two inches in depth and sometimes, towards the end of the winter, the compacted snow was up to 2 feet in depth. This method had the great disadvantage that, during the spring thaw, the snow takes a long time to melt and the runway is unserviceable during this period;

ii) compacting an area of snow adjacent to the runway. The advantage of this method was that the uncompacted snow on the runway thawed more rapidly and the runway could be used sooner;

iii) controlled compaction to a depth of 4 to 5 inches on the runway. This had the advantage of thawing more rapidly than deep compacted snow.

Airport authorities expressed the view that compacted snow provided a surface that was easy and cheap to maintain and one on which a good coefficient of friction could be retained by means of scarifying the surface or by sanding. Further, the sand tended to stay in place longer than on a cleared runway surface.

Objection to any form of snow compaction was expressed by several members of the airlines. This was that, even with controlled compaction, there was a danger of slush during times of thawing which sometimes occur in the winter as well as in the spring. It was claimed by some airport authorities, however, that the spring thaw could be anticipated and the compacted snow broken up and cleared away.

d) Sanding

The use of sand to help increase the coefficient of friction on icy runways was universal. It had been established that sand, provided that it was not too coarse, did not damage turbo-jet engines and, in fact, it was stated that tests had shown that small quantities of sand thrown into the jet intake helped to clear the turbine of carbon deposits. Methods of applying the sand varied considerably. In some cases sand was kept at a temperature of 10°C (50° F) in a hanger and, immediately before spreading, it was thoroughly saturated with water. In other cases the sand was simply warmed to a temperature of 10°C (50° F) (at higher temperatures it sinks into the ice) and spread dry on the runway. In still other cases a water truck was used to wet the runway ahead of the sanding operation, and finally the method that had been found very effective in Norway and other places was to spread the sand and then "fix" it into the ice by means of a weed burning machine or flame thrower. Both processes of spread and "fixing" could be combined in one machine and the operation could be carried out expeditiously under well controlled conditions.

It was important to select the right size of sand particles to provide the best coefficient of friction. If the particles were too small they tended to be dislodged and blown away by jet blast and, if they were too large, they tended to act as roller bearings when they became dislodged from the ice and, at the same time, might damage turbo-jet engines.

On the question of the area of icy runway surface necessary to be treated with sand, a Canadian representative advised that, with the exception of training aerodromes on which the whole runway was treated, a strip covering the full length of the centre of the runway and approximately 12 metres (40 ft) wide was normally sanded. No figures as to the quantity of sand required were available to the meeting. However, the following figures were quoted as examples of the time spent on sanding operations during a typical winter in Canada: Montreal 808 hours, Gander 138 hours, Toronto 161 hours, Kapuskasing (with controlled compaction) 4 hours. It should be noted, however, that there were variations in equipment and methods as well as in climatic conditions.

In regard to the type of equipment used for spreading the sand the meeting was advised that several types were used in Canada. These included a simple type that was attached to the rear of a dump-truck and consisted of a circular plate, driven by the motor, which served to scatter the sand over a width of approximately 12 metres (40 ft). Another type consisted of an adjustable mechanical feed attached to a dump-truck. This equipment spread the sand over a width of 3 metres (10 ft). The latest equipment consisted of a special truck with a sand bin and a conveyor belt to a spinner driven by a separate auxiliary power unit. It could be controlled by one man and the rate of spread of the sand could be adjusted independently of the speed of the vehicle. In one trip at 10-12 miles per hour a strip 12 metres (40 ft) wide could be spread.

2.3.2.3 Arrester gear - jet landing barrier

A special type of jet landing barrier, developed by the United States initially for use in Korea, had proved very effective in reducing or practically eliminating accidents due to aircraft overrunning the end of the runway. Briefly, the device consists of what amounts to a nylon net approximately 1 metre (40 inches) high, stretched across the stopway or overrun. The net is attached to a flexible steel wire rope cable which is stretched across flat on the runway or stopway surface. Each end of the steel cable is held by a shear pin and is attached to some 60-90 metres (200-300 ft) of heavy iron chain which is placed so as to form two rows parallel to the runway centre line, one on each side of the stopway remote from the barrier.

First the nose wheel of the aircraft strikes the net and runs over the steel cable. As the net stretches it actuates releases which hold down the steel cable and the latter springs up between the nose wheel and the main landing gear. The main landing gear then comes in contact with the steel cable, the pins are sheared and the aircraft commences dragging the steel cable link by link down the stopway thus an increasing retarding force is applied to the aircraft through its main landing gear. This type of gear has, for example, stopped an F-86-F Sabre Jet, striking the barrier at 140 knots, in less than 150 metres (500 ft) with only minor damage to fairings. Its use is not confined to icy runway conditions since it has proved to be an excellent safety device in practically all cases of over-shooting with turbo-jet fighter aircraft. Considerable interest was shown by the meeting in the possibility of using similar devices for emergencies at civil aerodromes particularly where dangerous conditions exist a short distance beyond the ends of runways (e.g. a cliff, ditch, highway or railway) and efforts are being made by the Secretariat to obtain further details of such devices.

2.3.3 Methods of evaluating the coefficient of friction

Several methods have been used for measuring the value of the coefficient of friction on icy runways. In Norway, a 10-wheel truck was used. Tests were made with the truck running at 40 km./h. (25 m.p.h.), the wheels were then locked and the time in seconds and distance in metres to stop were measured. Full details of the method of making these measurements and their conversion into terms of braking action will be found at Attachment "B". In the United Kingdom tests had been made with a special trailer with one locked wheel. On wet surfaces, the friction coefficient had been found to vary between 0.39 and 0.7 at 48 km.h. (30 m.p.h.) and between 0.11 and 0.5 at 160 km.h. (100 m.p.h.). Tests with a special motorcycle driven at 27 km.h (17 m.p.h.) on an icy runway indicated a friction coefficient of 0.2 which, after the application of fine sand on the runway, was raised to a value of 0.43. It was planned to make further tests in the future with a "Tapley" brake meter fitted to a car or a van. This device was normally used to test the efficiency of brakes but could also be used to measure the coefficient of surface friction when the efficiency of the brakes was known. It was based on the use of a pendulum accelerometer with a scale reading in percentages of "G".

In other countries, tests were being made but no details were available to the meeting. Several representatives raised the question of the time factor involved in making these measurements. They felt that, to make sufficiently comprehensive tests over a large enough percentage of the runway surface to ensure representative results, would be time consuming. One method mentioned for overcoming this was based on highway practice in which a very large number of detailed tests were made and these were co-related with simple tests which could be done quickly. It was then necessary to apply some empirical method of allowing for non-uniform conditions along the road or runway.

2.3.4 Methods of informing pilots of the state of the runway

Early in the discussions, a matter of principle was raised as to whether airport authorities should assume any responsibility for informing pilots of the state of slipperiness of the runway. It seemed to be generally agreed that there would be little point in making measurements if the results could not be passed to pilots. Several speakers voiced the opinion that information of this type was no more critical from the point of view of the responsibility of the aerodrome authority than was other information such as the visibility, ceiling, runway visual range, etc. It was generally appreciated that any measurements of the coefficient of friction would have to be evaluated in terms of braking efficiency or landing distance required for the particular aircraft (see Attachment "B" for the method used in Norway). Other opinions expressed were that it would be sufficient to provide the pilot with the value of the coefficient of friction to be expected on the runway and that the pilot could then assess the suitability of the runway conditions by reference to data in his aeroplane flight manual.

Simpler methods were used in some places either exclusively or in combination with more accurate measurements. These included passing the observations of a pilot who had recently landed on the runway to pilots who subsequently wished to land or, in cases where no aircraft had landed recently, for a pilot to inspect the runway and to estimate the braking efficiency. In any case, as was mentioned previously, it was generally agreed by the meeting that it was the responsibility of the man on the ground to provide the best information available and that the decision to use the runway and the subsequent results of such use, were the responsibility of the pilot.

Note: Subsequent to preparing the above material the following was noted in the "Technical Information DIGEST for Municipal and Airport Engineers and Officials" published by the Municipal and Airport Division of the American Road Builders' Association, World Centre Building, 918-16th Street, Northwest, Washington 6, DC, USA.

SNOW REMOVAL BY STEAM HEAT

"The American City" (470 Fourth Avenue, New York 16, New York), October 1954, Page 109.

Boston will soon benefit from a steam-heated roadway, the nation's largest snow-melting installation, when the city completes its Aerial Highway at a cost of $75,000,000 to $100,000,000. The snow melting-system in each ramp extends from the surface level to a point approximately halfway -- 300 to 400 feet -- up the ramp. This lower section is constructed on an earth fill, while the upper section connecting with the expressway is of open-steel viaduct construction.

An ethylene glycol solution is steam-heated and pumped through 1 inch pipe grids in the concrete roadway base. This base 9-1/2-inch thick has a wearing surface of 2-1/2-inch thick bituminous concrete.

SOLVING THE "SLIPPERY WHEN WET" ROAD PROBLEM

"Public Works" (310 East 45th Street, New York 17, New York), October 1954, Page 97.

Abrasive engineers have developed a "highway safety grain" which when applied to the highway surface, greatly enhances skid resistance. Tests indicate that stopping distance of cars travelling 30 miles per hour on wet asphalt can be reduced one third by the application of this material. The "grain" is a fused alumina abrasive of over 2,000 hardness compared with 850 hardness for quartz and flint, and 32 for limestone.

In practically all cases the "grain" is spread at the rate of 3/4 pound per square yard using a rotary type spreader, and in some cases the abrasive may be rolled into the existing pavement.

ATTACHMENT A

ARTICLE ON SNOW HANDLING ON CANADIAN AIRPORTS

by D.B. Rees, P. Eng.,

Airport Maintenance Engineer,

Air Services, Department of Transport,

Government of Canada,

Ottawa, Ontario.

SNOW HANDLING ON CANADIAN AIRPORTS

The early technique of winter maintenance of airports in Canada was concerned chiefly with creating a firm snow surface from which aircraft on skis could operate safely.

The development of heavier aircraft carrying bigger loads required year round operation on wheels. For this reason the problem of snow maintenance on Canadian airports has become more important. It is a very costly business and a complicated one because Canada is a large country and conditions of snow and weather vary from airport to airport across the country, a distance of 3,800 miles from coast to coast.

In some areas the snowfall is wet and heavy, whilst in others it is dry and light. The density of the snow differs considerably district by district and so do the periods of low winter temperatures. In some districts the cold remains steadily for five months, whilst in other districts frequent thaws occur which create icing conditions.

Almost all the work of snow maintenance has to be done with heavy automotive equipment. A large quantity of heavy equipment has always to be kept in readiness because runways have to be cleared quickly for aircraft coming in to land at any time.

The different methods of handling snow on airports may be classified under three headings, namely, clearing, compacting, and a combination of clearing and compacting.

SNOW CLEARING consists of removing the snow entirely from the runway surface. This is done by using several large, heavy type all-wheel drive trucks equipped with hydraulically controlled one-way snow plows mounted in front of the truck together with a side wing. The snow plows are made of heavy steel and are ten to fifteen feet long, depending upon the size of the truck. The side wings are also of steel and ten feet long. When in use the plows are set at an angle so that the snow slides off the end of the plow and forms a ridge along the length of the runway. The wings are used to push the ridge further away. (See illustrations 1, 2 and 3)

As soon as one or two inches of snow has fallen the trucks with snow plows are set to work and remain in operation until the storm is over. The trucks are driven at a speed of between twenty and twenty-five miles an hour plowing snow all the time. The operation is started by driving the plow-equipped truck along the center of the runway, plowing alternate furrows to left and right on each up and down trip until a fairly large ridge of snow is built up about twenty feet from each side of the runway.

In order to protect the runway lighting which is in place along the edge of the runway the snow near the lights is plowed from the runway edges towards the center for a width of fifteen feet or more to add to the ridge of snow built up by the plowing from the center of the runway.

When the plowing is all completed there will have been made two ridges of snow, one on each side of the runway fifteen feet in from the runway lighting. Snow blowers are then brought into operation.

A snow blower is a machine with a square open box-like front, eight feet by four feet by two feet deep, in which two or three steel horizontal augers are rotated so as to cut into a ridge of snow and feed it inwards to a heavy steel turbine. This turbine is about thirty inches in diameter and operates within a circular metal case with two chutes at the top. The turbine drives at right angles to the augers and at sufficient speed to throw the snow up one of the chutes and away from the machine a distance of seventy-five feet or more, depending upon the direction and force of the wind. The snow blower mechanism is driven by an auxiliary diesel or gasoline engine of 175 horse-power. This engine is mounted on the rear of an eight-ton all-wheel-drive truck powered by another 175-horse-power diesel or gasoline engine. The front of the snow blower rests on the ground supported by steel shoes or castors set to the proper height to allow the front bottom cutting edge to travel close to the pavement. The entire front mechanism is hydraulically controlled and can be lifted and lowered very quickly by tne driver in the cab. The chute can be turned in almost any desired direction to take advantage of the wind or it can be used to load trucks to haul the snow away. The snow blower is operated by steering the front of the blower into the ridge of snow with the augers shirling and feeding the snow into the turbine blades. The snow passes to the rotating turbine and is driven up and out through the chute and thrown well over the runway lights to be deposited and spread out onto the loose snow lying on the grass area in the center of the aerodrome and between the runways. (See illustrations 4, 5, 6 and 7).

When working, the snow blower travels from three to eight miles an hour.

If there is no convenient place to cast and deposit the snow, it must be loaded and hauled away. Loading and hauling has also to be done at runway intersections, parking areas and around buildings, and in these locations the snow blower is used to load the snow into trucks which haul it to a selected dumping area.

Difficulty is experienced in removing the last thin layer of snow off the runway surface and if a sudden thaw occurs, the snow may melt and a dangerous icing condition develop. Then in order to provide a good braking surface for aircraft wheels, sanding of the runways has to be resorted to. It is sometimes difficult keeping the sand on the runways because it is so easily blown away by winds or by the slipstream of aircraft propellers. The use of hot sand and also wet sand have been tried with varying degrees of success.

COMPACTION

Snow compaction, as the words suggest, is a means of packing the snow in place where it has fallen on runways and other areas. The compacted snow surface must be smooth and level.

As soon as the first two or three inches of snow has fallen, snow drags are used. They stir up the snow and get the air out of it so that it can be pressed together solidly without any voids. The snow drags also level the snow in the same operation. It is most important that the first snow be solidly cemented to the runway surface to form a compacted base on which to build subsequent layers of compacted snow. To achieve this, drags and rollers must be put to work immediately two inches or so of snow has fallen, regardless of the time of day or night, and rolling must be kept up continuously until a satisfactory surface is obtained. This is very important.

A snow drag is made of angle iron and has three cutting edges, each about eight inches deep and twenty feet long, supported on runners with a lever mechanism to control the raising and lowering of the cutting edges. (See illustrations 8 and 9) The snow drag is towed behind a crawler type tractor of 60 horse-power or more. The tractor is fitted with crawler type cleats only one inch deep. These short cleats are necessary to prevent the tracks digging into the snow too deeply and breaking off compacted sections of snow and making holes in the snow surface. The drag is towed at about three miles an hour and the snow spills over the first blade in such a manner to expel the air within the snow and cause it to compact more readily.

The tractor is usually powerful enough to tow a set of snow rollers behind the snow drag. A set of snow rollers consists of three snow rollers securted together, one in front and two in the rear overlapping each end of the front roller. Each roller is five feet in diameter and ten feet long. They are made of heavy gauge corrugated iron and held in place for towing by six inch diameter tubular steel members. The corrugations on the snow rollers make a slight impression on the snow and, under favourable conditions gives depth perception to the pilot when landing. (See illustrations 10 and 11)

Falling snow twelve inches deep can be compacted into a layer of solid snow only three inches deep. Layer after layer of snow is built up in this manner throughout the winter until by springtime there is a depth of two feet or more of solidly compacted snow on the runway.

Occasional thaws may make the surface icy. This surface condition can be remedied quickly by attaching scarifier teeth to the snow drag blades. These teeth are cut in a long steel plate and are about one and one-half inches deep. The cutting depth can be controlled in the same manner as the drag blades are controlled by lifting with spring loaded levers attached to the snow drag frame. The scarified or scrapped icy surface provides a good braking condition for aircraft wheels. The compacted snow surface may, if necessary, be sanded to provided a good braking action.

