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THE SNOW CHARACTERISTICS
OF
AIRCRAFT SKIS

BY

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SUMMARY

A large number of measurements of adhesion and sliding resistance were made on approximately half scale model skis of various shapes and surfaced with various materials. The tests were carried out over a large range of temperature and snow conditions and over a large range of unit loading. Highly loaded skis, surfaced with bakelite and having comparatively high aspect ratio and small bow angle are shown to be much superior to present day skis. A theory is proposed which agrees very well with the results of the tests.

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INTRODUCTION

There are certain snow conditions which make the operation of aircraft equipped with skis very difficult. Sometimes the sliding resistance of the skis is so great that it is impossible to reach flying speed. At other times, the skis adhere to the snow to such an extent that the airscrew thrust is not sufficient to start the skis sliding. The assistance of a ground handling crew may not always be available, and, when it is, the methods which have to be taken in order to free the skis are often so drastic that there is danger of damaging the undercarriage and other parts of the aircraft.

The uncertainty of the snow conditions at some remote landing field presents somewhat of a hazard in winter flying. Often, aircraft have to be operated at reduced load in order to fly at all.

Despite these difficulties, very little has been done to improve the snow characteristics of skis. It appears that, previous to the tests described in this report, there were only the researches of Gliddon (1) at McGill University in 1922, and Söderberg (2) in Sweden from 1929 to 1932. Due to the need for an improved type of aircraft ski and the scarcity of technical information on the snow characteristics of skis, the Laboratories of the National Research Council of Canada undertook tests of model skis on snow. The tests were made at Ottawa in the winters 1935-36 to 1937-38, and at Sioux Lookout, Ontario, where the temperatures are lower than at Ottawa, in the winter 1938-39.

THE MODEL SKIS

Since it was difficult to predict the effect of model size, the models were made as large as possible, consideration being given to the size of the towing vehicle available and to the amount of weight which had to be moved by hand during the tests.

Figure 1 shows the model skis outside the hangar which was used to house the skis and the ski dynamometer.

Fig. 1

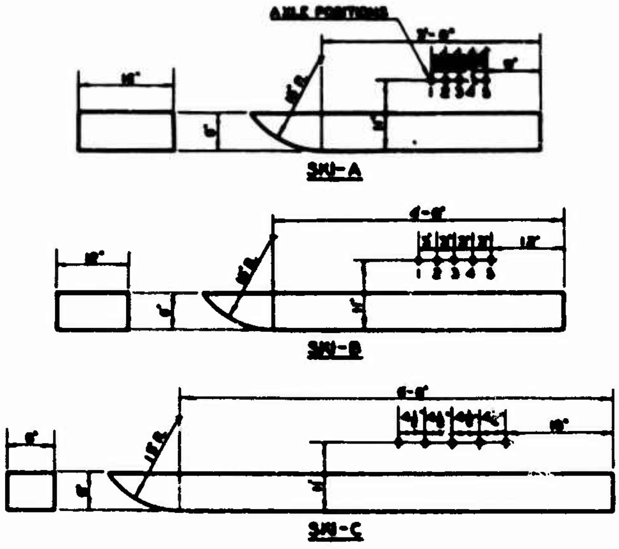


Fig. 2

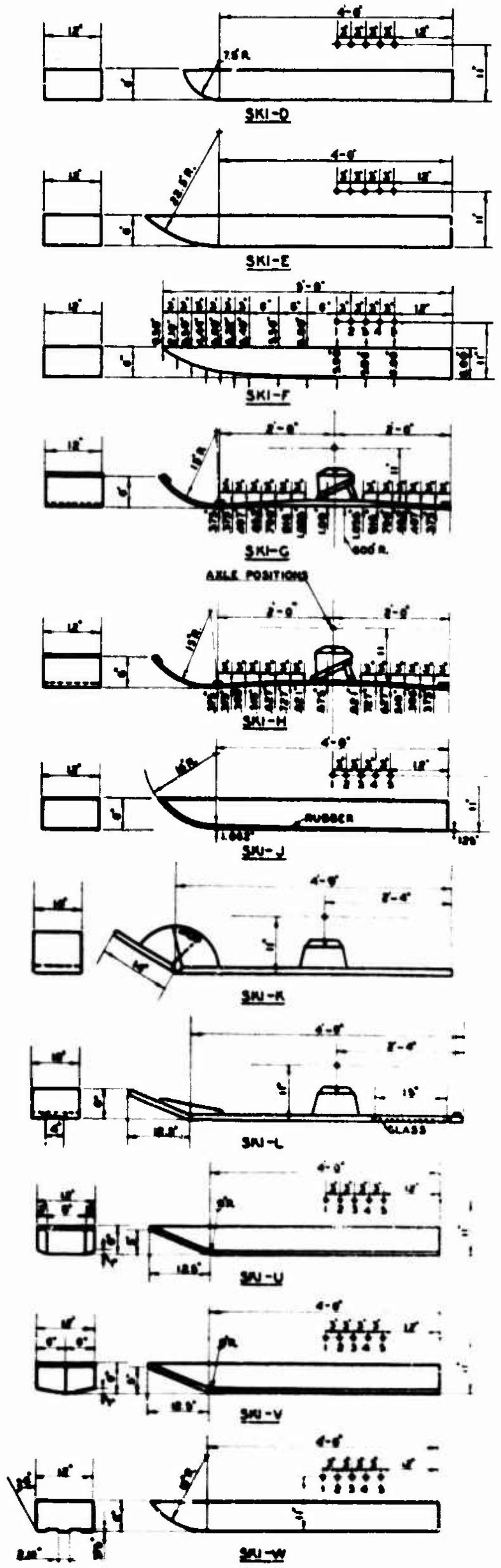


Fig. 3

The dimensions of the models are given in Fig. 2 and 3. The points numbered 1 to 5 indicate the different positions of the ski axle which were used in the tests.

The ratio of length to breadth of ski B was approximately that of most aircraft skis used in Canada. Ski B was therefore taken to be the standard model, and the skis with different materials on their bottoms were all of this shape. Data on the materials used to surface the ski bottoms are given in Table 1.

The skis of different shapes were surfaced with beeswax scraped to a very smooth surface. When damaged this surface could be restored very easily. Since the low friction of smooth beeswax on snow was a relatively small part of the total sliding resistance of the ski, it did not mask the effects of the different ski shapes.

All skis, except skis G, H, K and L, were of rigid box type construction, and were made of wood approximately one inch thick.

Skis G and H were made of American white ash and were so designed that their bottoms became straight when uniformly loaded to 200 pounds per square foot. When unloaded the arch of Ski G was 1%, and of Ski H, 2% of the length of the ski bottom neglecting the turned up end. This length was taken as 4 feet.

