DISCUSSION

by

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Mr. Work has discussed the requirements of an over-snow vehicle in a broad general way and has done it so well that it is difficult to add anything of real significance.

This paper's real value lies in that it clearly sets down these requirements from the point of view of one who has had considerable experience with various vehicles.

The rating table proposed by Mr. Work clearly reflects his experiences with the use of vehicles in snow surveys; and it is interesting to note the emphasis placed on mechanical dependability.

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THE CANADIAN SNOW-COVER SURVEY

by

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Every winter, for several months, almost the whole of Canada is covered with snow. This fact has made snow such a common-place material to Canadians that the need for its scientific study is not generally appreciated. Even the simplest study of the effects of snow on the Canadian economy will serve to show that, although long neglected, snow is a material which merits a great deal of scientific attention in Canada.

The National Research Council of Canada has appreciated the importance of snow and ice for some time and has been carrying out investigations in this unusual field of research since 1935. For the benefit of those who may not be familiar with the National Research Council of Canada, the Council is the Dominion Government's main research organization. It has eight Scientific Divisions covering practically all branches of science. Its laboratories are quite extensive, modern and well equipped and employ a staff of 3,000.

The initial problem undertaken in this field by the Council was the investigation of the performance of different types of aircraft skis on snow.

It soon became evident that the resistance of a ski was much more dependent upon the condition of the snow than on the design of the ski and it was not until a fairly detailed study of snow had been made that the ski problem could be properly resolved. Since the ski tests gave a great deal of insight into the character of snow and emphasized the unusually wide range of its properties, these tests have had a marked influence on our point of view with regard to snow and have been the background for the subsequent snow studies undertaken by the Council.

The knowledge gained from the peacetime study of snow was applied to a number of wartime problems during the years 1940-45. The Council took part in the development of the over-snow vehicle known as the "Weasel" and carried out ice studies as part of the famous "Habbakuk" project. It was in connection with the Weasel project that the problem of predicting snow conditions in general were very conflicting and the literature was found to be of little help. In the end, this phase of the Weasel project had to be abandoned, but it did serve to show the need for a systematic study of snow conditions and, in time, gave birth to the idea of the Canadian Snow-Cover Survey.

During the war the Council established a Low Temperature Section with the primary purpose of developing improved methods of protecting aircraft against accumulations of ice during flight. This Section has very complete facilities including a large refrigeration chamber, a refrigerated wind tunnel for studying icing and a special North Star aircraft equipped as a flying laboratory. This group has made important contributions to our knowledge of moisture conditions in the atmosphere. Mr. J. L. Orr, who is presenting a paper on the subject of induced precipitation to this Conference, is in charge of the Low Temperature Laboratory.

Late in the war the Council formed an Associate Committee on Soil and Snow Mechanics which fostered the further development of the snow studies with special reference to the performance of tracked vehicles. Major Bekker, a member of the Associate Committee, used models to study the mode of failure under the track of a vehicle and developed a theory which has led to a substantial increase in the tractive effort of tracked vehicles traversing soft soil or snow.

The Snow-Cover Survey was one of the first peacetime projects undertaken by the Associate Committee. A technique and instruments were especially developed for the survey and were given a preliminary trial during the Musk-Ox Expedition across Northern Canada early in 1946. The survey was commenced the following winter and has been continued up to the present time.

In 1947 the Council set up a new Division of Building Research with R. F. Legget, Chairman of the Associate Committee on Soil and Snow Mechanics since its inception, as Director of the new Division. Since soil and snow studies are fundamentally very closely related, Soil Mechanics and Snow Mechanics Sections were established in the new Division.