During the spring break-up the depth of compacted snow is slowly reduced by using the scarifiers to scrap the surface and allowing it to melt and evaporate during the heat of the day. However, there finally comes a period in the spring when the thaw is so rapid and the compacted snow so deep that aircraft cannot land with safety and the airport has to be closed for a while.

COMBINATION OF COMPACTION AND CLEARING

To avoid the necessity of closing to traffic in the springtime an airport on which the snow has been compacted, a system of combined snow compaction and snow removal is adopted. By this means the snow is kept to a constant compacted depth of say five inches, and any snow in excess of this is gathered in ridges or windrows by snow plows and blown away by snow blowers.

In the springtime the compacted five inches or so of snow is broken up by using a power driven grader equipped with large, strong scarifier teeth which can rip up the hard snow and ice close to the pavement surface. The snow plows then gather this into ridges and the snow blowers, with their powerful augers, grind into it, feed it into the impeller and blow it away. By this means there is no stoppage of flying operations in the springtime.

Complete snow clearing must be practised on international and terminal airports where heavy aircraft land on regular scheduled flights, and snow must be removed from all runways, taxiways and parking areas quickly.

On other airports from which feeder lines operate and where lighter aircraft are used, the snow may be compacted on the runways.

The quantity of equipment required varies with the size and importance of the airport.

For example, at Montreal Airport, which is an international airport, the runways, taxiways, and aircraft parking areas, represent a total pavement area of about 700,000 square yards and all of this area has to be completely cleared of snow constantly. This is sometimes a colossal task because in a single snowstorm five inches of snow may fall in six hours and this is 100,000 tons of snow, all of which must be removed off the pavement as it falls and within six hours. The snow has to be picked up, loaded and hauled away from the large ramp areas, parking areas and from runway intersections.

The set procedure at Montreal Airport is as follows:

1) A layout plan of the installations indicating routes and priorities of snow removal and ice treatment on runways, taxiways, aprons, parking areas, roadways and walks is prepared first.

2) Effective co-ordination between the plowing operation and the Control Tower is arranged for a minimum interruption of service. The snow plows and snow blowers are equipped with two-way radios having continuous contact with the Control Tower. All equipment has powerful spotlights and dome flasher lights.

3) All snow and ice are to be removed to the extent practicable without damage to pavement surfaces.

4) Residual snowbanks are maintained in such a state as to constitute no possible hazard to air or vehicular traffic during normal operations. Particular care is taken to avoid banks of snow at the sides or ends of runways.

5) Runway contact lights and other on-pavement or illuminated traffic guides are kept uncovered and exposed to view at all times.

6) The use of sand, cinders, or other abrasives is limited to emergency conditions only, and abrasives are swept from pavement surfaces immediately after a thaw.

7) First priority is given the duty runway and, if conditions warrant, all access taxiways thereto. The duty runway is kept open at all times during the storm. Simultaneously, a second crew clears the areas in front of all hangars in the entire perimeter of the loading apron or ramp.

Runways are considered satisfactory for emergency landing when snow has been cleared to a width of 150 feet and when the bordering snowbanks within 100 feet of the cleared area do not exceed 36 inches in height, with a gradual slope from the edges adjoining the cleared runway.

The ultimate objective is a cleared runway with a 175-foot safety band each side of center line and with the bordering banks sloped as described above and compacted. When clearing the remaining runways, care is taken to see that a windrow is not formed across any previously cleared runway. Special intersection clearance techniques are developed to avoid danger to taxiing aircraft.

8) All important roads are kept open for two-way traffic during all snowstorms. If ice conditions exist, sanding is done according to the priority for use of the area. No parking is allowed on roads during snow plowing operations.

After plowing, widening, and scraping of the highways is completed all waterways, such as catch basins, inlets, flumes, and culverts, are opened to permit rapid discharge of water from melting snow and rain. Culverts or underground drains in which ice or snow has obstructed free flow of water are cleared by the use of steam heat whenever steam jetting equipment is available or by hand.

The duty runway is cleared first and kept cleared to receive incoming aircraft. In the meantime other equipment is being used to clear the taxi-way and parking areas by loading the snow and hauling it away. Other pavement areas are cleared in the order of their importance. The adjoining snow covered area and infield areas are then dragged and rolled to prevent the snow from drifting from these areas by the force of the wind. If the snow on these adjoining areas or the areas of blown snow are allowed to drift, it will quickly fill the valleys created by the cleared runways and a second clearing job will have become necessary.

All these urgent requirements make it necessary to hold in readiness for winter maintenance on each international and terminal airport the following minimum equipment:

2 Snow blowers each mounted on an eight ton all-wheel-drive truck	$ 70,000.00
2 All-wheel-drive five ton trucks c/w one-way plows and right wings	30,000.00
2 Two ton dump trucks with snow boxes	8,000.00
1 Power driven blade grader c/w scarifier and snow plow	15,000.00
1 Wheeled tractor, 18 horse-power, complete with rotary broom and one-way sidewalk snow plow	2,500.00
2 Sand spreader dump truck attachments	1,500.00
1 One-half ton pick-up truck	1,800.00
2 Crawler type tractors, 50 horse-power, c/w angledozers	25,000.00
1 Snow drag	1,000.00
2 Sets snow rollers	2,400.00
	$157,200.00

OPERATING TIME

In snow plowing operations, trucks are driven from twenty to twenty-five miles an hour and, at each trip, they clean a swath eight feet wide. In one and a half hours one truck, equipped with a snow plow and wing, can gather the snow on a runway 150 feet wide by 6,000 feet long into windrows, if the snowfall is light. The snow so gathered can be blown clear of the runways by a snow blower in about one hour. In actual practice the work is done far more quickly by employing several trucks and more snow blowers on one runway.

A crawler tractor towing a snow drag and a set of snow rollers is operated at three miles an hour. Therefore, a runway one hundred and fifty feet wide by six thousand feet long could be dragged and rolled once in two to three hours with one tractor towing drags and rollers. Four or more combined dragging and rolling operations are necessary to achieve proper initial snow compaction, so that the first complete compaction will take about ten hours.

OPERATING COSTS

Costs vary at each airport in proportion to the volume and type of snow and the winter conditions experienced.

In Eastern Canada, the snow is wet and heavy and the average annual snowfall is about one hundred inches; therefore, costs are high. In Western Canada, the snow is dry and light in weight and snowfall is only about fifty inches each year and the cost of snow handling is less.

A staff of thirty equipment operators and mechanics are required for proper winter maintenance of an airport in Eastern Canada, whilst in Western Canada a similar airport could be maintained with fifteen men.

An allowance for depreciation of equipment should be added to this cost. Depreciation will be high because most of the equipment can only be used for snow removal, therefore, the yearly depreciation must be charged against the few months of winter operation.

The Department of Transport, at present, operates and maintains most of the airports in Canada. These include nearly all the large airports on the trans-Canada route and also those on the feeder routes to the north and the south.

The Department operates and maintains over a hundred airports of major importance and size across the length and breadth of Canada and in so doing uses the following list of heavy equipment to do the job:

Snow blowers, rotary type	88
Trucks, 5 ton, c/w snow plows	109
Trucks, 3 ton, dump	77
Trucks, 1/2 ton, pick-up	307
Station wagons and passenger cars	127
Graders, large, self-propelled	37
Tractors, crawler type, c/w bulldozers	186
Tractors, rubber-tired	132
Snow roller sets	135
Snow drags and scarifiers	125
Rotary sweepers	27

DEPARTMENT OF TRANSPORT - AIR SERVICES

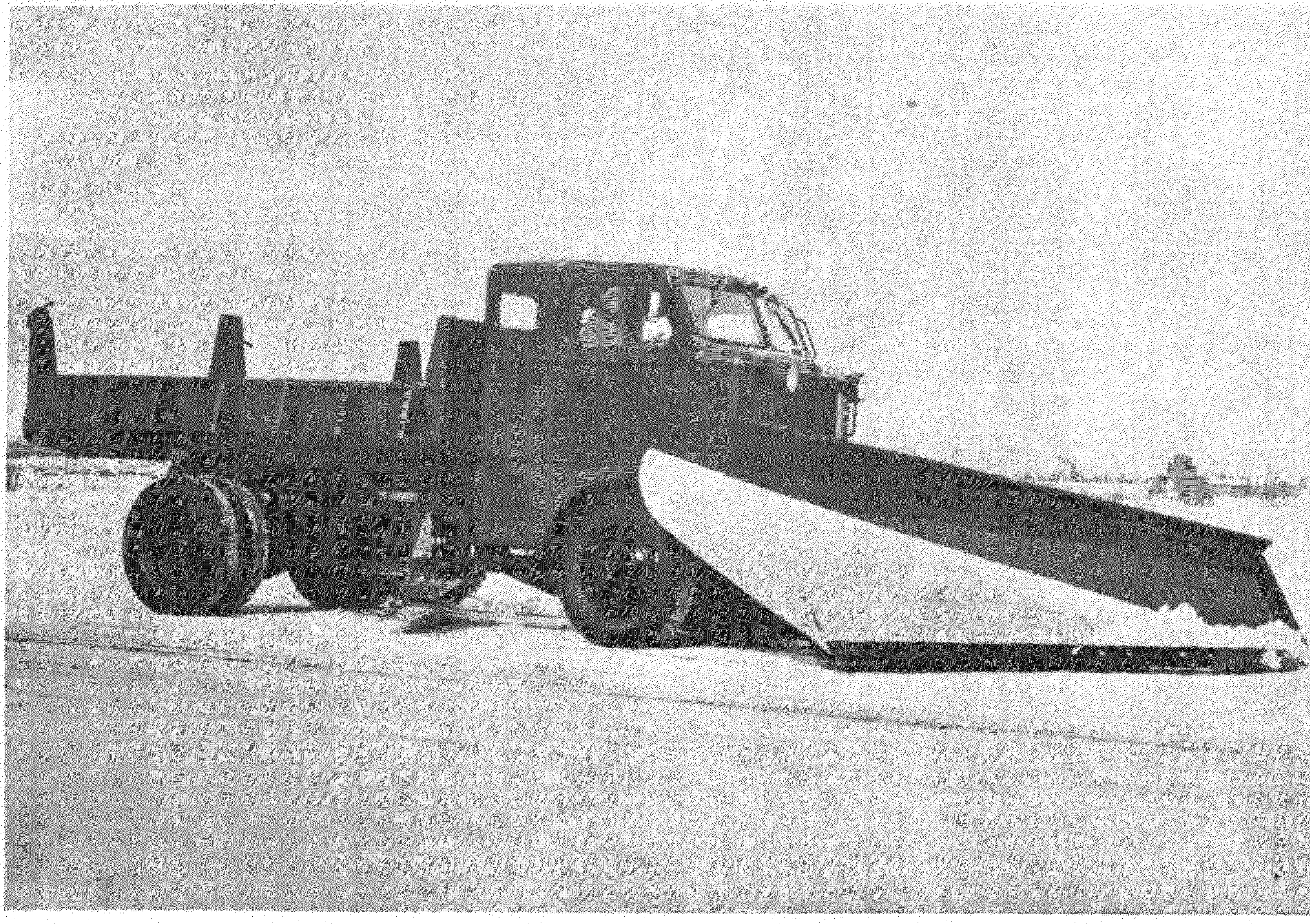
Annual Average

SNOW HANDLING OPERATIONS

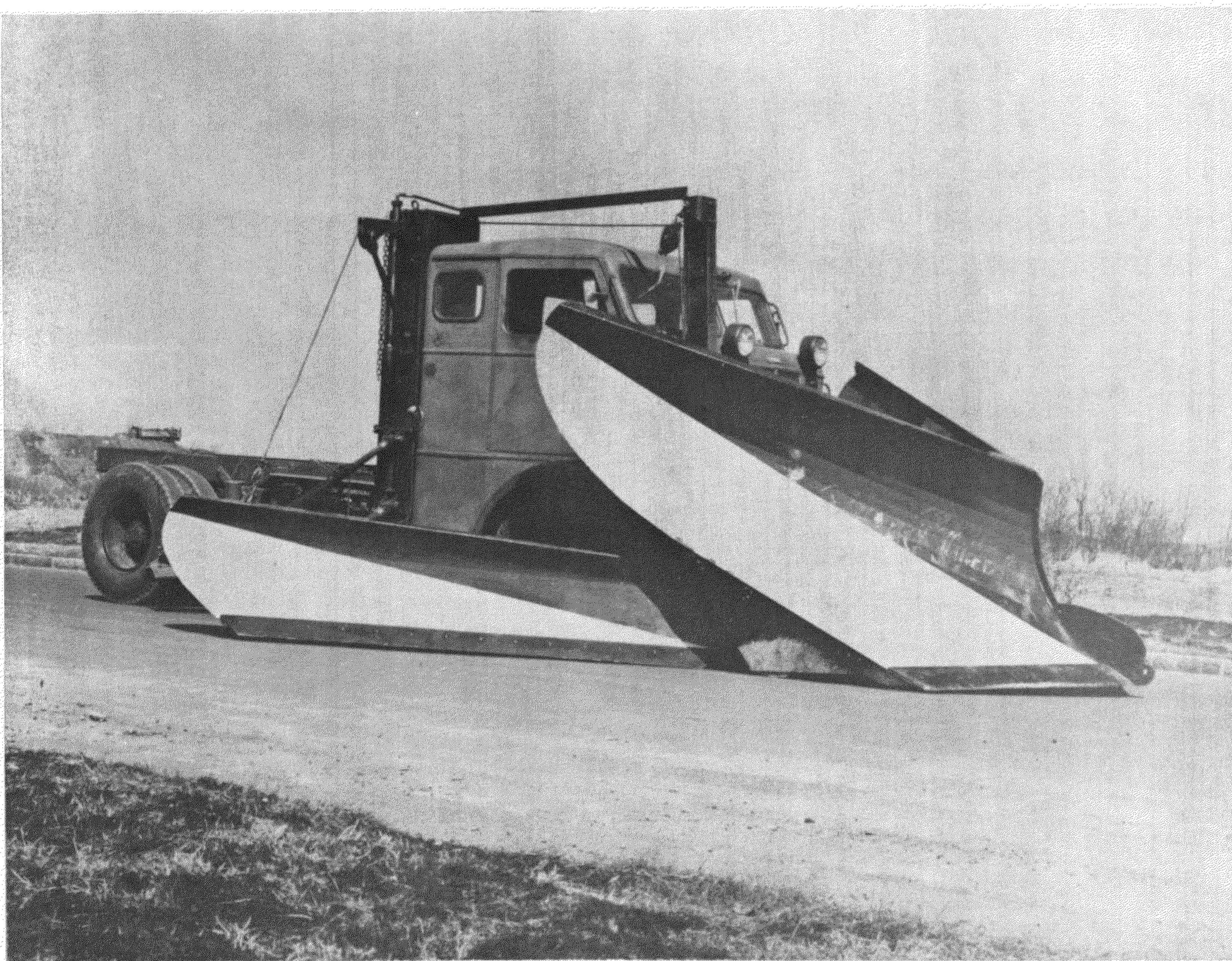
Airport	Blowing	Plowing	Rolling	Dragging & Scarifying	Hauling	Sanding	Cost: Repairs - Labour & Material	Cost: Fuels, Oils & Greases	Cost: Labour - Snow Handling	Snowfall	Snow Handling Operations	Rainfall	Area Cleared	Area Compacted	Total Cost	Equipment Used	Remarks
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	$	$	$	Ins.	Mos.	Ins.	Sq.Yds.	Sq.Yds.	$		
Newfoundland -Gander	1783	3654	-	534	-	138	37,694	6,665	16,970	90	7	15	956,754	-	61,329	10 Sicard Snow Blowers 2 Walter Snow Fighters 5 FWD Trucks with Plows 7 Dump Trucks 6 Crawler Tractors 2 Power Graders 1 Sand Loader	
Prince Edward Island -Charlottetown	258	273	43	-	-	2	370	670	562	58	5	10	203,953	-	1,602	2 Sicard Snow Blowers 1 Crawler Tractor 2 FWD Trucks 1 Dump Truck 1 Power Grader	
Nova Scotia -Sydney	107	205	76	40	-	16	909	603	1,234	40	4	15	478,184	-	2,746	3 Sicard Snow Blowers 2 Walter Snow Fighters 2 Crawler Tractors 1 Power Grader 1 FWD Truck	Airport unserviceable 1 hour due to snow
-Yarmouth	57	194	-	49	8	46	238	153	412	33	4	16	452,746	-	803	1 Snow Blower 3 FWD Trucks with Plows 1 Dump Truck 1 Crawler Tractor 1 Farmall Tractor & Plow	
New Brunswick -Moncton	528	463	267	296	19	48	1,893	1,768	4,163	84	7	23	326,762	470,561	7,824	3 Sicard Snow Blowers 2 Crawler Tractors 1 Walter Snow Fighter 1 Power Grader 1 FWD Truck & Plow 3 Dump Trucks	Airport unserviceable 7 hours due to heavy snow
Quebec -Mont Joli	485	1435	535	321	-	26	1,036	2,476	3,646	136	5	9	422,000	350,639	7,158	3 Sicard Snow Blowers 1 Walter Snow Fighter 1 FWD Truck & Plow 2 Dump Trucks 5 Crawler Tractors	
-Montreal	1003	1637	159	131	808	163	8,322	2,328	10,707	71	6	11	766,899	-	21,357	4 Sicard Snow Blowers 3 FWD Trucks & Plows 2 Graders 6 Dump Trucks 3 Crawler Tractors 2 Dump Trucks - Sanding 1 Tractor with Blower	Airport serviceable at all times
-Quebec	352	811	214	340	13	6	461	1,510	2,282	96	7	16	327,600	385,000	4,253	2 Sicard Snow Blowers 1 Walter Snow Fighter 2 FWD Trucks 4 Crawler Tractors 1 Dump Truck 2 sets Snow Rollers & Drags	Airport serviceable at all times