The purpose of the rubber wedge on the bottom of Ski J was to decrease the adhesion resistance. The wedge provided variable shear flexibility along the length of the ski so that the shearing stress between the ski and the snow would be concentrated at the stern of the ski.

The adjustable bow of Ski K provided a means for determining the maximum bow angle at which wet new snow would not adhere to the bow during sliding.

The glass window in the bottom of Ski L permitted observation of the contact between the ski bottom and the snow.

Small model skis, having the dimensions shown in Fig. 4 were used in wear tests of wax impregnated wood.

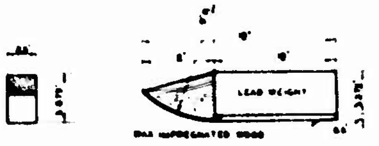
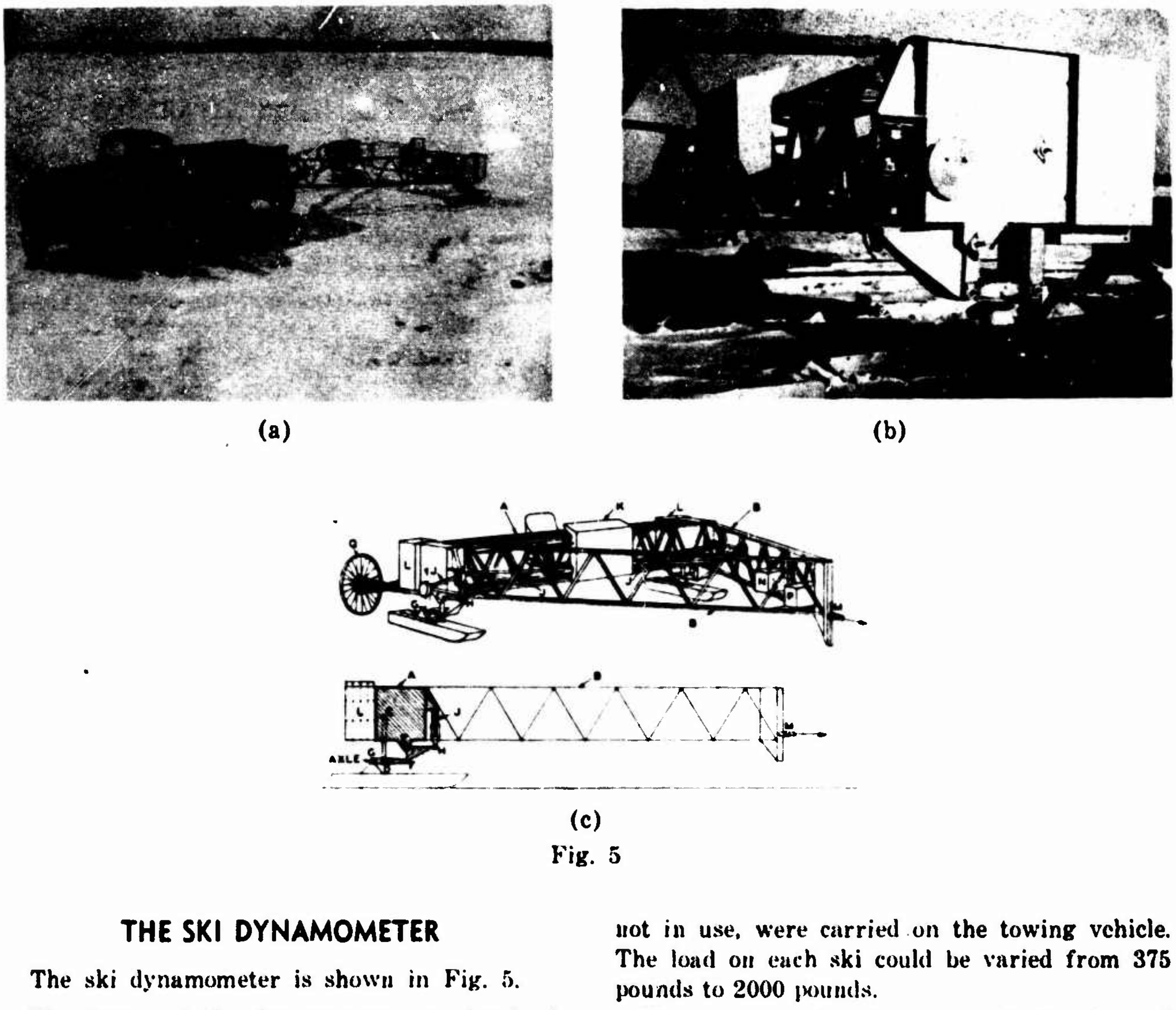


Fig. 4

The impregnation of the wood was performed in a small tank which could be connected to either a suction pump or a compressor. The wood was subjected to a high vacuum for at least 30 minutes, after which it was submerged in the molten wax and a pressure of 100 pounds per square inch applied until the wax had solidified. The excess wax was removed with a scraper. By this method, the volume of wax which could be forced into bass wood—which was the wood used for all the small models—was equal to 2/3 the volume of the wooden block.

The waxes used for impregnating the small models are given in Table II.



(a)

(b)

(c)

Fig. 5

THE SKI DYNAMOMETER

The ski dynamometer is shown in Fig. 5.

The frame of the dynamometer consisted of three members A, B and B which were joined together to form a large isosceles triangle in plan. Each end of the member A was supported on skis, while the apex of the triangular frame was supported by the towing vehicle. The universal-joint type towing fitting could be raised or lowered for levelling the dynamometer frame.

The frame of the dynamometer was loaded by placing weights in the weight boxes L. The weights were of lead, 25 pounds each, and, when not in use, were carried on the towing vehicle. The load on each ski could be varied from 375 pounds to 2000 pounds.

The dynamometer frame was built of wood joined together with sheet metal gussets and bolts. The links were of sheet metal and welded steel construction with ball-bearing pivots. The linkage was very free from friction.

The resistances of the two skis were communicated to the recording spring balances K through the links GF, the bell cranks F E H and the levers J.

The drum of the recording spring balances was driven by the bicycle wheel Q which ran in the packed track of the starboard ski.

The recording spring balances are shown in Fig. 6. Their capacity was 1000 pounds resistance per ski.

Fig. 6

Iso-Elastic Springs made by John Chatillon and Sons were used as the force measuring elements. These springs are very accurate over a wide range of temperatures.

The recording balances had very little friction. Although no damping device was used, the balances performed very satisfactorily.

The recording paper was a thin black paper coated with a very thin layer of wax. A stylus, with a smooth rounded point, made very sharp records by squeezing away the wax. There was very little friction between the stylus and the paper, and the wax protected the paper very effectively against the weather.

Besides recording the resistances of the two skis, equal intervals of time were indicated on the record by a marker which was operated by a clock controlled relay. Since the spacing of the time marks on the record was proportional to the towing velocity, a scale was constructed for measuring the towing velocity directly from the time marks.