As a result of the cooperation between the Swiss Institute for Snow and Avalanche Research and the National Research Council of Canada, arrange-

ments were made for the chief scientist of the Institute, Dr. Marcel de Quervain, to spend a year with the Council in order to assist the Division of Building Research with the establishment of the Snow Mechanics Section and to recommend a programme for snow and ice research in Canada. Dr. de Quervain's comprehensive report very clearly demonstrates the value of fundamental research into the properties of snow and ice and points to the way in which the work should be pursued if Canada is to give appropriate attention to these common-place materials which are of such economic importance. Plans have been made to provide adequate laboratory facilities for the Snow Mechanics Section in the new building which is being erected for the Division of Building Research.

The object of the Snow-Cover Survey was to obtain data on the physical features of the snow-cover at a number of observation stations. The data would give a general picture of snow conditions in different parts of Canada and would be valuable in a wide variety of winter problems. The survey was also intended to provide a basis for future studies of the fundamental properties of snow.

The observations were commenced in January 1947 and were carried out by the Meteorological Service of the Department of Transport. During the first winter there were ten observation stations, located as shown in Fig. 1, and in the following winter an observation station at Aklavik and another at Resolute Bay were added. Practically all of the stations were "exposed stations" with a flat test area completely exposed to wind and sun.

A complete set of the instruments is shown in Fig. 2. These instruments have now become the standard in Canada for obtaining specific data on fallen snow.

The method followed at each station was to dig a test pit in the snow cover once each week and to carry out measurements of temperature, specific gravity, free-water-content, hardness and average size and shape of the snow grains in each distinctly different layer from the snow surface down to the ground. Air temperature, snow-cover depth and the location of the snow layers were also determined. The daily average air temperature, wind speed, hours of sunshine and the kind and amount of new precipitation were taken from the daily meteorological records of the station in order to maintain continuity from one set of test pit measurements to the next. Later it was found that very little value was lost by limiting the test pit measurements to once every two weeks.

The results of the 1947 survey were given in a paper presented at the Oslo Conference of the International Union of Geodesy and Geophysics in 1948. Copies of this paper (Reference 1) are available from the National Research Council of Canada.

Several papers at the Oslo Conference pointed to the need of a standardized international classification for snow with the result that a Committee on Snow Classification was formed. Dr. Vincent Schaefer of the Knolls Laboratory, G. E. Co., Dr. Marcel de Quervain of the Swiss Snow

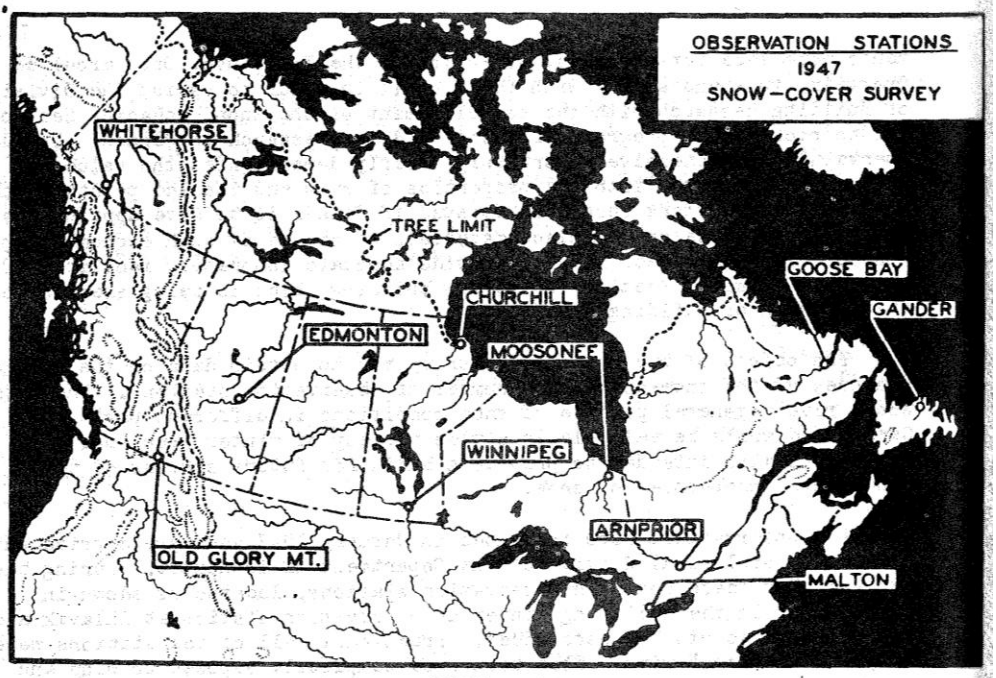
OBSERVATION STATIONS
1947
SNOW-COVER SURVEY
WHITEHORSE
TREE LIMIT
GOOSE BAY
CHURCHILL
GANDER
EDMONTON
MOOSONEE
WINNIPEG
ARNPRIOR
OLD GLORY MT.
MALTON