Airport	Blowing	Plowing	Rolling	Dragging & Scarifying	Hauling	Sanding	Cost: Repairs - Labour & Material	Cost: Fuels, Oils & Greases	Cost: Labour - Snow Handling	Snowfall	Snow Handling Operations	Rainfall	Area Cleared	Area Compacted	Total Cost	Equipment Used	Remarks
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	$	$	$	Ins.	Mos.	Ins.	Sq.Yds.	Sq.Yds.	$		
Ontario																	
-Fort William	499	242	237	180	-	2	129	1,155	1,233	123	6	2	347,300	237,000	2,517	2 Snow Blowers 1 FWD Truck & Plow 2 Crawler Tractors	Runways serviceable all season
-Gore Bay	217	536	128	21	-	4	1,763	842	1,293	100	5	5	207,770	238,000	3,898	1 Sicard Snow Blower 1 Power Grader 1 Walter Truck, 5 ton 1 Dump Truck 1 Crawler Tractor	Runways serviceable at all times
-Kapuskasing	181	289	541	541	-	4	1,440	957	2,132	145	6	4	151,419	238,369	4,529	1 Sicard Snow Blower 1 FWD Truck, 5 ton 2 Crawler Tractors	
-Killaloe	-	20	413	236	-	-	106	234	424	84	6	7	45,000	400,000	764	2 Crawler Tractors with Rollers & Drag 1 Leaning Wheel Grader	Airport unserviceable 5 days
-London	396	712	28	-	-	54	393	746	1,122	112	5	11	270,000	510,000	2,261	1 Sicard Snow Blower 1 Power Grader 2 Dump Trucks 1 Crawler Tractor	Runways serviceable at all times
-Toronto	192	469	-	-	20	161	1,476	560	1,530	44	5	8	567,113	-	3,566	3 Sicard Snow Blowers 3 FWD Trucks 5 Dump Trucks 1 Power Grader	Runways serviceable at all times
-Nakina	-	55	260	-	-	-	35	444	284	106	5	1	47,520	353,332	763	2 Crawler Tractors & Rollers 2 Dump Trucks	1 day unserviceable due to 5" wet snowfall
-North Bay	1157	1186	296	206	127	324	584	1,730	3,833	120	8	8	393,911	456,888	6,155	3 Sicard Snow Blowers 3 All-Wheel Drive Trucks 1 Crawler Tractor 1 Power Grader	3 days unserviceable due to snow
-Ottawa	775	1079	182	129	108	188	2,658	1,797	4,415	92	5	8	437,950	575,565	8,870	4 Sicard Snow Blowers 4 All-Wheel Drive Trucks 1 Power Grader 2 Crawler Tractors	Runways serviceable at all times
-Windsor	63	281	-	-	-	94	319	148	922	52	5	11	333,000	-	1,389	1 Snow Blower 1 Power Grader 2 Dump Trucks 1 Crawler Tractor	
Manitoba																	
-The Pas	-	120	572	544	28	-	385	477	1,119	49	7	2	186,760	414,700	1,981	1 Snogo Snow Blower 1 All-Wheel Drive Truck 2 Crawler Tractors	Runways unserviceable 5 days during spring break-up
-Winnipeg	106	289	230	146	-	4	115	850	764	43	7	3	479,500	540,000	1,729	3 Sicard Snow Blowers 2 FWD Trucks 3 Crawler Tractors	Serviceable all season
Saskatchewan																	
-Dafoe	-	96	406	406	-	-	211	324	502	35	6	-	3,733	494,500	1,037	2 Crawler Tractors, Bullgrader & Snow Rollers	Runways unserviceable 3 weeks due to spring break-up
-Regina	271	309	493	-	-	-	258	797	1,073	54	6	-	262,130	484,169	2,128	1 Snogo Snow Blower 1 Sicard Snow Blower 1 FWD Truck 1 Crawler Tractor	

Airport	Blowing	Plowing	Rolling	Dragging & Scarifying	Hauling	Sanding	Cost: Repairs - Labour & Material	Cost: Fuels, Oils & Greases	Cost: Labour -- Snow Handling	Snowfall	Snow Handling Operations	Rainfall	Area Cleared	Area Compacted	Total Cost	Equipment Used	Remarks
	hrs.	hrs.	hrs.	hrs.	hrs.	hrs.	$	$	$	Ins.	Mos.	Ins.	Sq.Yds.	Sq.Yds.	$		
Saskatchewan -Saskatoon	291	293	344	469	-	-	1,648	1,445	1,072	63	8	2	376,588	911,591	4,165	1 Snogo Snow Blower 1 Sicard Snow Blower 3 Crawler Tractors 2 FWD Trucks	Runways unserviceable 6 hours due to heavy snow
Alberta -Cowley	-	50	178	-	-	-	50	136	228	109	8	2	73,920	833,333	414	1 Crawler Tractor with angledozer Rollers Drags	Airport closed 2 days due to drifting snow and 1 week during spring break-up
-Fort McMurray	-	361	291	291	-	-	283	368	652	82	8	4	239,769	281,667	1,303	2 Crawler Tractors with Rollers & Drags 1 Power Grader	Serviceable all season
-Grande Prairie	325	527	24	7	-	6	240	1,032	902	73	7	1	398,994	95,555	2,174	2 Snow Blowers 2 Crawler Tractors 1 Power Grader 2 Dump Trucks	Runways unserviceable 1 day due to severe blizzard
-Lethbridge	147	406	6	28	-	-	1,406	693	587	73	8	3	326,146	-	2,686	1 Snow Blower 2 Crawler Tractors 2 Dump Trucks 1 Power Grader	Runways serviceable all season
British Columbia -Fort St. John	321	608	304	53	-	-	2,091	2,026	1,604	87	8	1	373,300	189,000	5,721	2 Sicard Snow Blowers 2 Crawler Tractors 2 Trucks with Plows 1 Power Grader	
-Patricia Bay	-	95	32	-	-	3	101	28	223	22	3	17	111,000	-	352	1 Power Grader 1 Crawler Tractor 2 Dump Trucks	
-Port Hardy	-	100	-	12	-	-	12	38	459	2	3	13	369,915	-	509	1 Power Grader 1 Crawler Tractor 1 Dump Truck	Runways serviceable all season
-Prince George	176	627	294	-	163	24	924	1,153	2,079	93	7	4	241,800	106,600	4,156	1 Sicard Snow Blower 1 Walter Snow Fighter 3 Dump Trucks 1 Crawler Tractor	Runways serviceable all season
-Quesnel	40	140	5	-	-	-	331	541	194	67	5	3	13,830	-	1,066	1 Sicard Snow Blower 1 Walter Snow Fighter 1 Crawler Tractor	
-Sandspit	-	9	-	-	-	-	-	-	-	54	5	29	85,850	-	63	(9 hrs. plowing at $7.00 per	hr. by contract)
-Terrace	-	251	-	-	-	-	589	179	420	143	5	-	63,359	-	1,188	1 All-Wheel Drive Truck with Plow 1 Crawler Tractor	Runways serviceable for ski aircraft only
Northwest Territories -Yellowknife	-	523	920	920	65	-	3,255	1,377	1,819	23	8	1	97,742	404,777	6,451	3 Crawler Tractors 2 Snow Rollers & Drags 1 Power Grader	1 runway unserviceable 3 days for snow removal



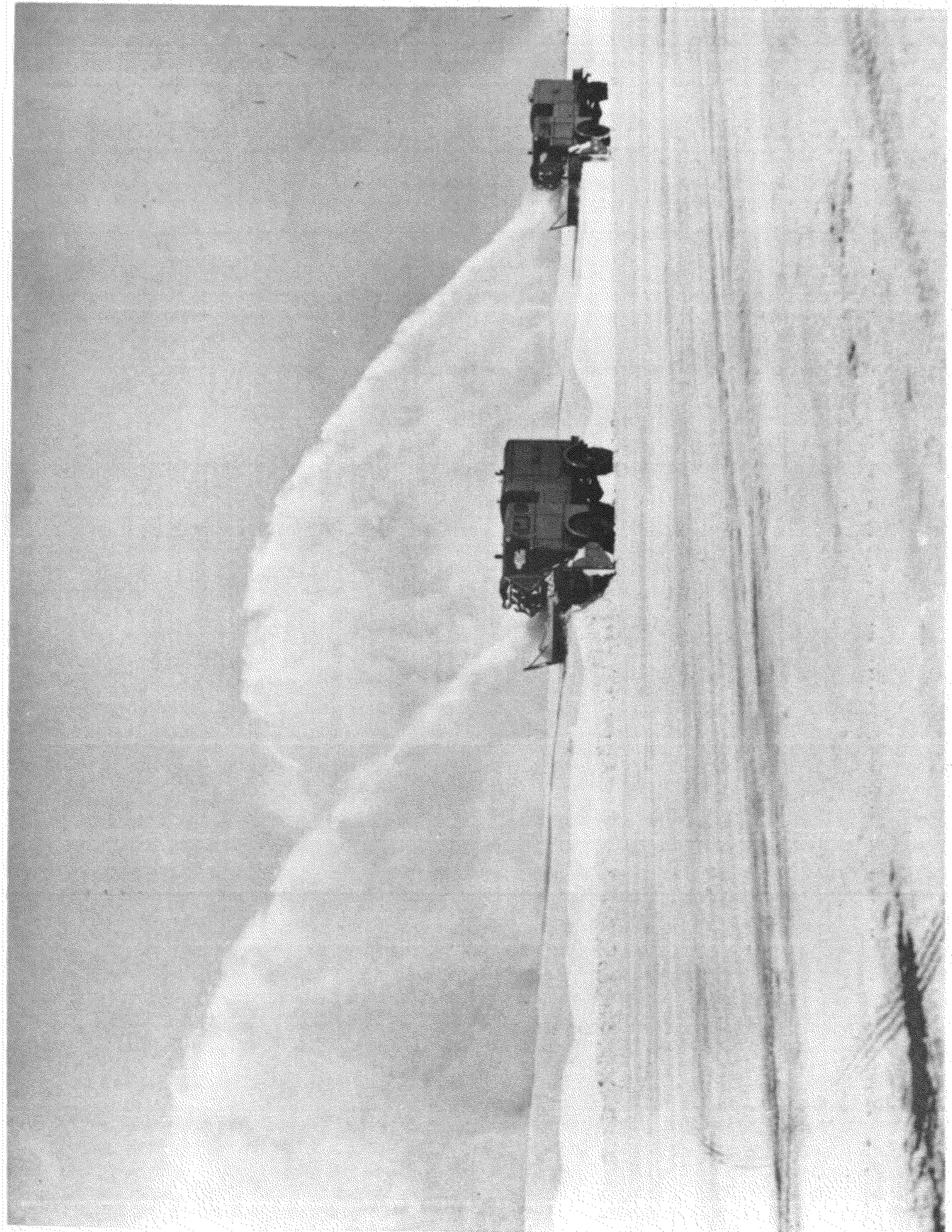
1. One-way snow plow and underbody blade mounted on all wheel drive 5 ton truck



2. Vee plow and side wing mounted on all wheel drive 5-ton truck

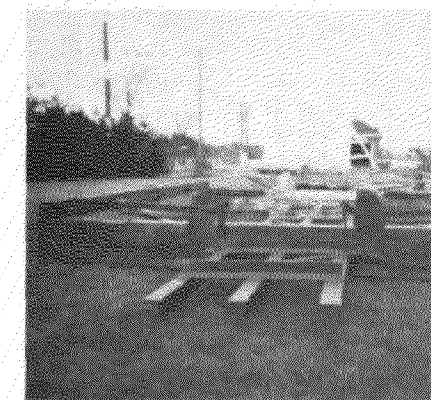

RANSPORT
MINISTERE
DES
TRANSPORTS

4. Rotary type snow blower showing feed augers and impeller behind the augers

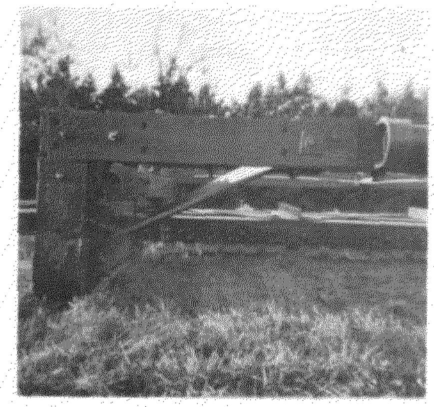


6. Snow blower clearing a heavy snow bank

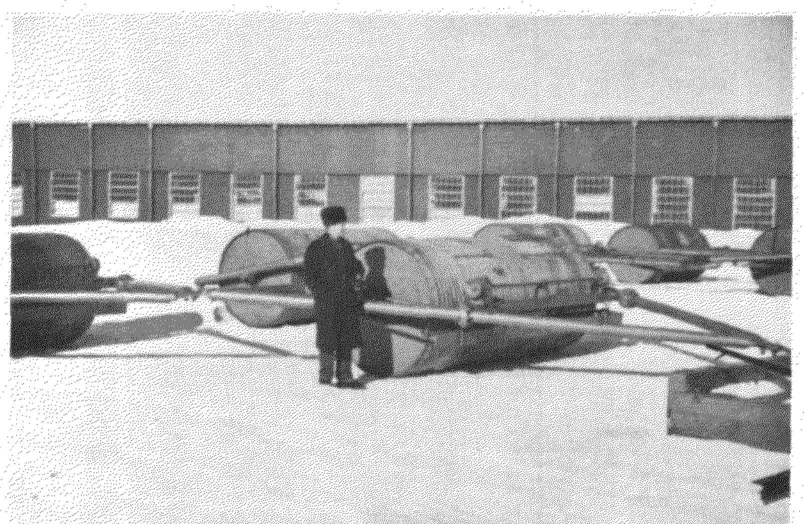
7. Snow blower clearing light windrow of snow over runway lights which are marked by green spruce trees.