A stylus connected to a short heavy pendulum recorded the fore and aft out-of-level angle of the dynamometer frame. The mean fore and aft out-of-level angle was required for correcting the mean measured resistance. The pendulum was magnetically damped. The out-of-level recording device is not shown in Fig. 6.

THE TOWING VEHICLE

The vehicle which was used for towing the dynamometer is shown in Fig. 1(a). It was a Ford V-8, 1½ ton truck, equipped with skis and an Innes-Cunningham Universal Half Track Rear Driving Unit. This vehicle had a speed range from 1.5 to 15 feet per second when towing the loaded dynamometer.

The towing fitting on the vehicle was mounted on a slide. By operating a long lever connected to the sliding mechanism, the dynamometer could be drawn aproximately ¾ inch toward the vehicle, thus providing a very steady pull for the adhesion tests. The vehicle was not moved while the adhesion resistance was being measured.

MISCELLANEOUS APPARATUS

(a) Recording Penetrometer

Curves of unit pressure against depth of penetration for a disc being forced into the snow cover were obtained with the apparatus shown in Fig. 7. The area of the disc was 0.4 square feet; the maximum pressure, slightly over 500 pounds per square foot, and the maximum penetration, 11 inches. The force measuring element consisted of a group of Iso-Elastic Springs. The curve shown in Fig. 14 was taken from one of the records. By arithmetically integrating the records obtained with this apparatus a curve of energy against unit pressure could be obtained.

Fig. 7

(b) Snow Sample Cutter

The specific gravity of the snow was obtained with a snow sample cutter which consisted of a thin brass tube approximately 2.2 inches diameter and 1.6 inches long. Both ends of the tube were open and the handle, which was attached to the outside of the tube, was bent to coincide with the tube axis. The internal volume of the tube was 100 cubic centimetres. Samples were obtained by pushing the tube horizontally into the snow and at the same time rotating the tube about its axis to minimize compressing the snow. The sample was cut off flush with the ends of the tube using a knife. The samples were placed in jars and, after melting, the volume of the water was measured in a graduate. The specific gravity of the snow was then given by:

$$\text{Specific Gravity} = \frac{\text{volume of the water}}{\text{volume of the snow}}$$

(c) Camera

Macrophotographs of samples of snow grains were made with a Leica camera and the lens extension attachment shown in Fig. 8. Magnifications of either 4 or 8 times, depending on the length of the extension tube, could be used. A rotating head at the top of the tube carried the camera, a ground glass focusing screen and a microscope eye-piece. When used as a microscope the magnification was either 40 or 80 times. A focusing stage was attached to the lower end of the tube. The samples were placed in a blackened recess in the aluminum cover of a wooden cold box. A mixture of common salt and snow inside the cold box cooled the aluminum cover and prevented the sample from melting.

Fig. 8

Penetrometer records, specific gravity, and macrophotographs of samples of snow grains were taken every day during the tests. The air temperature was measured at the beginning of every test.

DEFINITION OF COEFFICIENTS

The results of the tests are presented in the form of coefficients.

Let L = load on the ski + weight of ski, lb.,
b = breadth of ski, ft.,
l = length of ski bottom, ft. (the area $b.l$ was taken as 4 sq. ft. for all skis),
R = aspect ratio = l/b,
p = unit pressure = L/bl, lb. per sq. ft.,
d = depth of ski track, ft.,
E = energy required to pack one sq. ft. of snow to a unit pressure p, ft. lb.
S = sliding resistance, lb.
P = resistance due to packing the snow, lb. (part of the sliding resistance),
A = adhesion resistance, lb. (force required to start the ski sliding),

then $\gamma = E/d.p$,
$\mu_p = \gamma.d/l$ (coefficient of resistance due to packing),
$\mu_s = S/L$ (coefficient of sliding resistance),
$\mu_f = \mu_s - \mu_p$ (coefficient of resistance due to friction),
$\mu_a = A/L$ (coefficient of adhesion).

THE SLIDING TESTS

The sliding tests were usually made at approximately 2.5 and 10 feet per second. Their purpose was to determine the effect on sliding resistance of (a) ski shape, (b) unit loading, (c) point of application of the load, (d) material in contact with the snow, and (e) snow conditions such as temperature, structure, etc. Tests were also made with flexible and rigid skis to investigate the effect of flexibility on sliding resistance.

The continual change in the skiing qualities of snow made it impossible to compare the sliding resistances of two different skis unless the skis were tested at the same time. For this reason, Ski B surfaced with beeswax was always used as one of the two skis in a test.

In each test, a correction for the mean out-of-level angle of the dynamometer frame was made to the mean recorded resistance to obtain the sliding resistance.

The results of the sliding tests are given in the following.

(a) Ski Shape

The most important factor in the shape of the ski was found to be the aspect ratio R; the greater the ratio, the lower the sliding resistance. Usually other considerations, such as ease of turning while taxiing, or interference with the propeller, etc., fix the upper limit to the length of the ski. The tests indicated that the aspect ratio should not be less than 5, that good proportions would be about 6, and that there is little to be gained in increasing the ratio beyond 9.

Tests with Ski K showed that, when the bow angle was greater than 20° or 25°, wet new snow adhered to the forward part of the bow. Whenever a small amount of wet new snow adhered to the bow, more snow rapidly added to it and often formed a large slab of snow which was pushed forward by the ski. This considerably increased the sliding resistance.

The sliding resistance of Ski F was usually the same as that of Ski B. However, in deep, wet new snow, Ski F had less sliding resistance than Ski B because its bow was finer and remained clean, whereas the snow adhered to the bow of Ski B. Apparently the shape of the ski profile is unimportant, provided the bow is sufficiently fine.

The cross-sectional shape of the ski was found to be relatively unimportant, although Ski W-2 was slightly better than Ski B-2.

(b) Unit Loading

In all cases, except Ski B-18, increasing the unit loading decreased the sliding resistance coefficient. This is shown in Fig. 9. Each point represents the average of from 15 to 40 sliding tests on different days irrespective of the snow conditions. Practically all of these tests were made on *wind toughened snow*.