FIG. 1.

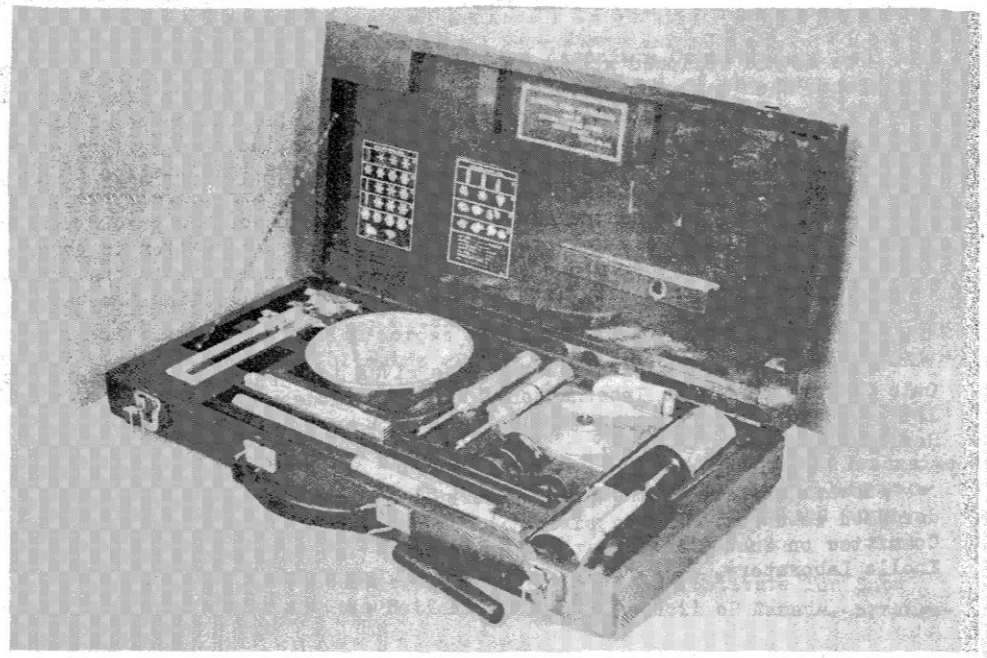

FIG. 2.

Research Institute and the present author are members of the Committee. Prof. U. Nakaya of Hokkaido Imperial University, Japan, also took part in the meeting at which a Tentative Snow Classification was drafted. The Tentative Snow Classification has been widely circulated and, although a few minor changes appear to be advisable before it is recommended for adoption, it has, in general, been received with considerable favour.

Because the Tentative Snow Classification was a step forward in the method of describing snow, this classification was adopted in the Snow-Cover Survey. It has been in use for two winters and has proven to be ideal for this purpose. The technique used in the survey has therefore been revised and is available as Technical Memorandum No. 18 of the Associate Committee on Soil and Snow Mechanics (Reference 2). This Memorandum should be of considerable interest to everyone engaged in snow studies.