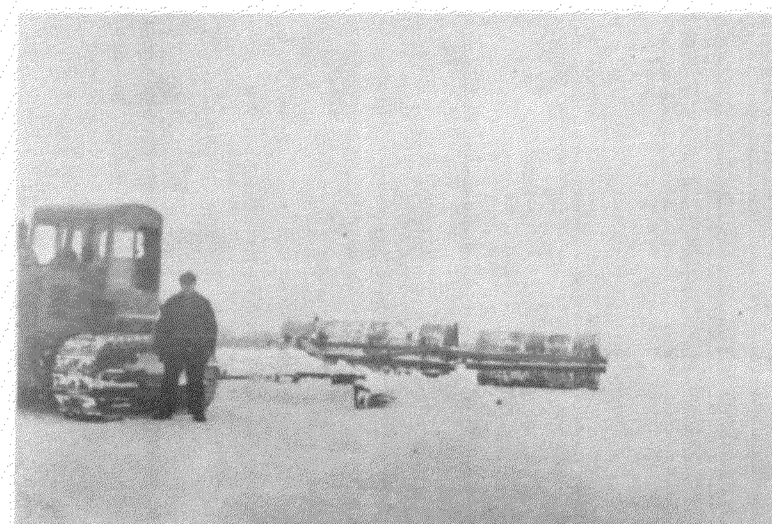
8. Snow drag



9. Snow drag



10. Snow rollers



11. Tractor towing drag and snow rollers

ATTACHMENT B

REPORT ON THE PROCEDURE FOR CORRECTION OF MINIMUM RUNWAY LENGTH UNDER WINTER CONDITIONS AT OSLO AIRPORT, FORNEBU

by O. Kollerud,

Airport Manager,

Oslo, March 1954

Report on the procedure for correction of Minimum Runway Length under Winter conditions at Oslo Airport, Fornebu

Because of the varying braking possibilities which occur on runways covered by snow and ice, it is desirable to find a procedure by which to prepare runways under different conditions and a safe method for measuring the braking action.

The estimated braking possibilities at most of the airports are given as good, medium and poor. This is perhaps satisfactory on airfields having runway lengths far above those stipulated for the types of aircraft using the airport, but for airfields which have not this excessive runway length, the condition should be such that the braking action would be sufficient for the required retardation (60% of R) and that braking possibilities may be safely determined.

Friction coefficient on clear runways is so large that it cannot be utilized by aircraft. Measured by means of a lorry having a speed of 25 mph the coefficient was between 0,7 - 0,9. On snow and ice covered runways the coefficient was measured in the same way - friction coefficient from about 0,13 - 0,33.

Analyzing the factors affecting the braking of an aircraft (not using the engines for reversing) either on landing or take-off, these will be found to vary with speed. Friction coefficient will be reduced at greater speeds, vertical load will increase with decreasing speeds inasmuch as the lift on the wings will be reduced with the square of the speed and the drag is reduced with the square of the speed.

Braking is thus a result of several varying factors. It is therefore considered that the simplest way of finding a method for establishing the requirements for braking possibilities is by means of experiment and measurement. For the time being the use of reversing of the propellers for braking will not be taken into account. This, however, will be referred to later.

Measuring methods and units

Before one could start experimenting and measuring one had to have a method of measuring which safely gave the necessary figures for judging the braking possibilities. After different experiments one found that the use of an accelerometer for measuring the retardation gave the best results.

The advantage of this method is that the retardation is measured as a result of various factors previously mentioned which affects the braking. The accelerometer also draws up retardations graphically and one obtains a basis by which the measurements can be fitted into theory.

As the purpose of these tests is to take measurements in practice which would give the braking possibilities on the runway, one chose to use the retardation of a lorry being braked at a speed of 25 mph (40 km/h) as a measure for braking action. It is difficult to use an aircraft for such tests.

As the unit for retardation is $m/sec.^2$ it would be natural to use this as a unit for measuring.

Measurements

The problem now arose as to what braking possibilities an aircraft has on landing or at discontinued take-off at varying speeds with a certain measured retardation in relation to a lorry which is braked at a speed of 25 mph (40 km/h).

This was on the assumption that the braking of the aircraft should take place without the wheels skidding and one then assumed that the braking of the lorry should take place in the same way. It was, however, impossible to get any uniformity in braking the lorry in such a way that the wheels were not skidding, inasmuch as it was also dependent upon how the brakes were used and not friction only. One therefore started to measure the retardation when the braking of the car was made with locked wheels.

The measurement should therefore decide the retardation possibilities of the aircraft without skidding in relation to a lorry with a measured retardation with locked wheels from a speed of 25 mph (40 km/h).

For these tests a DC-4, a Chevrolet station wagon and a GMC lorry with 10 wheels were used. By placing the accelerometer alternatively in the aircraft and in the lorry one obtained a graphic picture of the retardations.

Three landings were carried out. Conditions were 2 - 3 cm hardened snow with about 1 cm loose snow on top (no sand) temperature minus 1,8°C (very good braking conditions). The following retardation were obtained with a touch-down speed of 75 kt: 1,23 - 1,32 - 1,41 $m/sec.^2$. The difference between these figures is a result of using the brakes differently, inasmuch as there was no skidding during braking. By means of a lorry with locked wheels from a speed of 25 mph the retardation was measured at 3,26 $m/sec.^2$ (average 8 tests).

This measurement only showed us that the braking effect (retardation) at 3,26 measured with the lorry was satisfactory, but the possibilities of more pronounced braking of the aircraft without skidding in these conditions were present.

New tests were therefore carried out under very poor runway conditions. Ice with wet snow on top, temperature plus 3,0°C (not sanded). An experiment with the wheels of the aircraft locked during a landing was considered. However, as the runway was extremely slippery and there were piles of snow along the sides, one did not dare to risk such a test. Four taxi tests were therefore made with locked wheels at speeds from 45 - 65 kt. The retardation measured varied from 0,65 to 0,78 m/sec.^{2}. There was a varying wind during the test and one assumes that this was the reason for such great variations. The retardation of the lorry measured 1,54 m/sec.^{2} (average 7 tests).

These tests showed that by comparing the braking of the lorry and aircraft with the wheels skidding, the retardation of the aircraft was below half of the lorry. One knows that when the wheels are skidding during braking, the braking effect is below that which you might get under the same conditions when the wheels are rolling. Tests are therefore continued on the assumption that the retardation of the aircraft is half that of the lorry.

The measurement of the braking of the aircraft showed that the retardation was so to stay constant for the whole braking distance. This gives a theoretical possibility to calculate approximately the stopping distance for aircraft at varying speeds and retardation possibilities.

As previously pointed out the friction coefficient decreases with higher speeds. Its effect on the retardation is small during the first seconds after braking has started. Furthermore, the speeds which are of interest are within a limited area. This variation of the friction coefficient has such a small influence on the retardation that it has no practical importance for the theoretical calculations.

According to the above-mentioned adjustments, figure 1 shows the calculated retardations and stopping distances.

Necessary braking possibilities for different types of aircraft

A minimum runway length for take-off and landing for the different aircraft is found in the Flight Manual and from this one can calculate an average retardation for take-off and landing. For the DC-6 and DC-6B the retardations will be about 1,7 and 1,45 respectively. This equals a retardation measured by means of a lorry in accordance with previous-mentioned procedure of 3,4 and 2,9 to be able to stop within the required minimum runway length given in the Flight Manual.

These retardations should therefore be the maximum for normal landings and the above-mentioned retardation possibilities must be present when the runway length equals the minimum runway length with regard to aircraft type and weight.

To reach a braking effect on snow and ice covered runways at 3,4 is very difficult. Under such runway conditions one must calculate with a lower retardation and one must therefore add such a distance to the runway lengths given in the Flight Manual that the aircraft gets a retardation which equals the braking effect. With regard to landing the new stopping distance should be calculated at 60% of the runway length to satisfy the requirements.

It has been found possible, under all runway conditions, to prepare the runway in such a manner that one can count on a braking effect of 2,7. Theoretically, on this basis one can approximately determine the aircraft types and weights with which to operate the airport without hindrance from weather conditions.

In the figures 2, 3 and 4, based on the Flight Manual and the theoretical adjustments shown on the diagram in figure 1, diagrams have been drawn which show the DC-6 and DC-6B with discontinued take-off and landing lengths with different braking effects. As shown in these diagrams, extensive runway lengths are required, especially for landing. They can perhaps appear a little exaggerated, but one is of the opinion that it is best to be on the safe side. Especially for short runways one must be aware of the fact that on final approach and touch-down the aircraft uses a speed which lies above the calculated minimum speed in the diagrams in the Flight Manual. An excessive speed of 10 kt on the touch-down speed shown in the Flight Manual calls for an additional landing runway length of about 300 m at these low braking effects. Taking this into consideration the results arrived at, may not be so unreasonable. The fact that larger aircraft use full reversing as a principal means for braking, is the reason why one generally does not see the necessity for this requirement. But according to valid regulations regarding the calculation of necessary runway lengths, full reversing must not be reckoned with. If the regulations are to be based on snow and ice covered runways, one must either be permitted to calculate with more reversing or the braking effect must be increased so that the retardation possibilities equal the runway length (shown in figures 2, 3 and 4) or a combination of both.

It is considered that under no circumstances must the braking effect be much under 2,0. A braking effect of 1,5 is so poor that an aircraft cannot be controlled by the nose-wheel or brakes during take-off or landing even at low speeds. Even a braking effect of 2,5 is insufficient for the warming up of an aircraft at high RPMs. Below this value the aircraft will immediately start skidding.

The valid calculating method has also been chosen for retardation which is below that upon which the minimum runway length in the Flight Manual is based. The runway is therefore prepared so that the braking effect on a 1 800 m runway satisfies these requirements. For a DC-6 and DC-6B a braking effect of 2,7 for landing and 2,4 for take-off has been stipulated. Take-off and landing for a DC-4 is now put at 2,2. For a runway of 1 250 m it was previously 2,7 with reduced weights.

Experience regarding measurements

Since January 1950 one has worked along these lines and in close contact with the pilots. During the first months most of the landings were controlled and they showed that they were consistent with the assumptions which had been made. The pilots who continually use the airport have become familiar with this procedure and have confidence in it.

As previously mentioned, an accelerometer was used for the actual measuring of retardations. However, this appeared to be difficult in practice as the instrument is very delicate and intricate and only special people could operate it. A GMC 10-wheeled lorry was therefore also used during the tests. By measuring the braking distance a value for the retardation was also obtained and these values coincided with the accelerometer. The time used for braking was taken by a stopwatch and in those instances when it was difficult to measure the braking distance accurately, the calculations were based on the time.

An empty GMC 10-wheeled lorry (good tyres) is therefore used for measuring the braking effect and there are always people on the airfield who are able to do these tests. By measuring both braking distance as well as taking the time, a double check is obtained, thus obviating the possibility of inaccuracy. During the last five winters the braking effect has been measured in this way and the result has been quite satisfactory.

One has come to the conclusion that the tests should be made at the following points on the runway: 300 - 600 - 800 - 1 000 - 1 200 - 1 400 - 1 600 - 1 700 m in the direction of take-off and landing and at each of the above distance along the center-line and at 15 metres on either side. It takes about 1 hour to carry out such a test, and it is often difficult to use the runway for such a long period in view of incoming and outgoing aircraft, but it is not often that the entire test must be carried out. One finds it unnecessary to carry out the whole braking test if by making a check at a few places along the runway, the braking effect is found to be above the value which is laid down for the actual condition. If there is any doubt the entire test should be carried out.

Experience with regard to runway conditions and braking effect

On snow and ice covered runways the braking effect varies from about 1,5 - 3,5. It is very difficult to state exactly how and why the runway conditions vary. If, however, the braking effect is good, it will not be worse if the temperature decreases, but if the temperature rises to zero degrees C or more, the braking effect will decrease rapidly. The braking effect is very much dependent upon the temperature and especially when it is around zero degrees C. Some of the various conditions influencing the braking effect are given below:

Braking effect 1,5 - 2,0

a) Slush or rain on snow or ice covered runway.

b) Change from frost to temperatures above zero.

c) Change from mild to frost (not always).

d) The type of ice which is formed after long periods of cold.

e) A thin layer of ice formed by frozen ground having been exposed to humidity or rain at zero degrees C or above.

Braking effect 2,0 - 2,5

f) Snow conditions at temperatures just under zero.

g) Snow covered runways at temperatures under zero, exposed to sun.

Braking effect 2,5 - 3,5

h) Snow covered runways which have not been exposed to higher temperatures than about minus 2 - 4°C.

This classification is only meant as a guide based on our own experience and it must not be used for establishing the requirements for the braking effect. There are so many variations in runway conditions that each condition must be measured to be able to judge the braking possibilities. This classification has been included to give those who work with the problem an impression of what the figures which we give as braking effect represent with regard to the runway conditions.

Preparation of the runway in order to obtain the necessary braking effect

In this report the question of how runways are cleared of snow has not been included, as this is no longer a technical problem but rather an economical one. One has come to the conclusion, however, that the runway should not be cleared right down to the permanent surface for the following reasons: in the first case the runway will be much more slippery because the humidity forms ice on the cooled down surface at temperatures above zero (see braking effect 1,5 - 2,0) and secondly, the runway surface may be damaged by snow clearing machines.

The runway is covered by 2" - 3" layer of ice and snow throughout the winter. This does not create any difficulty when it begins to melt in the Spring.

As previously mentioned, the braking effect should be at least 2,2 for the DC-4 and 2,7 for the DC-6 and DC-6B. Extensive work is often involved in preparing the runway so that a braking effect of 2,7 is obtained. In the past years a great deal of experience has been gained at this airport which has shown how this work should be done under different runway conditions.

Sand is used for the preparation of the runway. Damp sand with such a temperature that freezing is prevented during the sanding process is preferred, because it adheres well to the ice. Dry, warm sand did not show very good results.

The same classification is used with regard to the preparation of the runway as was used for the braking effect.

a) Slush or rain on snow and ice covered runways

This condition is the most difficult. The runway is scraped with a motor grader until the firm surface is reached. This motor grader makes stripes in the snow and ice. Then the surface is sanded until the desired braking effect is reached. It sometimes happens that a braking effect of not more than 2,5 is reached under such conditions. Sanding must be carried out every day as long as the temperature is above zero. A 6 - 9 mm layer of gravel was also previously used, but some aircraft were damaged by the larger stones being thrown up by the propeller's slipstream. By using sufficient gravel a braking effect of up to 2,7 could always be reached.

b) Change from frost to temperatures above zero

Normally sanding alone is sufficient, but if the upper layer of the snow and ice becomes slushy, both scraping and sanding is necessary.

c) Change from mild to frost

Damp sand which is so warm that it does not freeze during the sanding is used. As long as the frost continues and the sand adheres to the ice, a runway prepared in such a way will last several days without further sanding.

d) Ice which is formed after long periods of cold

In the beginning this condition created great difficulties because it was not possible to get the sand to adhere to the ice. For the last three winters a flame-thrower has been used which rapidly gave a good braking effect. The runway is first sanded and then the flame-thrower is drawn over the surface at a speed of 15 km/h. The flame-thrower will then warm up the ice to such an extent that the surface throws off moisture. When this moisture freezes, the sand will adhere to the ice. As long as the frost continues, sanding is unnecessary, except when the cold period has lasted so long that too much sand has been loosened by the aircraft.

e) A thin layer of ice formed by frozen ground having been exposed to humidity or rain

Normal sanding is often sufficient, but occasionally it is necessary to use large quantities.

f) Snow conditions at temperatures under zero

The runway is scraped and sanded.

g) Snow covered runways at temperatures under zero, exposed to sun

The runway is sanded. If the surface is too soft it must be scraped, this condition occurs mainly in the Spring. In the scraping process the sand used on previous occasions will be reached and this will give a good braking effect.

h) Snow covered runways which have not been exposed to temperatures above minus 3 - 4°C

If the braking effect is not quite up to requirements, a little sanding is sufficient.

It can be mentioned that a quantity of about 300 m^3 of sand is used each winter for the preparation of the runways.

As previously mentioned, conditions are varied, especially when the temperature swings around freezing point. The method for the preparation of the runway will therefore also vary, dependent upon the climatic conditions of the airport. Thus every airport will have its own special method for some of the conditions mentioned.

Propeller reversing on snow and ice covered runways and runway lengths

As previously mentioned, we have looked away from that part of propeller reversing which for certain aircraft types is included in the calculation of the minimum runway length. In the Aeroplane Flight Manual for those aircraft types we know, only a small part of the propeller reversing effect is included when calculating accelerate-stop distance. For the braking effects (retardations) which has been established, reversing makes such little difference that it can be disregarded in the theoretical adjustments made. For a braking effect below 2,0, however, it will be more important because the time used for braking is longer and the reversing will thus be a greater per cent of the total work necessary to stop the aircraft.

The opinion is, that at these low braking effects, one should not calculate with such a great reversing effect as that used for the calculation of the required runway length. The reason for this is that by reversing on three engines the aircraft will have a tendency to yaw as the runway is so slippery that one cannot use the brakes or the nosewheel for steering. At the same time, the rudder effect decreases rapidly. To avoid this, reversing on two engines only should be reckoned with, one engine on each side.