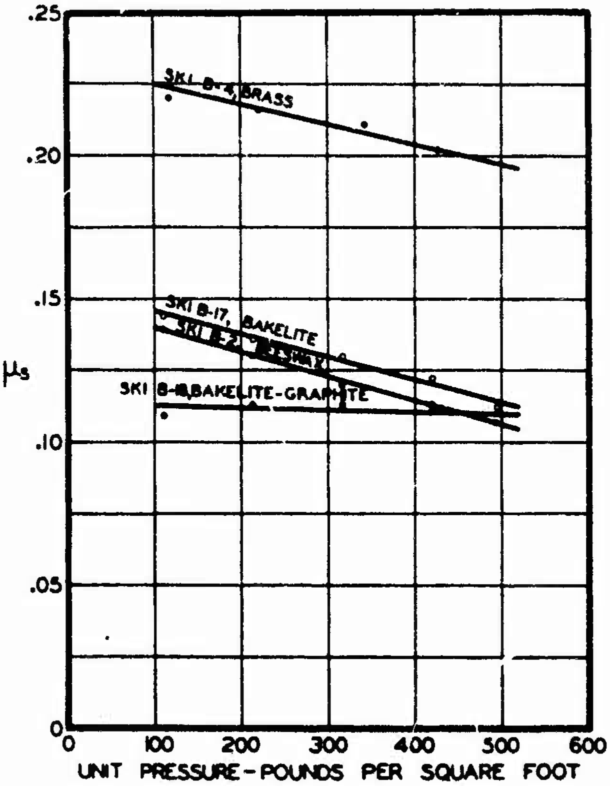


Fig. 9

(c) Point of Application of the Load

The best point of application of the load for Skis A, B, C and E was axle position No. 2, for Ski D it was No. 3, and for Ski F it was No. 1. The curves of sliding resistance against axle position were all very flat near the best axle position, so that the proper location of the ski axle is not very critical. Apparently the resultant of the vertical load, the horizontal force acting through the axle to overcome the sliding resistance and the moment due to the ski trimming gear should pass approximately through the centre of the length of the flat bottom of the ski. Since sliding resistance varies appreciably with different snow conditions, very high axle positions must be avoided. Short skis with high axles tend to dive when the sliding resistance is high. The towing vehicle skis, which were short, had high axles and comparatively blunt bows, tended to dive in deep wet new snow.

(d) Material in Contact with the Snow

The results of the sliding tests of skis surfaced with different materials are given in Table III.

The materials which had low sliding resistance were: beeswax, monel metal, white ash treated with raw linseed oil, most of the bakelites, and the Schwarz finish. The frequent need for rewaxing, which would be somewhat difficult in the case of aircraft skis, makes the use of wax impractical. Wood, treated with linseed oil, would probably require frequent treatment also. The objection to the use of monel metal is that it has a high adhesion resistance. The Schwarz finish was found to be too brittle to be serviceable as a ski surface. Therefore bakelite appears to be the most satisfactory material especially when the skis are highly loaded.

A number of Canadian aircraft operators have used highly loaded bakelite shod skis for several winters with very satisfactory results. Besides having excellent snow characteristics, bakelite has very high resistance to wear, being much superior to sheet metal in this respect.

The effect of the large number of screws in Ski B-23 was to slightly increase the sliding resistance.

(e) Snow Conditions

The highest sliding resistances occurred when the snow was *slightly* wet but still retained some of its dendritic or needle-like structure. Highly loaded bakelite shod skis had considerably less resistance on this type of snow than any other.

Dry new snow, of dendritic structure, gave high sliding resistance, but once the snow had lost its dendritic structure the sliding resistance was low. There seemed to be some evidence in the tests that, for similar snow structure, the finer the structure, the higher the sliding resistance.

Figs. 10, 11 and 12 show the effect of temperature on sliding resistance for *wind toughened snow*. All skis showed a similar effect.

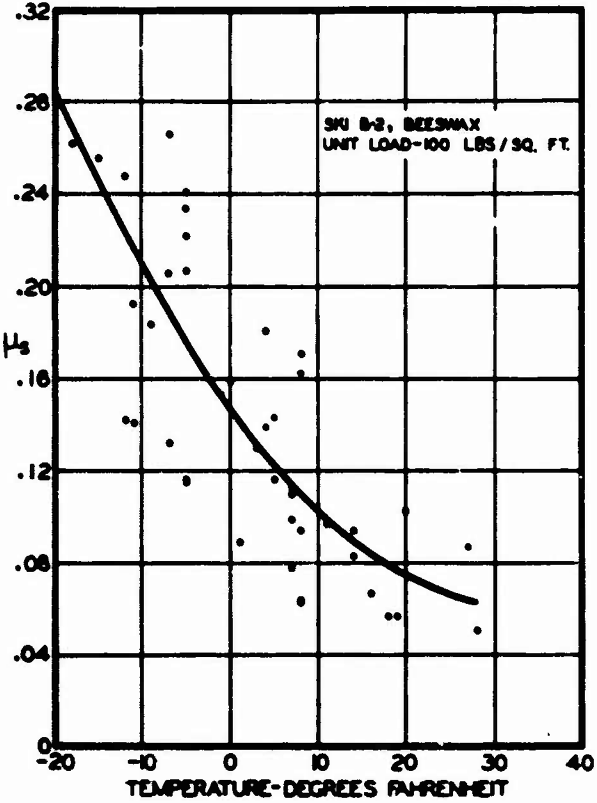


Fig. 10

Whenever the snow was very wet, the sliding resistance was higher at the higher towing speed, and if the snow was very hard packed and covered with water, the sliding resistance, although low,

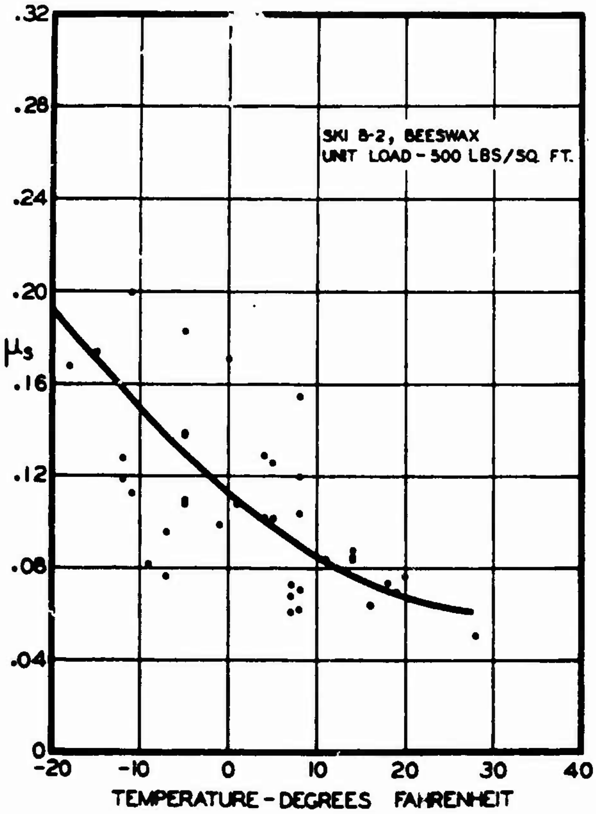


Fig. 11

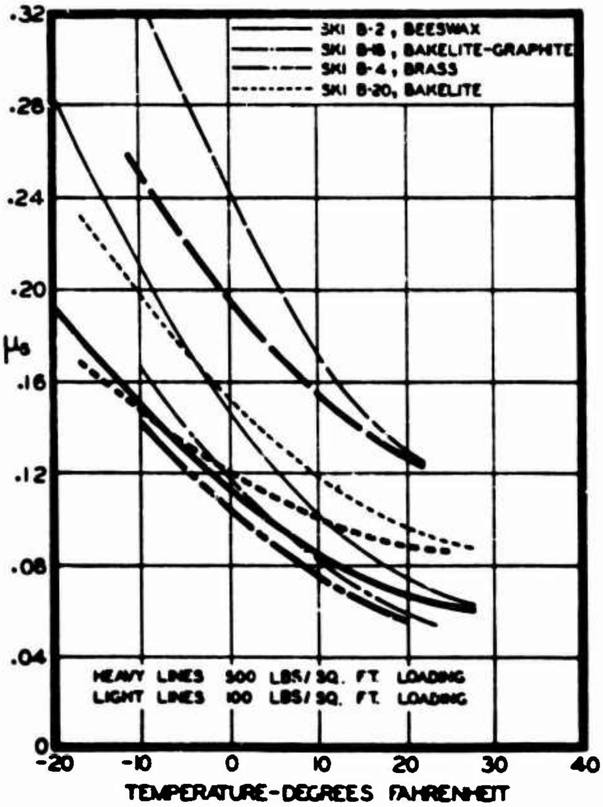


Fig. 12

was even higher than the adhesion resistance. For all other types of snow the sliding resistance was practically the same at the two towing speeds.

There was an appreciable difference between the results of the tests at Ottawa and at Sioux Lookout. This was due to the difference in the snow conditions at these places. At Sioux Lookout, during most of the winter, the air temperature is always well below the freezing point, and the wind soon toughens the snow and gives it a very fine structure. The snow at the surface is very seldom melted by the sun. At Ottawa the temperatures are higher so that wet snow is quite common. Often the snow passes through many cycles of melting and freezing which gives the snow a fairly coarse structure. For any one material, the minimum sliding resistance coefficient obtained at Ottawa was less than that obtained at Sioux Lookout, and the maximum sliding resistance coefficient obtained at Ottawa was appreciably higher than that obtained at Sioux Lookout.

(f) Flexibility

Flexibility of the ski had no effect on the sliding resistance.

THE ADHESION TESTS

All the adhesion tests were made using axle position No. 1. The period of time in which the skis were permitted to adhere to the snow was always 5 minutes.

In each test, the recorded resistance was corrected for the out-of-level angle of the dynamometer and the out-of-level angle of the deck of the ski.

The results of the adhesion tests are given in Table IV.

(a) Material in Contact with the Snow

The most important factor in the adhesion tests was the material in contact with the snow. With the exception of Ski B-13, all the bakelites and the bakelite varnish had low adhesion resistance.

The surface scratches of Ski B-22 definitely increased the adhesion resistance, while the screws in Ski B-23 increased the adhesion resistance very little.

(b) Unit Loading

The adhesion coefficient, in most cases, decreased with increased unit loading. An example is given in Fig. 13.

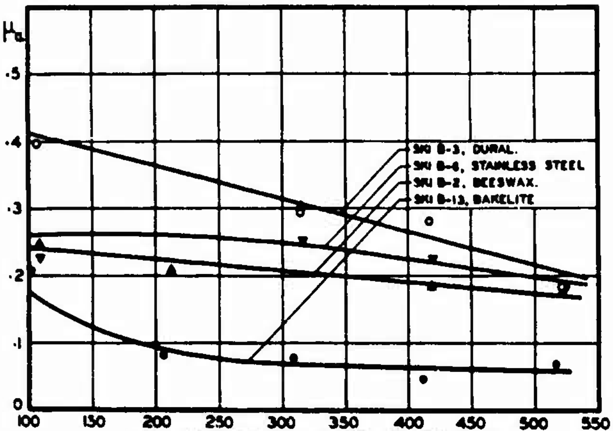


Fig. 13

(c) Flexibility

The adhesion resistances of the flexible skis G, H and J were between 80% and 85% of the adhesion resistances of rigid skis surfaced with the same materials. There was no measurable difference between Skis G and H. Apparently, due to the height of the axle, a flexible ski tends to bend when the towing force is applied, which results in a non-uniform distribution of the shear between the ski and the snow.

(d) Shape

The shape of the ski had no effect on the adhesion resistance.

(e) Snow Conditions

The tests showed very little correlation between snow conditions and adhesion resistance. The only conclusions which could be drawn were: (1) the adhesion resistance of all skis was low when the snow was *very wet*, (2) the adhesion resistance of all skis surfaced with bakelite or beeswax was low for air temperatures above +20°F, and (3) the adhesion resistance of all the metal shod skis was particularly high for air temperatures between +20°F and +40°F.

THE WEAR TESTS OF THE SMALL SKIS

The small, wax impregnated skis were towed by horizontal wires fastened to frames projecting from the sides of the towing vehicle. At intervals, the ski bottoms were examined. After being towed for 12 miles in slightly wet snow, all the skis showed that the wax had been worn away but that the wood fibres had not worn appreciably. It was concluded that wax impregnated wood was not a satisfactory material for the bottoms of aircraft skis.

THE PENETROMETER RECORDS

An example of a penetrometer record is shown in Fig. 14.

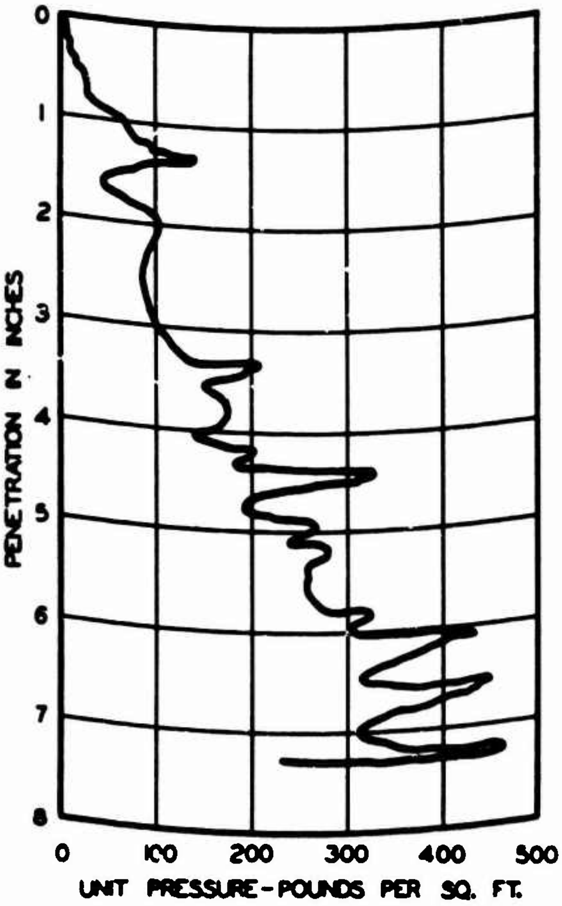


Fig. 14

In order to obtain the average shape of the penetration curve, the ratios of the penetrations at 50, 100, 150, ... 450 and 500 pounds per square foot, to the penetration at 500 pounds per square foot, were found for all the penetration tests at Sioux Lookout, and a curve drawn through their mean values. The resulting curve is shown in Fig. 15. The average and maximum penetrations, at 500 pounds per square foot, were 6.18 and 9.8 inches respectively.