Taking into consideration one cannot fully use that amount of the reversing which has been included in the calculations and also that the accelerate stop distance has no safety margin, one has come to the conclusion that the runway lengths shown in figures 2 and 3 are not excessive, in spite of the fact that the risk is minimal because discontinued take-off seldom occurs.

When landing, however, a certain reduction of the runway lengths shown in figure 4 may be justified. As the landing distance from 50 ft to full stop gives a safety margin of 40%, the reversing effect will, if not taken into account, be regarded as additional safety margin. A certain percentage of the reversing effect from two engines may, however, be considered justified.

As to the landing distance, the use of the gross weights and runway lengths regarding braking effect as shown in figure 5 has been considered. In this diagram the landing distance according to the braking effect is not 60% of the minimum landing runway length, but to the minimum runway length given in the Aeroplane Flight Manual is added the increase in landing distance obtained by the aircraft having a lower retardation than that specified in the requirements. Further reduction of the runway lengths is not justified, because the snow banks on each side of the runway often cause the braking to be performed moderately to prevent the aircraft from turning off the runway.

Views on jet aircraft under winter conditions

The above report has only dealt with piston engined aircraft, as the knowledge of the requirements of a jet aircraft with regard to the braking possibilities is very small. As figure 1 shows, the speed of the aircraft at the commencement of braking is very important. The landing speed of a jet aircraft is larger than that of a piston engined aircraft. These jet aircraft which today are in scheduled service have only drag and friction as a means of braking, and the safety margin which the reversing effect gives is not present. These aircraft therefore require more attention with regard to runway lengths and the preparation of the runway surface.

As to sand on the runway, this may also cause difficulties as a jet engine is very sensitive to sand particles which may be sucked into the engine. A further point is that a jet aircraft may reduce the braking effect because of heat radiation and the blowing off of the sand.

Necessity of further tests

This report has been based on the weather conditions of this airport and on the aircraft types which use the airport. The results reached are satisfactory and the problem has therefore not been ventured deeper into.

It would have been of great interest, however, to have performed further measurements of the retardation of the aircraft under different conditions, especially at poor braking effects. At Fornebu Airport the latter is disregarded, as the runway surface under such conditions must be specially prepared because of the short runways. At airports having excessive runway lengths, however, it would perhaps be necessary to perform such tests at conditions with poor braking effect. To satisfy the requirements, these braking tests should be performed without reversing during the landing run. It should again be pointed out that the runway length is not the only factor to be considered when establishing the minimum braking effect, but also the steering possibility of the aircraft. The latter is specially important when snow is piled up along the sides of the runway. The simplest method of analyzing the braking effect is possibly by means of an accelerometer which shows the retardation graphically. The instrument used at Fornebu also marked off the time, thereby making it possible to analyze the whole progress of braking.

As previously mentioned, this accelerometer was very sensitive and intricate. If any one should proceed with such tests an instrument which is more suitable for this special task is to be recommended.

Fig. 1

DIAGRAM SHOWING THE RELATIONSHIP BETWEEN RETARDATION AND STOPPING DISTANCE FOR VARYING SPEEDS

Note: The R-coefficients are those measured with a lorry in m/sec^2, those of the aircraft being half the value

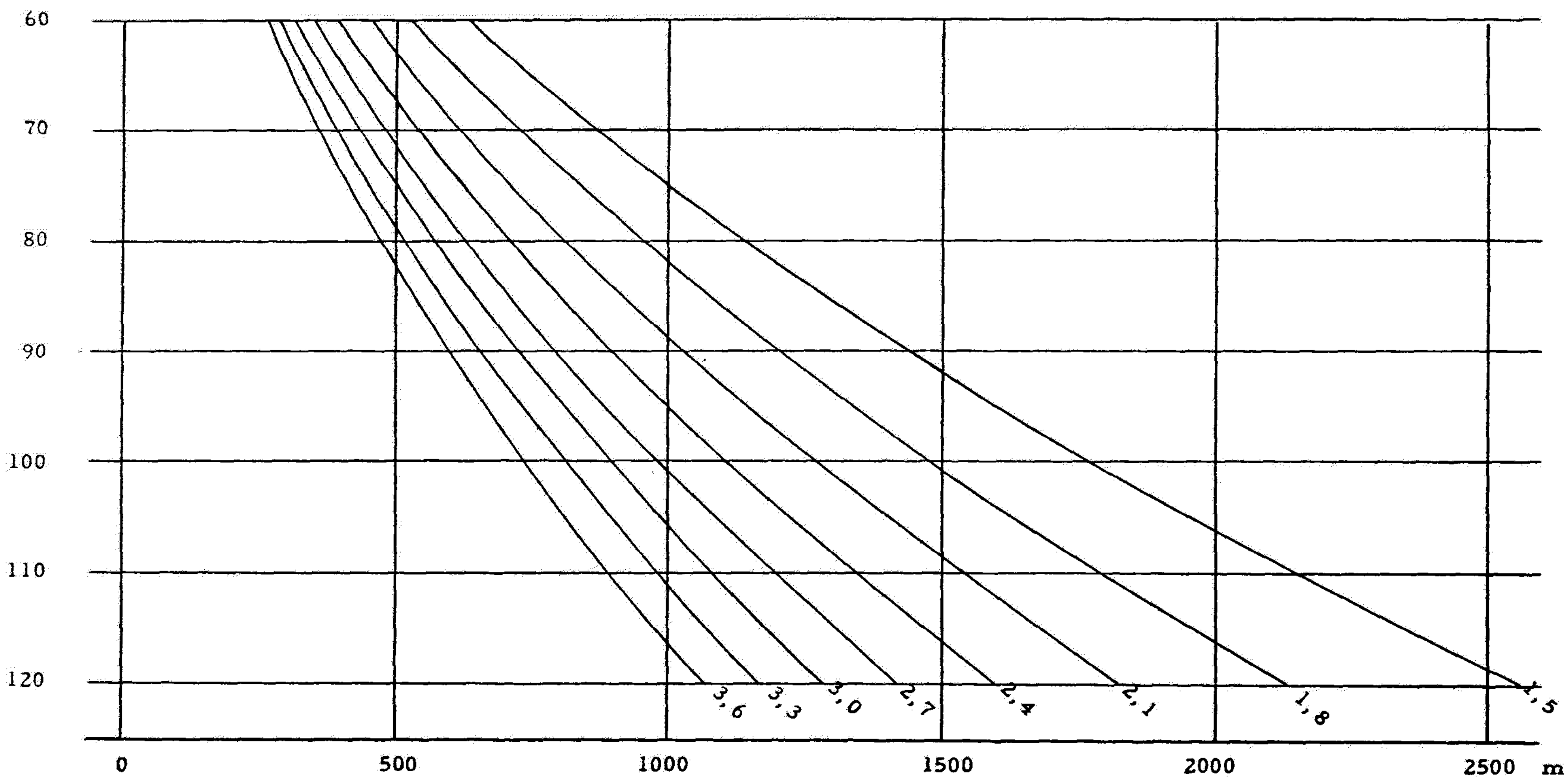


Fig. 2

DIAGRAM SHOWING MIN. TAKE-OFF RUNWAY LENGTH (ACCELERATE-STOP DISTANCE) FOR A DC-6 WITH VARYING BRAKING EFFECTS

Accelerate - Stop Distance for varying Braking Effects (R) — — — —

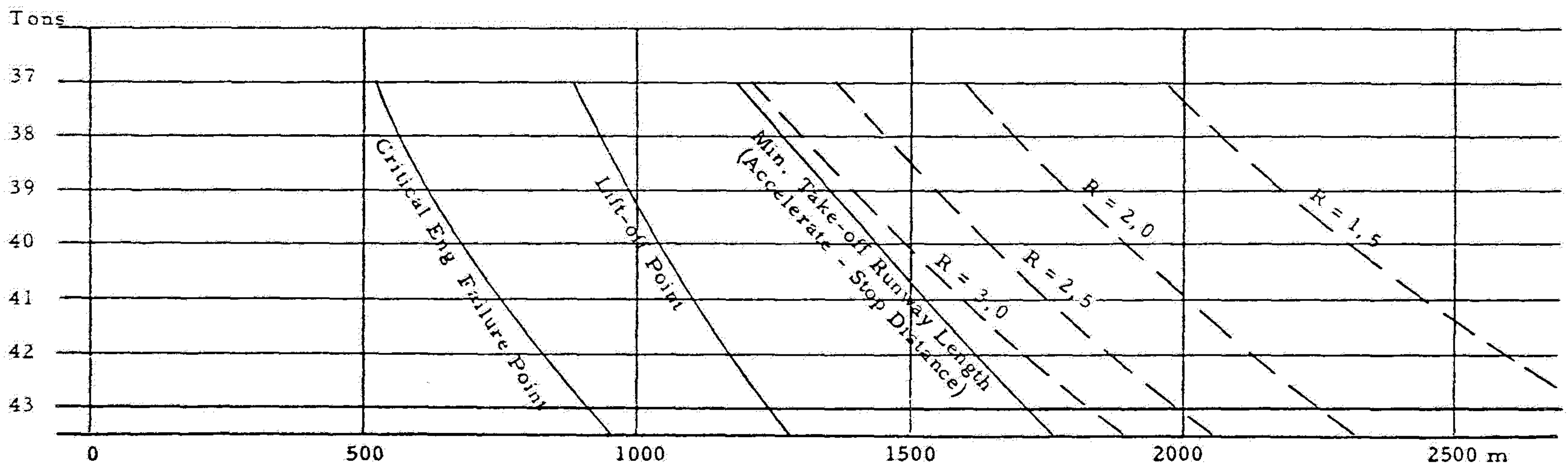


Fig. 3

DIAGRAM SHOWING MIN. TAKE-OFF RUNWAY LENGTH (ACCELERATE - STOP DISTANCE) FOR DC-6 B WITH VARYING BRAKING EFFECTS

Note: Fulldrawn lines indicates standard requirements as extracted from the Aeroplane Flight Manual.

Min. Take-off Runway Length for varying Braking effects (R) — — — — —

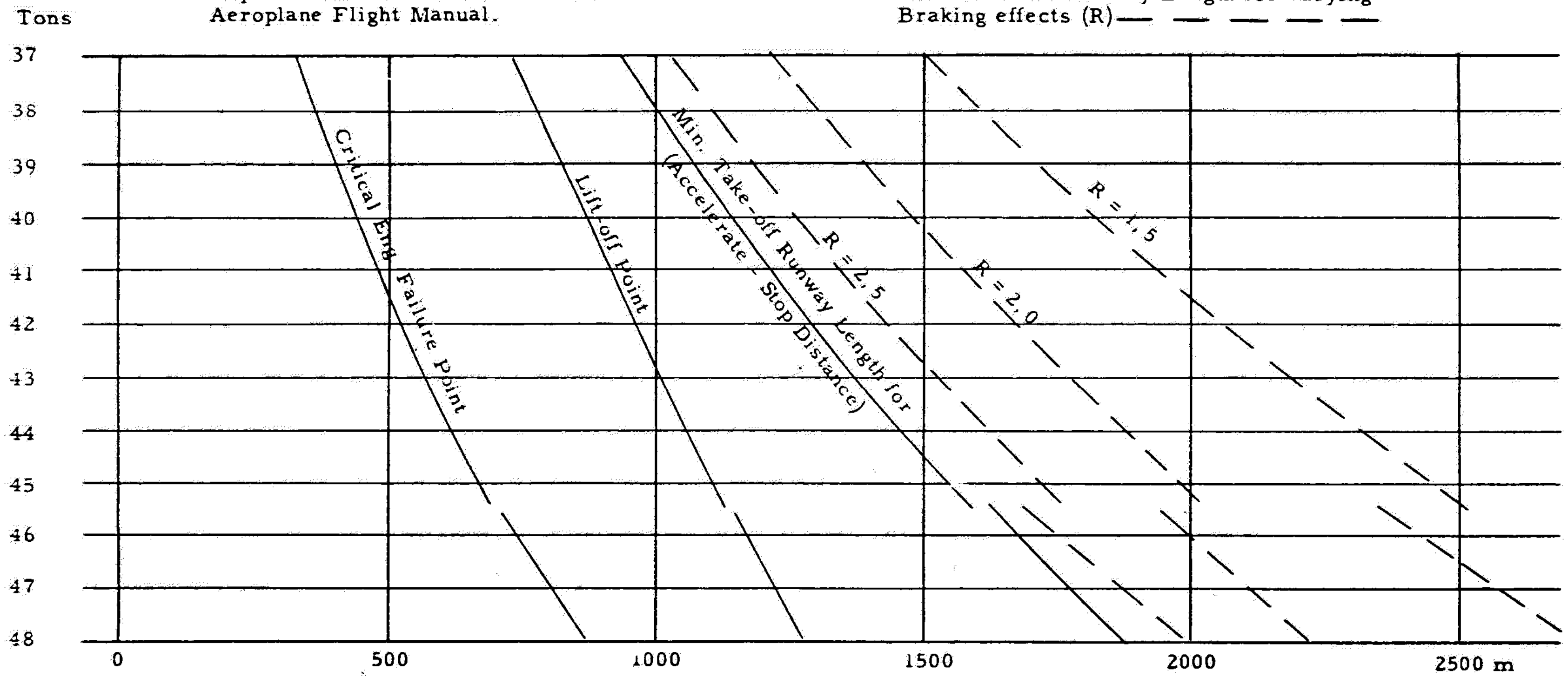


Fig. 4.

DIAGRAM SHOWING LANDING DISTANCE FROM 50 FT AND MIN. LANDING RUNWAY LENGTH FOR DC-6 AND DC-6 B WITH VARYING BRAKING EFFECTS

Landing Dist. (60%) from 50 Ft for varying Braking effects (R) — - — - — - — - —

Min. Landing Runway Length for varying Braking effects (R) — — — — — —

Note: Fulldrawn lines indicates standard requirements as extracted from the Aeroplane Flight Manual