At any point "P" on the curve

$$\frac{\text{Area OPA}}{\text{Area OBPA}} = \gamma$$

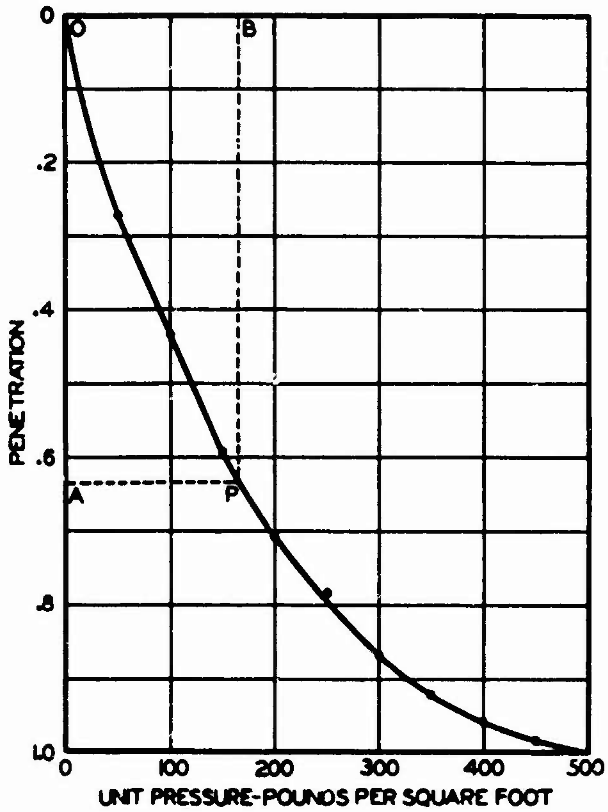


Fig. 15

Values of the coefficient γ plotted against unit pressure are shown in Fig. 16.

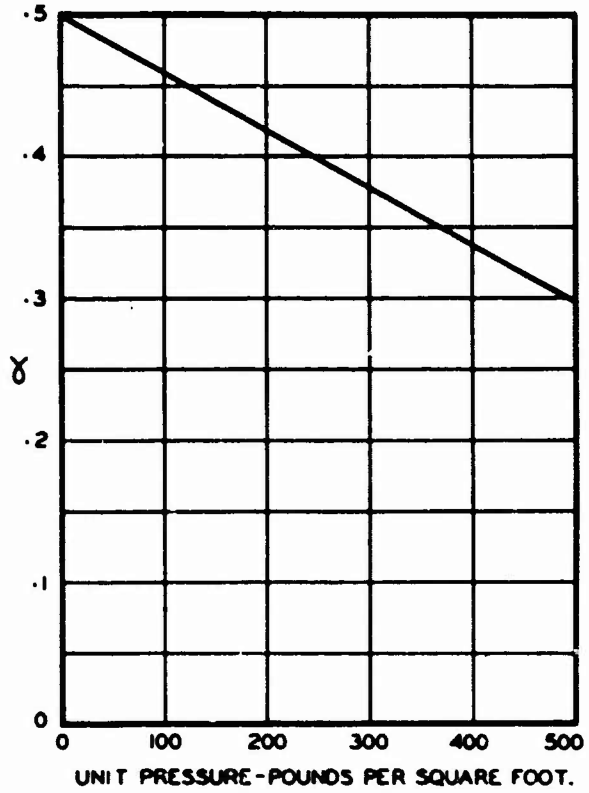


Fig. 16

The energy required to pack s feet of ski track is equal to:

$$s . b . \gamma . d . p$$

The energy required is also equal to P. s, therefore:

$$P = b . \gamma . d . p$$

and $\mu_p = \frac{P}{L} = \frac{b . \gamma . d . p}{L} = \frac{\gamma . d}{l}$

Therefore the resistance due to packing a ski track is equivalent to climbing a grade having a rise d in a length of l/γ. The length l/γ is between 2 and 3 times the length of the flat bottom of the ski.

This expression for μ_p may also be derived by integrating the horizontal component of the pressure acting normal to the bow of the ski. It should be pointed out that μ_p is independent of the shape of the bow provided the bow is not so blunt that it acts like a plough.

The curves of Fig. 15 and 16 were used to calculate the value of μ_p for a ski carrying 2500 lbs. The penetration was taken as 6 inches for p equal to 500 lbs. per sq. ft. The results are plotted in Fig. 17. The upper curve is for an aspect ratio of 4, and the lower curve for an aspect ratio of 8.

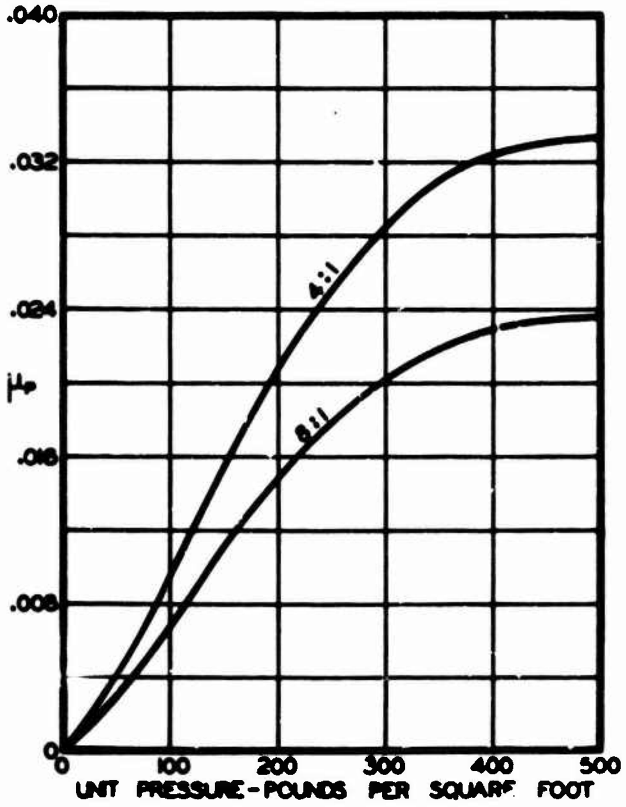


Fig. 17

Fig. 17 gives the order of the *mean* value of μ_p since it is based on the mean of the penetrometer results. Other conditions being equal, μ_p varies directly as $\sqrt{L}$ and inversely as $\sqrt{R}$.

Considering the aspect ratio variable and all other conditions fixed, the variation of μ_p, calculated by the above method, is not sufficient to account for the variation of μ_s found in the tests. Apparently μ_f also varies with aspect ratio; the higher the aspect ratio, the lower the value of μ_f.

A THEORY OF SKI RESISTANCE

The results of all the sliding tests can be explained by a theory based on the idea that the contact between the ski and the snow takes place at a large number of small areas, and that sufficient heat is generated by friction to melt enough snow to provide water lubrication. The friction is considered to be made up of (a) solid friction, most of which occurs at the bow of the ski, (b) viscous resistance, due to shearing in the thin film of water, and (c) resistance due to surface tension effects. Each of these components of the total friction will vary with temperature, snow structure, unit loading and material in contact with the snow.

The surface tension resistance is due to drops of water which enclose each small area of contact. During sliding, the force due to surface tension does not act normal to the ski bottom, since the leading angle of contact of the drops of water is greater than the trailing angle of contact. There is, therefore, a tangential component which resists the sliding of the ski. The tangential component is proportional to the sum of the perimeters of all the drops of water and to the difference between the leading and trailing angles of contact for the material on the ski bottom.

The ski with the glass window was constructed in order to obtain some evidence to support this theory, and it was found that the snow did contact the ski bottom at a large number of small areas, each enclosed in a drop of water. It was estimated, from observation, that the total area of contact was of the order of 20% at a unit loading of 200 lbs. per sq. ft., and 50% at 500 lbs. per sq. ft.

Further, it was observed that, whenever there was evidence of wear on the ski bottom, it always occurred at the lowest part of the bow, which supports the supposition that solid friction takes place at the point where the ski meets the undisturbed snow.

When the snow is *slightly* wet and of dendritic structure, the sum of the perimeters of all the drops of water, and therefore the surface tension resistance, is much greater than for any other type of snow. Increasing the unit loading causes adjacent areas of contact to join, which decreases the sum of the perimeters of all the drops of water, and thus decreases the surface tension resistance.

On dry snow, the amount of water required for lubrication, and therefore the amount of solid friction, would be roughly proportional to the width of the ski. This explains the variation of μ_f with aspect ratio.

When the temperature is very low, a considerable amount of heat must be generated to supply sufficient water lubrication. This indicates that very narrow skis are required, i.e., high unit loads and high aspect ratios, in order to decrease the amount of snow which would have to be melted to provide the lubrication.

In very wet snow, the entire bottom of the ski is wet, and most of the resistance is due to viscous resistance which varies as the wetted area and the square of the speed. Increasing the unit loading, i.e., decreasing the wetted area, seems to be the only method of decreasing sliding resistance in very wet snow.

RECOMMENDATIONS FOR SKI DESIGN

If the following recommendations are adopted, the snow characteristics of the skis will be improved under all snow conditions. The maximum sliding resistance coefficient will be less than one-half, and the maximum adhesion resistance coefficient less than one-third of present values.

1. Material

Bakelite was found to be the most satisfactory material for the bottoms of aircraft skis because, under all adverse snow conditions, its sliding resistance was lower than any other, its adhesion resistance was much lower than any other, and in actual service it has been found to have high resistance to wear. However, it should never be used on the bottoms of sport skis, because its unusually low adhesion resistance would make climbing very difficult.

There are two satisfactory methods for applying the bakelite to the ski: (a) laminated bakelite sheet fastened to a ski of ordinary wooden construction with countersunk screws or rivets (the thickness of the sheet need only be sufficient for countersinking), and (b) thin laminated bakelite sheet (.035" to .070" thick) fastened to a bakelite bonded ply wood ski with a hot or cold setting bakelite adhesive.

2. Unit Loading

Although highly loaded skis sink deeper in the snow, their adhesion and sliding resistance coefficients are lower than those of lightly loaded skis. A unit loading of between 400 and 500 lbs. per sq. ft. is recommended instead of 200 lbs. per sq. ft. which is the present general practice. Still higher unit loading is recommended for skis that are to be used at temperatures below -40°F.

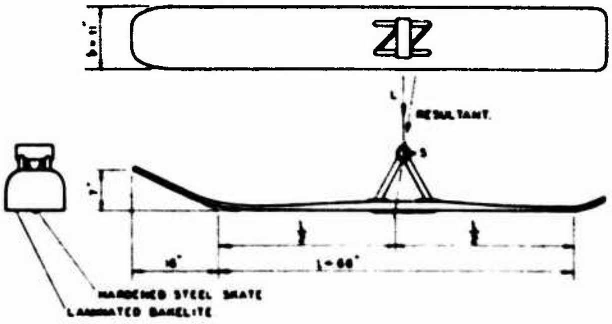
3. Aspect Ratio

The aspect ratio should be about 6. If the skis are to be used at very low temperatures, i.e., below -40°F., the aspect ratio should be even higher.

4. Cross Sectional Shape

Since the shape of the cross section had practically no effect on the adhesion or sliding resistances, the simplest shape is the most suitable. A cross sectional shape similar to that of Ski U is suitable for streamlined skis. A flat cross section is recommended for skis which are not streamlined.

The side slipping of skis on smooth ice can be eliminated by a short, hardened steel skate as shown in Fig. 18.



SKI FOR 5000 POUND, LOW POWERED AIRCRAFT

Fig. 18

5. Bow

The maximum angle of the bow should be between 20° and 25°.

The height of the bow depends principally on the roughness of the landing fields on which the skis are to be used. In Canada, 6 to 8 inches is quite common, although skis with only 4 inches bow height have been used without difficulty. For heavily loaded skis, a bow height of from 6 to 8 inches seems reasonable.

The stern of the ski should be bent up, as shown in Fig. 18, to facilitate ground handling of the aircraft.

6. Flexible or Rigid Construction

Streamlined skis are usually used on high speed aircraft which have ample power to overcome the adhesion resistance of highly loaded bakelite skis. There is, therefore, no need to make streamlined skis flexible. However, flexible skis which are not streamlined are more suitable for low powered aircraft than rigid streamlined skis.

7. Axle Position

The axle should be so located that the resultant of the force acting through the axle to overcome the sliding resistance, the load, and the moment due to the ski trimming device, will pass approximately through the centre of the length of the ski bottom.

The axle height should not be greater than one-fifth the length of the ski bottom.