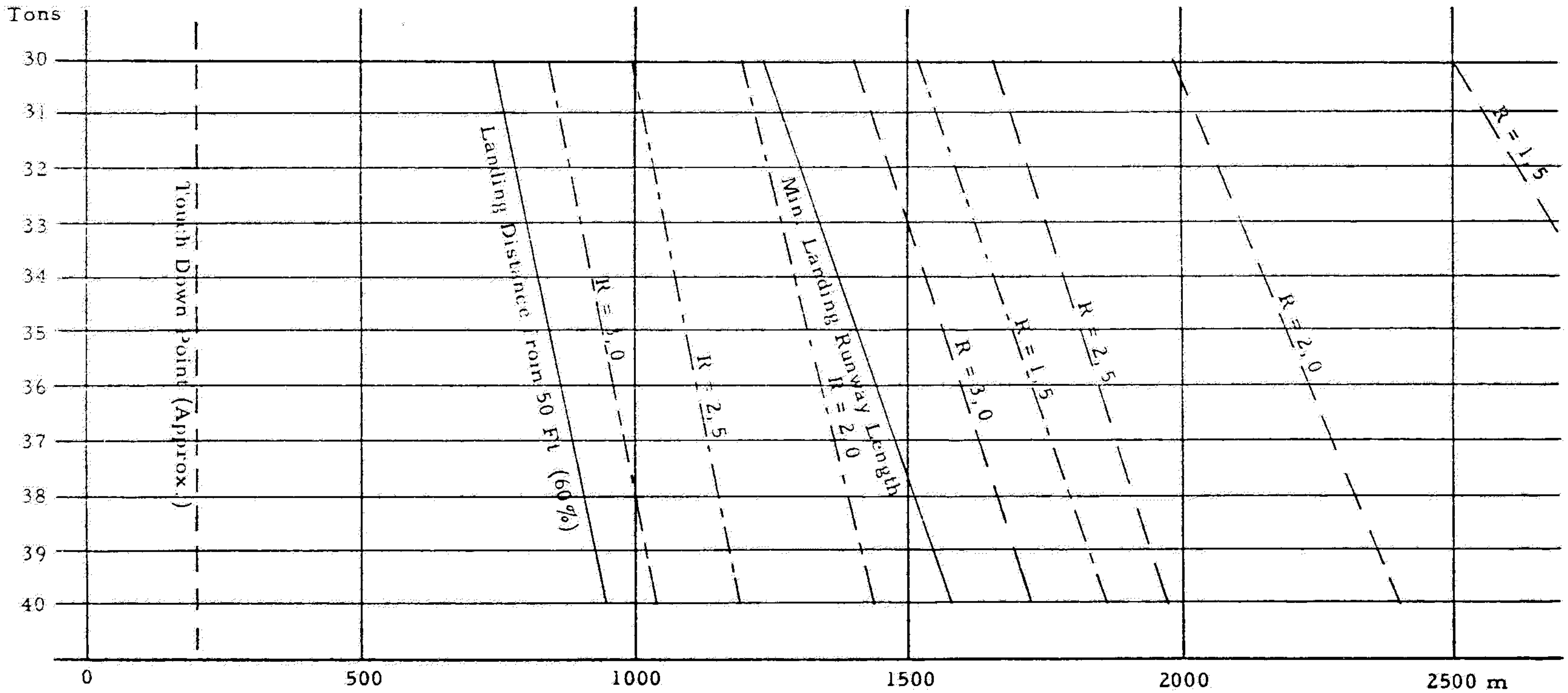


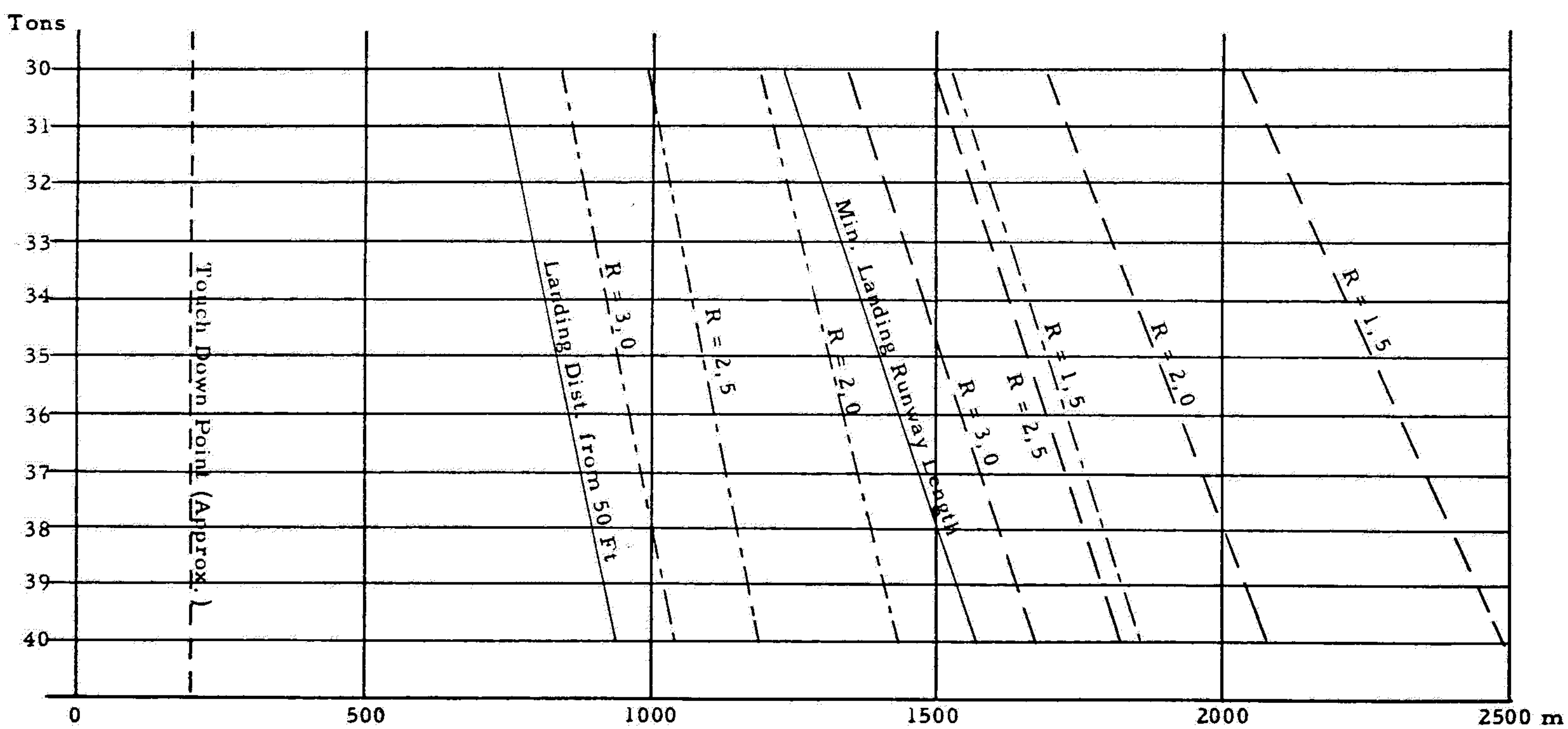
Fig. 5

DIAGRAM SHOWING MIN. LANDING RUNWAY LENGTH FOR DC-6 AND DC-6 B WITH VARYING BRAKING EFFECTS, THE INCREASE IN LANDING DISTANCE DUE TO LOWER RETARDATION BEEING ADDED TO STANDARD REQUIREMENTS

Note: Fulldrawn lines indicates standard requirements as extracted from the Aeroplane Flight Manual

Landing Dist. from 50 ft for varying Braking effects (R) — - — - — - — - —

Min. Landing Runway Length for varying Braking effects (R) — — — — —



ATTACHMENT C-1

SNOW REMOVAL AT AERODROMES

Prepared by

DIRECTORATE OF AIR BASES - GENERAL STUDIES SECTION

SECRETARIAT OF STATE FOR PUBLIC WORKS AND CIVIL AVIATION

FRANCE

(1953)

PRELIMINARY CONSIDERATIONS

A. Snow-fall characteristics at metropolitan aerodromes

Knowledge of these characteristics is essential to the selection, from among the various types of snow removal equipment used in different countries, of the kind which will solve the problem in the most economical manner when properly used. Both in the case of road clearing, for which the normal highway services of the mountain areas of our country have gathered sufficient experience, and of snow removal at foreign aerodromes described in technical periodicals, the equipment and methods used depend, very largely, upon the thickness of the snow layer.

The number of days of snow gives an indication of the frequency of occurrence of the problem and establishes its importance in the overall maintenance schedule.

From an analysis of statistical information supplied by the National Meteorological Service, it is possible to deduce the average amount of snow that will fall in the various parts of the country situated nearly at sea level or at relatively low elevations, as is the case with most French civil and military aerodromes with the exception of a few aerodromes of secondary importance. The number of snow days per year is rather small and may be expressed in terms of the thickness of the snow layer. It has been noted, for instance, that thicknesses of more than 25 centimetres are quite exceptional and that values of 20 to 25 centimetres are rare*.

Nevertheless, in order to provide a margin of safety in the somewhat uncertain estimation of the time required to remove snow, a thickness of 20 centimetres was assumed for determining the methods and equipment to be used.

B. Variability of certain snow characteristics

There are two physical snow characteristics which have a decisive bearing on the problem before us: specific gravity, which may be as low as 30 kg per cu. m. compared to some 900 kg per cu. m. for non-porous ice, and cohesion, which is at a minimum immediately after snow-fall and increases gradually at varying rates, depending upon the weather. Increases in specific

* The combined results of the following 7 stations: Belfort, Besançon, Dijon, Epinal, Lyon-Bron, Nancy, Paris-Le Bourget, for periods ranging from 10 to 23 years, show a total of 36 days on which the thickness exceeded 20 centimetres.

gravity are produced by the weight of the layer as it builds up and by variations in temperature. Snow removal operations are facilitated and shortened if undertaken immediately after the snow has stopped falling, or in certain cases even during the snow-fall. This point is of capital importance and will be dealt with later.

C. Snow removal operations at aerodromes

Snow removal on highways consists of clearing a one-lane or, at the most, a two-lane passage along the road; clearing operations may extend over many miles of highway. The cleared snow is either left as a ridge on one or both sides of the passage, or is pushed against the drift-way or down the side-slope on mountain roads.

At an aerodrome, the shape of the area to be cleared is quite different, a typical example being the runway of a code letter A aerodrome, which is a rectangle measuring 2500 by 60 metres. The snow has to be removed from the runway throughout its length in successive furrows, offset laterally with respect to each other, until the whole of the area is swept. The snow ridges produced after several passages must be pushed sideways beyond the pavement.

SUGGESTED METHODS AND EQUIPMENT

A. Methods

Runways: The machine used for clearing successive furrows is a plough, preferably with a single skew blade rather than a V-shaped stem, which forms only one lateral snow ridge.

If the layer is not very thick, say 10 to 12 centimetres, and if the snow is newly fallen, the skew blade is made to advance as fast as the state of the snow, the setting of the blade against the surface of the pavement, and the condition of the pavement, will permit. The snow builds up laterally during several passages until a snow bank is formed. This bank is then cleared off the pavement by a snow blower. Normally, when there is no wind, or when the wind is negligible, the operation is begun at the centreline of the runway, and conducted throughout the entire length until half the runway surface is cleared. There is no difficulty in guiding the plow so as to ensure complete clearing of the area, since the residual ridge is always on the same side of the blade with reference to its progress. It should be noted that owing to the curve in the blade, which causes the snow to roll without being compacted until it reaches the bank, the machine cannot be used in reverse. If the cross-wind is strong, the operation is begun along the windward edge of the runway and the plough is worked progressively towards the lee side. Also, the snow blower is called in earlier.

Thicker layers of snow will not entail any change in the method of operation, but will slow down the plough's progress. A ridge requiring the use of a snow blower will form after a smaller number of passages. The snow blower might, exceptionally, be called upon twice to clear all the snow from the pavement.

Taxiways: The technique is the same as for a half-runway, the operation being started from one edge and conducted progressively towards the other. The work is easier than for a half-runway of a code letter A aerodrome, the taxiway width being of the order of 25 metres, and therefore less than half the width of the runway (30 m).

Aprons: The portions to be cleared depend on operational requirements, and the snow need not necessarily be removed from the whole area. The equipment used is still the snow plough and the blower. However, since snow banks may in certain cases be tolerated along the periphery of the area to be cleared, it is sometimes possible to do without blowers. It may also happen that owing to the shape of an apron or the position of buildings and hangars, the use of an ordinary blower for the removal of the snow banks would not be effective. In such cases, hand-operated machines using less power but based on the same principle as the snow blower may be put into action to load the snow on trucks for subsequent removal.

B. Equipment

Snow ploughs: These machines are equipped with a single sheet metal blade of some 4 mm in thickness, mounted at an angle to the centre line of the driver vehicle, which may be a tractor or a heavy truck. The effective working width is normally between 2.50 and 2.80 metres. There is advantage in selecting the largest possible effective width to reduce the number of passages required. The twist in the blade, referred to earlier, is designed to force the snow to roll without being compacted until it reaches the ridge. The surface of the blade is therefore not cylindrical and the machine cannot be used indiscriminately to the right or to the left; it is not "reversible". There is therefore no need to make provision for pivoting the blade about a vertical axis. Similarly, the blade need not be made up of independent segments which yield before an obstacle and later resume their initial position, as suggested by some manufacturers, since the chances of meeting any alien matter on a runway are not as great as on a highway. On the other hand, a safety device should be provided by means of which the blade could be made to tilt whenever it passes over an unexpected bump, without causing more damage than, say, the snapping of a safety bolt.

The blade should have two positions on the driver-vehicle:

- idling position: the blade is kept suspended by two or three strong chains.
- working position: the blade rests upon the ground.

To avoid damaging the joints and to ensure the closest possible hugging of the runway surface, the blades are provided with a strip of rubber along their lower edge. In addition to a specially designed curve in the blade, as mentioned earlier, efforts to improve efficiency have led to the development of a highway snow removal process tried out last winter in a French mountainous area by the local road service*. After the fashion of "waxing" skis, a special vinyl resin-based compound was applied on some of the ploughs. This compound adheres very strongly to the steel and substantially increases steel-to-snow slipperiness. Although the tests were carried out on a small scale, the results obtained in raising the efficiency of the ploughs appear to be very encouraging and should be borne in mind, particularly in view of the overriding importance of the time factor in snow removal operations at aerodromes.

Snow ploughs are currently being produced by several experienced French manufacturers and there does not seem to be any need to resort to foreign industry. This equipment need not necessarily be mounted on tractors and may be driven by heavy trucks of the aerodrome's general services department. The mounting of a snow plough may be designed to fit the characteristics of any tractor or truck.

Snow blowers: A snow blower is either an auger or a turbine - in practice, two coupled turbines - ejecting snow laterally at high speed through swivelled chutes. The horizontal distance over which the snow is projected depends on the power of the machine and the specific gravity of the snow. The auger or turbine is mounted on a specially designed tractor which also carries the driving engine.

Auger-equipped snow blowers can be used for the removal of compacted, hard and heavy snow, of specific gravity between 500 and 600 kilograms; on the other hand, the turbine type is best suited for fresh snow, where its output is vastly superior to that of the auger. It was pointed out earlier that snow clearing operations should be started immediately after or even during snowfall; in such circumstances, the turbine type blower is ideal for clearing aerodromes situated in a plain or at a low elevation, which - apart from a few airfields of secondary importance - is the case of most French aerodromes.

Snow blowers commonly used on American and Canadian aerodromes are equipped with diesel engines of up to 200 and even 275 horsepower. They are very expensive and their use on French aerodromes where snow conditions are not so severe would not be justified.

---

* See "Revue générale des routes et aérodromes" No. 259, August 1953, pages 31 and 32.

It should be possible to solve the problem of snow removal at French aerodromes by means of less expensive equipment of European make, either of the auger or the turbine type, manufactured mainly in France. The power of these machines developed in recent years, is of the order of 80 to 120 horsepower. For the removal of large amounts of snow, however, there are caterpillar-type machines with electric diesel engines of 230 HP.

The type of snow blower will depend on the maximum amount of time available for the clearing of runways and aprons and also on the output of the machine. It will be recalled that in the case of freshly fallen snow, the highest output will be obtained with the turbine.

SNOW CLEARING ON RUNWAYS INTENDED FOR JET AIRCRAFT

The snow clearing equipment and methods described above can successfully be used to meet the requirements of propeller-driven aircraft traffic. However, there remains on the pavement a thin layer of frosted snow a few millimetres in thickness, which inevitably forms after the passage of snow clearing machines, particularly the snow plough. This thin residual layer will remain regardless of the design of the equipment and in spite of any efforts to work close to the surface. Sideways rotation of the blade to follow any warps in the pavement, and the strip of rubber along the lower edge of the blade, are to no avail. This ice layer on runways may render them completely unserviceable for jet aircraft and has to be removed. Snow clearing must therefore be followed by de-icing, and in this connection the reader is referred to Note E-60 of November 1951. (See Attachment C-2).

To facilitate the work of the maintenance services, a detailed explanation of a method of snow clearing followed by de-icing is given hereunder. It has already been successfully used on a runway for jet aircraft at a foreign military aerodrome where the snow characteristics are similar to those at French aerodromes:

1. Formation of unilateral ridges by means of snow ploughs advancing continuously and clearing a half runway at a time, as explained earlier.

2. Removal of ridges from the runway by means of a turbine blower.

3. Vigorous scrubbing of the residual ice sheet to disintegrate it as much as possible.

The mechanical sweepers used were equipped with brushes of relatively fine steel wire which offered much longer wear than ordinary brushes and prevented the clotting of snow between bristles.

4. Spreading of dry sodium chloride - proportions: 10-20 gr per sq. m - by means of a sand/salt spreader.

5. Passage of a metal-brush sweeper to remove the slush produced by the melting ice.

After this, the runway should not be washed with fresh water. A thin film of salt water on the pavement will melt any snow falling subsequently, if it is not excessive.

The success of this process is dependent on snow clearing being undertaken as soon as the thickness reaches 5 cm.

For a 1500 by 40 metre runway and a snow-fall of 8 centimetres, the time required to perform all of the above operations was about one day.

The following equipment was used:

2 snow ploughs
2 automotive metallic brush sweepers
1 centrifugal sand/salt spreader
1 snow blower

To clear a 2400 by 45 metre runway in the same amount of time, and particularly in less time, the snow clearing equipment (i.e. snow ploughs and snow blowers) should be doubled.

Remarks:

1. Immediate clearing of the snow as soon as the thickness reaches 5 centimetres is an absolute requirement for the success of the ensuing operation. It is therefore necessary, in winter, to have a special round-the-clock alerting device for calling the clearing crews to action.

2. The spreading of sand or other abrasives on runways is prohibited in view of the serious accidents which may be caused to jet aircraft.

3. Fresh water washing of chloride-treated pavements is recommended as soon as there is no longer any danger of freezing.

SNOW CLEARING ON RUNWAYS INTENDED FOR PROPELLER-DRIVEN AIRCRAFT

Experience has shown that normally a runway on which the thickness of snow is not greater than 5 centimetres or has been reduced to 5 centimetres, may be opened to propeller-driven aircraft traffic. On the other hand, any icing which forms or is likely to form on the runway, should be removed. In certain cases, it may be possible to use materials such as sand or cinders, alone or mixed with sodium chloride, but in each case prior agreement must be secured from the users regarding the type of abrasive to be spread.

SPECIAL OBSERVATIONS

Effect of sodium chloride on pavements and on aircraft

Useful information on de-icing will be found in Note E-60 of November 1951 mentioned earlier. (See Attachment C-2).

Pavements: The amount of salt used should be reduced to a minimum, in order to avoid damage to the runway through sudden drops in pavement temperature as a result of the melting of ice. The proportions of 20 gr per sq. m should be followed except in unusual circumstances and with pavements of excellent quality. It is therefore important that the film of ice remaining on the runway after the passage of a snow plough should be reduced as much as possible. This in turn implies that there should be an effective means of setting the blade of the snow plough as close to the pavement as possible.

Aircraft and vehicles: It has been noted that the slush resulting from de-icing with chlorides sometimes penetrates into the braking mechanism of vehicles using the runways. In the case of aircraft, there is risk of corrosion, particularly of the landing gear. Instructions should therefore be issued for the careful washing of parts of aircraft and vehicles which have been splashed by this briny slush. Spreading of special petroleum-base products on landing gear and other exposed parts, is sometimes resorted to as a preventive measure against such effects.

Use of non-specialized equipment: Snow ploughs need not necessarily be driven by special tractors. It has been pointed out that this may be done by means of heavy general service trucks available at the aerodrome. Manufacturers will, on request, adapt the snow plough mountings to the features of vehicles owned by the user.

The snow plough itself may be replaced by one or more motor-graders which might happen to be available.

If the maintenance service does not own a snow blower, any bulldozer available at the aerodrome may be used to push snow banks formed by the snow plough beyond the runway and apron limits.

ATTACHMENT C-2

NOTE

ON DE-ICING OF RUNWAYS, TAXIWAYS AND APRONS AT AERODROMES

Prepared by

THE DIRECTORATE OF AIR BASES - TECHNICAL SERVICES GROUP

MINISTRY OF PUBLIC WORKS, TRANSPORT & TOURISM

FRANCE

November 1951

NOTE

ON DE-ICING OF RUNWAYS, TAXIWAYS AND APRONS AT AERODROMES

INTRODUCTION

In the following study no distinction is made between:

- glazed frost proper, i.e. the thin layer of frozen water which forms after the occurrence of rain or the condensation of fog composed of drops or droplets of supercooled water, and

- the layer of compacted and frozen snow remaining after the passage of a snow plough.

De-icing is generally understood as covering all operations designed to neutralize the harmful effects of sheet ice or the layer of frozen snow, on vehicular traffic.

Although very few solutions to the problem of road de-icing have been developed, it is not possible to devise any new ones in the case of aerodromes because the problem is presented under the same physical conditions and must therefore be dealt with in much the same way, subject to practical adjustments to meet aeronautical requirements. The solution consists, therefore, in selecting the most suitable methods from among those used on highways.

I - ROAD DE-ICING METHODS

APPLICABILITY TO AERODROMES

In de-icing of highways, use is made of the following:

1. Chemical salts - in practice, sodium and calcium chloride - which act as "thawing agents". Chlorides also have an "anti-freeze" effect: when water containing sodium or calcium chloride, or any other electrolyte in solution, is gradually cooled, ice crystals will form at a temperature lower than 0° C, depending on the kind of salt used and its concentration;

2. Abrasives, such as sand, cinders or clinker spread over the ice to provide an adequate tire-to-pavement frictional coefficient;

3. A mixture of salts and abrasives, which encrusts the ice surface with grains of abrasive.

While the first method is the only one ensuring complete disappearance of the ice, its adoption is not essential in the case of road traffic. Quite frequently only the second or the third method is used whenever the ice is thick and the supply of chloride limited, or simply for reasons of economy.

This option does not exist in the case of aerodromes; the take-off and landing speeds of modern aircraft are such as to prohibit the use of abrasives, which may have a damaging effect on the airframe, engines and tires. The danger is increased by the advent of jet aircraft and the possibility of abrasives being sucked into the engines.

In view of these considerations, de-icing at aerodromes is carried out solely by means of chemical salts acting as thawing agents. The present note is therefore devoted exclusively to an examination of this solution.

It was explained that de-icing generally implies the elimination of the effects of sheet ice or the layer of frozen snow remaining after the passage of a snow plough. However, since abrasives cannot be used, it will henceforward be assumed that de-icing at aerodromes means the elimination not of the effects, but of the ice sheet itself.

The ice sheet is generally very thin - sometimes only 0.5 to 1 mm, but commonly of the order of 2 mm in thickness. Values of 5 mm are exceptional. Our study will therefore centre on cases where the thickness is less than 5 mm and the ice sheet conforms to the descriptions given in the introduction.

II - USE OF DRY SALTS

A - CALCIUM CHLORIDE: $CaCl_2$

1. Theoretical considerations

"Road Note No. 2" published by the British "Road Research Laboratory" contains tabulations of the weight of $CaCl_2$ required at different temperatures to melt 1 kg of ice, and conversely the amount of ice that can be melted with 1 kg of salt. It will be seen later that these theoretical proportions are quite excessive in practice. The following table is nevertheless given for future reference.

TABLE I

Temperature		Weight of $CaCl_2$ in kg required to melt 1 kg of ice		Weight of ice in kg melted by 1 kg of $CaCl_2$	
F°	C°	Unprocessed	Anhydrous	Unprocessed	Anhydrous
30	-1	0.04	0.03	24.0	33.3
25	-4	0.13	0.09	8.0	11.1
20	-7	0.17	0.12	6.0	8.3
10	-12	0.26	0.19	3.8	5.3
0	-18	0.35	0.25	2.9	4.0
-10	-23	0.42	0.30	2.4	3.3

2. Comments and practical applications

Although $CaCl_2$ has been widely used for several years in the United States for de-icing of roads in winter, it has hitherto found limited application in France. In an effort to popularize this product, the Société Solway issued a special publication which draws extensively upon the literature of the American Road Builders' Association. Table II shows the proportions of chloride, for various temperatures and ice thicknesses, that are recommended in this publication.

TABLE II

Temperature	Thickness of ice sheet	
	2 mm and under	from 2 to 5 mm
From 0 to -5° C	20 to 30 gr/sq. m	100 to 125 gr/sq. m
Below -5° C	40 to 60 gr/sq. m	200 to 250 gr/sq. m

Let us compare the results of Tables I and II.

a) For a temperature of -4° and an ice thickness of 2 mm,

Table I gives 0.13 kg of unprocessed Ca Cl_2 per kg of ice*, i.e., assuming the density of ice to be 0.9, the amount required is: 0.13 x 0.002 x 1000 x 0.9 = 0.234 kg/sq. m or 234 gr/sq. m.

Table II merely gives an upper and lower limit to the proportions required for temperatures ranging from 0° to -5° C; in this case, it is the upper limit, corresponding to a temperature of -5° C, i.e. 30 gr/sq. m that should be used.

b) For a temperature of -4° C and an ice thickness of 5 mm,

Table I gives 0.13 x 0.005 x 1000 x 0.9 = 0.585 kg/sq. m or 585 gr/sq m.

Table II gives 120 gr/sq. m.

The large difference between the values derived from either of the two tables may appear surprising at first glance. This is explained by the fact that table I is based on the solidification curve of Ca Cl_2 solutions at temperatures below 0° C. The eutectic solution having the lowest freezing temperature is one in which the calcium chloride is concentrated to 30.05% by weight; in such a solution, ice crystals begin to form at -51.6° C. By means of this curve, it is possible to calculate the weight of pure ice that may be completely melted at a given temperature by a given weight of Ca Cl_2 and conversely, the amount of Ca Cl_2 required to melt a given weight of pure ice at a given temperature.

Experience has shown, however, that the amount of Ca Cl_2 required to loosen the ice on a road is much smaller than the values established theoretically from a graph on the basis of given atmospheric temperatures. This is due to the reserve of heat stored in the earth and to the fact that part of the ice is washed away by the melting liquid. In any event, it has already been pointed out that the figures given in "Road Note No. 2" were theoretical.

This presents a dual advantage. Since the required quantity of a relatively expensive product can be reduced, and since, as we shall see, chloride treatment of concrete runways and aprons should be used with caution.

The results given by Table I (theoretical proportions) and Table II (practical proportions) in the two cases concerned, may be expressed as a ratio:

practical proportions/theoretical proportions

* The anhydrous chloride content of granular industrial Ca Cl_2 is 77 to 80%.

This value is very close to:

1/8 for an ice thickness of 2 mm.

1/5 for a thickness of 5 mm.

Table III gives the recommended practical proportions of Ca Cl_2 derived from Table I on the basis of these reduction ratios, and provides accurate values for the wide range of temperatures omitted in Table II.

TABLE III

Recommended practical proportions of dry Ca Cl_2*

Temperature	Thickness of ice: 2 mm	Thickness of ice: 5 mm
- 4° C	30 gr/sq.m	120 gr/sq.m
- 7° C	40 "	150 "
-12° C	55 "	230 "
-18° C	75 "	300 "
-23° C	95 "	

* Quantities of Ca Cl_2 required for temperatures and ice thicknesses in between these values should be derived by interpolation.

B - SODIUM CHLORIDE: Na Cl

1. Theoretical considerations

"Road Note No. 2" of the above-mentioned British "Road Research Laboratory" also gives the weight of Na Cl required to melt 1 kg of ice, and conversely the weight of ice melted by 1 kg of Na Cl. As in the case of calcium chloride, the values are theoretical, and are reproduced in Table IV.

TABLE IV

Temperature		Weight of Na Cl in kg, required to melt 1 kg of ice	Weight of ice in kg, melted by 1 kg of Na Cl
F°	C°		
30	- 1	0.02	50
25	- 4	0.07	14.3
20	- 7	0.11	9.1
10	-12	0.19	5.3
0	-18	0.26	3.8

This Table permits calculation of the theoretical proportions of Na Cl required to melt sheet ice of 2 or 5 mm in thickness. For the same reasons as those given in the case of Ca Cl_2, it is necessary to apply reduction factors to obtain the table of practical values.

2. Comments and practical applications

On the basis of experimental results indicating the weight of Na Cl to be used per sq. m, without reference to the ice thickness or temperature, it seems that the permissible reduction ratios are 1:5 and 1:3, for sheet ice of 2 mm and of 5 mm in thickness respectively.

These reductions are smaller than those applying in the case of Ca Cl_2 (1:8 and 1:5 respectively), which is strongly exothermic when dissolved, as opposed to Na Cl which is endothermic. The action of Ca Cl_2 is therefore much more rapid and energetic. Also, the use of Na Cl reduces considerably the washing away of part of the ice by the melting liquid.

Table V shows practical proportions of Na Cl.

TABLE V

Recommended practical proportions of dry Na Cl*

Temperature	Thickness of ice: 2 mm	Thickness of ice: 5 mm
- 4°	30 gr/sq.m	110 gr/sq.m
- 7°	45 "	180 "
-12°	75 "	300 "
-18°	105 "	430 "

* The product used is pulverized rock-salt which may contain up to 8% of impurities (chiefly marl), and therefore the figures of the table were increased by 10% and rounded off upwards.

III - USE OF SALTS IN SOLUTION

Ca Cl_2 and Na Cl may also be used in aqueous solution sprinkled over the surface to be de-iced.

A - CALCIUM CHLORIDE: Ca Cl_2

Table VI shows the amounts of solution to be sprayed in litres per square metre. The proportions are equivalent to those given for dry salt (Table III) and for the same temperatures and ice thicknesses.

The values given in this table were divided into two different groups related to two different concentrations:

- the first is a eutectic solution with optimum anti-freeze properties;
- the second is a weaker solution which must be used in greater quantities.

Although the freezing point of this solution is higher than the first one, it is adequate in most cases.

It is advisable to have the second concentration available, as the amounts of eutectic solution prescribed for values at the end of this scale are so small that complications arise in the use of the spraying equipment. The eutectic solution should be used in temperatures of the order of - 18 to -20° C.

TABLE VI

Use of granular industrial $Ca\ Cl_2$ in aqueous solutions.

Proportions of granular salt used (See Table III)	Amount of solution to be sprayed (litres/sq. m)	
	Eutectic concentration or 30% (30 gr of anhydrous salt per 100 gr of solution)*	20% concentration (20 gr of anhydrous salt per 100 gr of solution)**
30 gr/sq.m	0.06 litres/sq.m	0.10 litres/sq.m
40 "	0.08 "	0.14 "
55 "	0.11 "	0.19 "
75 "	0.15 "	0.25 "
95 "	0.19 "	0.32 "
120 "	0.24 "	0.40 "
150 "	0.30 "	0.51 "
230 "	0.46 "	0.78 "
300 "	0.60 "	1.00 "

* This concentration is equivalent to 500 gr of unprocessed $Ca\ Cl_2$ at 77-80% for 1 litre of solution. Freezing point: - 51° C. In practice, the proportions are: 600 gr of unprocessed salt per litre of water.

** This concentration is equivalent to 296 gr of unprocessed $Ca\ Cl_2$ at 77-80%, for 1 litre of solution. Freezing point: -20° C. In practice, the proportions are: 340 gr of unprocessed salt per litre of water.

B - SODIUM CHLORIDE: Na Cl

Table VII which is prepared in the same manner as Table VI relating to Ca Cl_2, shows the amount of Na Cl solution to be used for the proportions of dry salt prescribed in Table V.

TABLE VII

Use of Na Cl (pulverized rock salt) in aqueous solution.

Proportions of dry salt used (See Table V)	Amount of solution to be sprayed (litres/sq.m)	
	Eutectic concentration or 22.4% (22.4 gr of salt per 100 gr of solution)*	13.6% concentration (13.6 gr of salt per 100 gr of solution)**
30 gr/sq. m	0.12 litres/sq.m	0.20 litres/sq.m
35 "	0.14 "	0.23 "
45 "	0.17 "	0.30 "
75 "	0.30 "	0.50 "
105 "	0.40 "	0.70 "
110 "	0.42 "	0.73 "
180 "	0.68 "	1.20 "
300 "	1.15 "	2.00 "
430 "	1.64 "	2.86 "

* This concentration is equivalent to 262 gr of Na Cl for 1 litre of solution. Freezing point: - 21° C. In practice, the proportions are: 290 gr of salt per litre of water.

** This concentration is equivalent to 150 gr of Na Cl for 1 litre of solution. Freezing point: - 10° C. In practice, the proportions are: 157 gr of salt per litre of water.

IV - CHOICE OF METHOD

A - DRY PROCESS

This method has been used almost exclusively for the treatment of roads in countries such as the United States, Canada, Britain and Belgium, where de-icing by means of chemical salts is carried out on a large scale. The equipment required by this process is simple and inexpensive and will be described to some extent in the appendix. The method is of easy application, use being made of either one or the other chloride, depending on the circumstances, and eliminates the need for preparation and stocking inherent in the solution process. Chloride stocks can be utilized directly and require no preparation by the maintenance services. If in the course of application, the amounts of salt used prove to be inadequate, it is always possible to spread additional amounts on the entire runway or on the portions requiring further treatment.

Among the disadvantages of this process there is the fact that chloride spreading is a toilsome task for the workmen, and that uniform application in accordance with the assumed theoretical proportions is difficult to achieve.

B - SOLUTION PROCESS

This method undoubtedly ensures a more even application conforming more closely to the adopted unit proportions. The operation itself also involves less arduous labour for the workmen. Moreover salts in solution are better suited for use as a preventive measure. If meteorological reports or local conditions warn the maintenance services that snow or the formation of sheet ice may be expected, a preventive sprinkling will avert any ice accretion. In case of false alarm, the sprinkled water will evaporate leaving behind a protective coating of salt.