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TABLE I

MATERIALS USED ON SKI BOTTOMS

Ski	Material on Ski Bottom
A- 1	16 g. Aluminum.
A- 2	1/16" thick Beeswax scraped very smooth.
B- 1	16 g. Aluminum.
B- 2	1/16" thick Beeswax scraped very smooth.
B- 3	16 g. Dural.
B- 4	16 g. Brass.
B- 5	16 g. Monel Metal.
B- 6	22 g. Stainless Steel (Firth's Staybrite).
B- 7	Bakelite varnish (Bakelite Corporation of Canada).
B- 8	Super Val Spar Varnish.
B- 9	Varnish made by dissolving 30% Polystyrene (Resoglas) and 0.75% Di n-butyl phthalate in 69.25% Benzene (by weight).
B-10	Varnish made by dissolving 30% Polystyrene, 1.5% Di n-butyl phthalate and 1.5% Sturbinol (grade F) in 67% Benzene.
B-11	American white ash treated with raw linseed oil.
B-12	1/16" thick Rubber (Gutta Percha Stock No. 10, shore hardness 63).
B-13	1/32" thick Bakelite grade L linen base, natural (yellow) finish.
B-14	1/32" thick Bakelite, grade XX, paper base, glossy black finish.
B-15	1/8" thick Bakelite, grade F8-2, fabric base.
B-16	1/8" thick Bakelite, grade F 14-2, fabric base.
B-17	1/8" thick Bakelite, grade F 14-1, fabric base.
B-18	1/8" thick Bakelite, grade F 15-1, fabric base with graphite incorporated in surface.
B-19	1/8" thick Bakelite, grade F 14-2, except fine weave fabric base.
B-20	1/8" thick Bakelite, grade E 8-2, paper base.
B-21	1/32" thick Bakelite, grade L, linen base.
B-22	1/32" thick Bakelite, grade L, linen base, surface scratched longitudinally with medium sandpaper.
B-23	1/8" thick Bakelite, grade L, fabric base fastened to ski with No. 8 flathead brass screws countersunk 1/32" below the surface. Screws on 2" centers both laterally and longitudinally.
B-24	Schwarz Finish (Canadian Vickers).
C- 1	16 g. Aluminum.
C- 2	1/16" thick Beeswax scraped very smooth.
D- 1	16 g. Aluminum.
D- 2	1/16" thick Beeswax scraped very smooth.
E- 1	16 g. Aluminum.
E- 2	1/16" thick Beeswax scraped very smooth.
F- 1	16 g. Aluminum.
F- 2	1/16" thick Beeswax scraped very smooth.
G- 8	Super Val Spar Varnish.
G-13	1/32" thick Bakelite, grade L, linen base.
H- 8	Super Val Spar Varnish.
J-12	Rubber wedge. Soft rubber core of Gutta Percha stock No. 560, Shore hardness 35, tapering from 1" to 1/16" covered with 1/16" rubber sheet, Gutta Percha Stock No. 10, Shore hardness 63. The core was cemented to the ski and the rubber sheet was cemented to the core.
K- 4	16 g. Brass on bow only.
K-13	1/8" thick Bakelite, grade L, fabric base.
L- 8	Glass window, 4" x 15", flush with ski bottom.
U- 2	1/16" thick Beswax scraped very smooth.
V- 2	1/16" thick Beeswax scraped very smooth.
U- 2	1/16" thick Beeswax scraped very smooth.

Note: Bakelite grades are those of the Bakelite Corporation of Canada.

TABLE II

WAXES USED FOR IMPREGNATING SMALL MODEL SKIS

Ski	Wax (percentage by weight)
a	100% Paraffin.
b	100% Ceresin.
c	80% Paraffin, 20% Candelilla.
d	80% Ceresin, 20% Candelilla.
e	90% Ceresin, 10% Oil (equal parts S.A.E. 30 and S.A.E. 60).
f	75% Ceresin, 25% Oil.
g	75% Ceresin, 25% Suet.
h	65% Ceresin, 35% Oil.
i	65% Ceresin, 10% Candelilla, 25% Oil.
j	55% Ceresin, 10% Candelilla, 35% Oil.
k	100% Socony amorphous.
l	75% Ceresin, 17.5% Rosin, 7.5% Turpentine.
m	100% Beeswax.

TABLE III

RESULTS OF SLIDING TESTS

	μ_s		
Ski	Min.	Max. †	Where Tested
B- 2	.029	.288	Ottawa and Sioux Lookout.
B- 3	.133	.314	Ottawa and Sioux Lookout.
B- 4	.122	.428	Ottawa and Sioux Lookout.
B- 5	.103	.167	Ottawa and Sioux Lookout.
B- 6	.128	.322	Ottawa and Sioux Lookout.
B-7 to B-10	.072	.211	Very few tests at Ottawa.
B-11	.069	.215	Sioux Lookout.
B-13	.075	.407	Ottawa and Sioux Lookout.
B-14	.125	.465	Ottawa and Sioux Lookout.
B-15	.084	.270	Sioux Lookout.
B-16	.064	.223	Sioux Lookout.
B-17	.065	.197	Sioux Lookout.
B-18	.068	.162	Sioux Lookout.
B-19	.071	.238	Sioux Lookout.
B-20	.074	.226	Sioux Lookout.
B-24*	.127	.148	Sioux Lookout.
W- 2	.078	.178	Only 4 tests at Sioux Lookout.

TABLE IV

RESULTS OF ADHESION TESTS

	μ_a		
Ski	Min.	Max. †	Where Tested
B- 2	.092	.808	Ottawa and Sioux Lookout.
B- 3**	.121	1.075	Ottawa.
B- 4	.226	.977	Ottawa and Sioux Lookout.
B- 5	.197	.847	Ottawa and Sioux Lookout.
B- 6**	.056	.992	Ottawa and Sioux Lookout.
B- 7	.336	.631	Ottawa.
B- 8	.558	.816	Ottawa.
B- 9	.290	.958	Ottawa.
B-10	.130	.991	Ottawa.
B-11	.420	.811	Sioux Lookout.
B-12	.508	1.106	Ottawa.
B-13**	.024	.932	Ottawa and Sioux Lookout.
B-14	.085	.580	Ottawa and Sioux Lookout.
B-15	.141	.717	Sioux Lookout.
B-16	.227	.620	Sioux Lookout.
B-17	.227	.590	Sioux Lookout.
B-18	.145	.605	Sioux Lookout.
B-19	.241	.359	Only one test, Sioux Lookout.
B-20	.421	.693	Only one test, Sioux Lookout.
B-21	.140	.688	Sioux Lookout.
B-22	.526	1.031	Sioux Lookout.
B-24	.375	.834	Sioux Lookout.

*—Only two tests. Schwarz finish too brittle.

**—Tests on hard packed wet snow gave μ_a min. less than μ_s min.

†—All maximum values occurred at low unit loading.

Note: By directly comparing two skis at a time certain skis were eliminated. Therefore, some of the skis were tested on only a few types of snow.