It should be noted that preventive measures against sheet ice, necessitated by dense city traffic, lose their importance at aerodromes. In view of the comparatively smaller volume of traffic and the desire to avoid unnecessary interruptions in air operations, the aerodrome maintenance services will probably be called in only after the ice has started forming.

Against these advantages, the solution process requires:

a) apart from an actual reserve of salt, special facilities and a qualified staff to replace and if possible, store the solution, so as to ensure that a supply is always on hand in the event of unexpected icing;

b) one or more spraying machines capable of atomizing the solution, similar in kind to the sprinklers used by the municipal services.

Furthermore, the exothermic reaction accompanying the dissolving of $Ca\,Cl_2$, particularly effective in the dry process, can no longer be relied upon since it has already taken place before the spraying. Should it be desired to retain the possibility of using either one or the other chloride, two separate storage systems must be devised. As regards preparing solutions in a common installation, it may be necessary to determine whether there are any mutually neutralizing effects, although no such cases have been reported.

C - COMPARATIVE MERITS OF THE TWO PROCESSES

The above listing of respective advantages and drawbacks of the two systems shows, in particular, that the solution process calls for the installation of special facilities and the earmarking of substantial maintenance and operating funds. Also, the spraying equipment is more expensive.

It seems, therefore, that the dry process should be used at small and medium aerodromes (mainly code letters B and C). The equipment consists of a truck towing a spreader or carrying a special machine mounted on the railing. A further description will be given in the appendix.

The dry process may also be used at large aerodromes, although in locations where winters are severe, particularly in the case of aerodromes of the international class, the solution process should be borne in mind if it appears more suitable. In any event, the availability of equipment and funds will be the governing factor.

V - CHOICE OF CHLORIDE

Once a decision has been made as to the type of process to be used, it becomes necessary to choose in favour of one or the other of the two chlorides

In most cases the decision will hinge on the fact that Ca Cl_2 costs five times more than Na Cl (excluding transport).

On the other hand, Ca Cl_2 causes the ice to melt very rapidly and retains its full effectiveness at temperatures down to -35° C, the theoretical service limit being at -51° C, whereas Na Cl begins to lose its effectiveness below -12° C. The power of Na Cl is weak at temperatures of the order of -20° C and becomes absolutely non-existent below -22° C. The superior anti-freeze properties of Ca Cl_2 over Na Cl are particularly apparent in cases of sudden drops in temperature following an application.

It seems, therefore, that Na Cl should be used at small or medium aerodromes (mainly code letters B and C), located in areas where the winters are not rigorous. It should also be used in most cases at large aerodromes (code letter A). Ca Cl_2 may be applied in the case referred to above, of an important aerodrome located in an area where the winter is severe, and equipped with solution sprinkling machinery.

VI - SPECIFIC CASE OF ICE SHEETS OF MORE THAN 5 mm

Up to now, consideration has been given to glazed frost proper, where the ice sheet is thinner than 5 mm. For thicker layers, consisting of compacted and frozen snow, it may be useful to refer to the procedures adopted in other countries.

The thawing agent sometimes resorted to, is Ca Cl_2. The following proportions are used in practice for a layer of 12 mm:

at -4° C: 400 gr/sq.m

at -7° C: 500 gr/sq.m

In view of the high cost of this salt, such quantities are warranted only in exceptional cases. Beyond these temperatures and ice thicknesses, the cost of the operation becomes prohibitive.

$CaCl_2$ has also been applied not only to melt the ice, but to soften its surface prior to the passage of the ice breaker. In such cases, the recommended proportions are 120 gr/sq.m.

Mention should be made of a trial conducted by the Department of Roads of the Belgian province of Luxembourg on a thick, hard-frozen and smooth layer of snow, at temperatures of -10° to -15° C. The spreading of granular $CaCl_2$ at a rate of 120 gr/sq.m considerably reduced the slipperiness. Small craters were formed, and the ice became powdery to a depth of a few millimetres.

VII - EFFECT OF CHEMICAL SALTS ON PAVEMENTS AND VEHICLES

A - PAVEMENTS

Temperature drops produced by the melting of ice are liable to cause a certain amount of damage, depending on the initial temperature of the pavement, its type and the amount of product used.

Pavements made of materials mixed in tar or bitumen, and having an open granular structure, are quite vulnerable. On the other hand, high-grade bituminous concrete can withstand such treatment satisfactorily.

Green on lower grade cement concrete is liable to deteriorate. However, although high-grade concrete offers much better resistance, care should be taken not to exceed the prescribed quantities and to apply the chloride as evenly as possible.

Air-entrained concrete is known to be resistent to frost and is therefore likely to behave satisfactorily at low temperatures. Its use is advantageous in winter climates where the ice is frequently melted by means of chemical salts. It has been used for many years in the United States and has successfully withstood the effects of salts.

In the State of New York a special protective process for concrete highways was introduced in cases where salts were applied frequently or in large quantities. The surface was sprinkled with petroleum oil, mixed with a volatile mineral oil which facilitated its application and absorbtion by the concrete. Preliminary laboratory tests have shown that a single coating, applied on a newly constructed highway once every two years, was adequate*.

* Research currently conducted on camouflaging of concrete runways, will probably lead to the spraying of pavements with bitumen or coal tar dissolved in substances such as petrol or benzol. These solutions could act as a protective coating against the effects of chemical salts.

Actually, although there is not very much experience on the action of chemical salts on aerodrome pavements, we believe the danger is overestimated. No damaging effects were noted at Orly as a result of spreading dry Na Cl on runways during the 1950-1951 winter season. As long as care is taken and the proportions observed, it would appear that no ill-effects need be feared. In certain cases, useful information can be obtained from preliminary tests.

B - VEHICLES

It was noticed that the slush resulting from de-icing had a tendency to penetrate into and damage the braking mechanism and bearings of vehicles. Care should therefore be taken to ensure that in frosty weather, vehicles are properly lubricated and cleaned. The landing gear of aircraft, particularly, should be carefully cleaned after passage over a chloride-treated runway. To reduce contacts with slush to a minimum, the liquid forming on the runway surface should be drained off as rapidly as possible. The drainage system should be free of any obstructions.

The likelihood of damage to vehicles has been equally exaggerated. Although chemical salts have been commonly used for many years in highway snow removal and de-icing operations in the United States and Canada, there is hardly any reference to this aspect of the problem in articles dealing with this subject in technical reviews. When Na Cl was used at Orly, the airlines merely requested to be advised in time of the chemical treatment of the runways, in order to have the opportunity of performing the special cleaning and rinsing required.

APPENDIX I

SALT SPREADING EQUIPMENT

I - DRY PROCESS

Calcium and sodium chloride are produced respectively in the form of small grains and crystals and may therefore be applied by a mechanical sand spreader.

The most suitable types of equipment seem to be the following:

A - CENTRIFUGAL SAND SPREADER

This machine can be towed by any truck and consists of an automobile rear-axle carrying two wheels with pneumatic tires and having a conical screen-bottom feed hopper. The width of strip on which the sand or salt is applied can be varied by means of movable vanes. Rotation of the spreader turn-table is achieved by a right-angle gear mechanism set in motion by the forward movement of the trailer. Two workmen standing on the truck feed the chloride into the hopper with shovels. A conical governor makes it possible to adapt the spreader to the type of product used. The spreading rate is governed by the truck speed. The sand spreader weighs approximately 250 kg.

This machine is manufactured by the "Société PIQUARD Frères et DUREY-SOHY", 59, rue de la Voûte, Paris 12e, under the same of "Sableuse-Centrifuge" (centrifugal sand spreader) Type DS-1345.

The "Société AMMANN", 36 rue Coriolis, Paris 12e manufactures similar equipment known as mark AMA and mark AMA-5.

B - MECHANICAL SPREADER

This machine consists essentially of a feed hopper and circular turn-table spreader, which may be mounted on the side or the rear of any ordinary truck. In the first case, all four wheels will pass over treated portions of the pavement, whereas in the second case only the rear wheels will do so. The spreader has no auxiliary motor, and power is transmitted by a strong flexible shaft easily connected to the axle of one of the rear wheels of the truck. The ratio of the turn-table and truck speeds may be varied within certain limits by means of a gear system. The hopper is fed by two workmen standing on the truck.

The machine is manufactured by the same company "Société PIQUARD Frères et DUREY-SOHY", under the name of "Distributeur-Mécanique" (mechanical spreader), type DIMESA.

C - POWERED SAND/SALT SPREADER

The machine consists of a 50 litre sheet metal hopper feeding a rotating spreader. A conical-pendulum governor controls the uniform delivery of salt. The spreader which is provided with two nozzles 60 cm apart, diametrically opposite each other, ejects the salt on to the pavement by rotation. This motion is transmitted by a vertical shaft passing through the conical-pendulum governor and driven by a 2 HP, 2,000 RPM motor through a spring-coupled 10:1 reduction gear. The rotational speed may be made to vary by means of a multiple-speed accelerator.

The unit is mounted on a steel frame attached to the left side or the rear of the truck. The circular area sprayed will encompass all four wheels of the vehicle if the unit is attached to the side, and only the rear wheels if attached to the rear. The hopper is fed by two workmen who can control the rotational speed of the mechanism. When not in use, the sand/salt spreader may be stored on a special rack. The amount of salt applied is governed both by the speed of the truck and by that of the turn-table. At maximum speed, the spreader can deliver 10,600 litres per hour, the area encompassed at any given time being a circle 9 m in diameter.

The manufacturers are the "Société ERMONT (Chaudronnerie et Ateliers de Construction d'Ermont)", 1, rue du Professeur Dastre, Ermont (Seine-et-Oise).

D - COMPARISON OF THE DIFFERENT MACHINES

A comparison of the characteristics and performances of the three types of machine described above, will show up the advantages of the sand/salt spreader equipped with an auxiliary motor over the other two, whenever the salt has to be spread evenly and in prescribed quantities. The spreading may be regulated both by the speed of the auxiliary motor and by that of the truck. The manufacturers have been able to produce excellent reference from various services of the Highways Department which have used this machine as a sand spreader. Equally good results may be expected in the case of salt spreading.

The first two types can also give satisfactory results, once the required quantities have been determined by initial trial and the equipment handed over to a qualified staff.

II - SOLUTION PROCESS

Use is made of large-capacity motorized sprinklers similar in kind to those of the municipal roads services. These vehicles may even be used as sweepers.

During a recent visit to the central district office of the street cleaning service of the City of Paris, we were told that in Paris, solutions of rock-salt were sprayed by ordinary sprinkler/sweepers. The machines shown to us were manufactured by DION-BOUTON and were rather old. They dated back to 1930 and were no longer manufactured. The quantities of sprayed brine varied considerably, from 1 and 1.5 to 2 litres per sq. m, sometimes even more. Not much attention seemed to be given to this matter. Sprinkling covered a central strip of 2 metres in width and the crown of the road was relied upon to ensure spreading of the solution across the full width.

The unit proportions suggested in this study may be as low as 0.10 litres/sq.m and call for an actual atomizing of the solutions which is not always possible with the equipment of the Paris roads department. The new sprinkler/sweepers recently ordered by the City authorities would be more suitable for this work. We were able to examine a prototype of this machine, the L.M.V.52 presented by the manufacturers - the "Société LE MATERIEL DE VOIRIE", 156, rue Armand Silvestre, Courbevoie (Seine).

The spraying rate of this sprinkler varies from 0.100 to 0.500 litres per sq.m, and therefore covers the range of proportions indicated for solutions.

An area of 55,000 sq.m could be treated without reloading with a water tank of tank of 5,500 litre capacity, assuming the proportions to be 0.10 litres per sq.m.

This highly efficient atomizer may also be used for ordinary sprinkling and sweeping, and is the latest fruit of long-standing experience in road servicing.

- END -

ICAO TECHNICAL PUBLICATIONS

The following summary gives the status, and also describes in general terms the contents of the various series of technical publications issued by the International Civil Aviation Organization. It does not include specialized publications that do not fall specifically within one of the series, such as the ICAO Aeronautical Chart Catalogue *or the* Meteorological Tables for International Air Navigation.

INTERNATIONAL STANDARDS AND RECOMMENDED PRACTICES are adopted by the Council in accordance with Articles 54, 37 and 90 of the Convention on International Civil Aviation and are designated, for convenience, as Annexes to the Convention. The uniform application by Contracting States of the specifications comprised in the International Standards is recognized as necessary for the safety or regularity of international air navigation while the uniform application of the specifications in the Recommended Practices is regarded as desirable in the interest of safety, regularity or efficiency of international air navigation. Knowledge of any differences between the national regulations or practices of a State and those established by an International Standard is essential to the safety or regularity of international air navigation. In the event of non-compliance with an International Standard, a State has, in fact, an obligation, under Article 38 of the Convention, to notify the Council of any differences. Knowledge of differences from Recommended Practices may also be important for the safety of air navigation and, although the Convention does not impose any obligation with regard thereto, the Council has invited Contracting States to notify such differences in addition to those relating to International Standards.

PROCEDURES FOR AIR NAVIGATION SERVICES (PANS) are approved by the Council for worldwide application. They comprise, for the most part, operating procedures regarded as not yet having attained a sufficient degree of maturity for adoption as International Standards and Recommended Practices, as well as material of a more permanent character which is considered too detailed for incorporation in an Annex, or is susceptible to frequent amendment, for which the processes of the Convention would be too cumbersome.

As in the case of Recommended Practices, the Council has invited Contracting States to notify any differences between their national practices and the PANS when the knowledge of such differences is important for the safety of air navigation.

REGIONAL SUPPLEMENTARY PROCEDURES (SUPPS) have a status similar to that of PANS in that they are approved by the Council, but only for application in the respective regions. They are prepared in consolidated form, since certain of the procedures apply to overlapping regions or are common to two or more regions.

The following publications are prepared by authority of the Secretary General in accordance with the principles and policies approved by the Council.

ICAO FIELD MANUALS have no status in themselves but derive their status from the International Standards, Recommended Practices and PANS from which they are compiled. They are prepared primarily for the use of personnel engaged in operations in the field, as a service to those Contracting States who do not find it practicable, for various reasons, to prepare them for their own use.

TECHNICAL MANUALS provide guidance and information in amplification of the International Standards, Recommended Practices and PANS, the implementation of which they are designed to facilitate.

AIR NAVIGATION PLAN documents detail requirements for facilities and services for international air navigation in the respective ICAO Air Navigation Regions. They are prepared on the authority of the Secretary General on the basis of recommendations of regional air navigation meetings and of the Council action thereon. The plans are amended periodically to reflect changes in requirements and in the status of implementation of the recommended facilities and services.

ICAO CIRCULARS make available specialized information of interest to Contracting States.

EXTRACT FROM THE CATALOGUE

ICAO SALABLE PUBLICATIONS

ANNEX TO THE CONVENTION

Annex 14 — Aerodromes.
(2nd edition) September 1953 (incorporating amendments 1 to 6)
66 pp. Letterpress **$1.25**

ICAO CIRCULARS

4 — AN/3 —
Crash fire and rescue equipment at aerodromes, June 1948. 18 pp. **$0.10**

17 — AN/14 —
The effect of turbine-powered civil aircraft on the design, construction and equipment of land aerodromes, November 1950. 24 pp. **$0.10**

23 — AN/20 —
Problems associated with the advent of turbine-engined airplanes, February 1952. 46 pp. **$0.45**

25 — AN/22 —
Runway design methods for multiple wheel landing gears, 1952. 50 pp. **$0.25**

36 — AN/31 —
Problems arising in AGA field as a result of the Introduction of turbine-engined aircraft, 1953. 38 pp. $0.25

37 — AN/32 —
Strength of runways, 1953. 40 pp. $0.25

41—AN/36—
Suggested aircraft rescue and fire fighting equipment and operating procedures for airports, 1955. 50 pp. $1.00

NB.- Cash remittance should accompany each order.
Catalogue sent free on request.

PRICE: $0.75 (Cdn.) (Montreal)
Equivalents at date of publication:

15.00 bahts	(Bangkok)
18.00 pesos	(Buenos Aires)
L.E. 0.265	(Cairo)
14.75 soles	(Lima)
5s. 2d.	(London)
6s. 10d.	(Melbourne)
Rs. 3-12-0	(New Delhi)
265 francs	(Paris)

5/55, E/P1/1000
2/57, E/P2/400