A notable feature of the survey is the fact that all the results fit remarkably well together and present a clear picture of Canadian snow conditions on exposed areas. Although the results for the four winters follow closely those presented in the Oslo paper, considerable data of statistical value have been added. A complete report on the results of the survey is being prepared at the present time. The results throw far more light on the characteristics of snow than was anticipated.

Some recent tests carried out by the Council may be of interest. An attempt was made to correlate snow hardness, as measured by the N. R. C. hardness gauge, with the tensile strength of the snow, but no definite correlation could be obtained. It was possible, however, to correlate tensile strength with shear strength and to correlate the hardness of settled snow with its specific gravity as shown in Figure 3 and 4 respectively. Thus, either tensile strength or shear strength appear to be of more fundamental significance than hardness.

Since the results of the 1947 Snow-Cover Survey, as published in Reference 1, are generally true for the survey as a whole, only the principal results are given below.

Air temperature and wind had a decided influence on the condition of the snow-cover, while the effects of sunshine were relatively small.

Wet snow conditions were surprisingly rare and were almost entirely confined to the short period of thaw in spring.

Moderately hard wind packed snow (hardness 100 to 1000 gms. per sq. cm.) was very common at all exposed stations. Only rarely did the depth of relatively soft snow at the surface exceed 10 inches.

At temperatures well below freezing the specific gravity of settled snow was usually in the range of .25 to .35, while for wet settled snow the specific gravity rose to as high as .65.

Conclusions

The survey has provided a great deal of general information about snow and the variety of forms in which it occurs on the ground. It has also

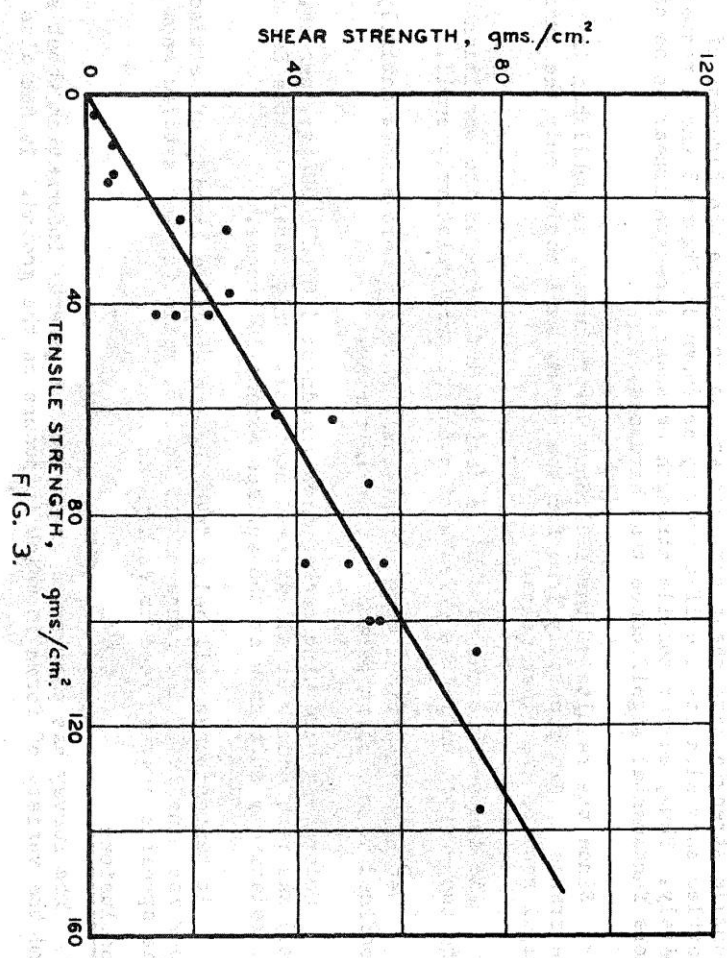
SHEAR STRENGTH, gms./cm.²
0
40
80
120
TENSILE STRENGTH, gms./cm.²
0
40
80
120
160

FIG. 3.

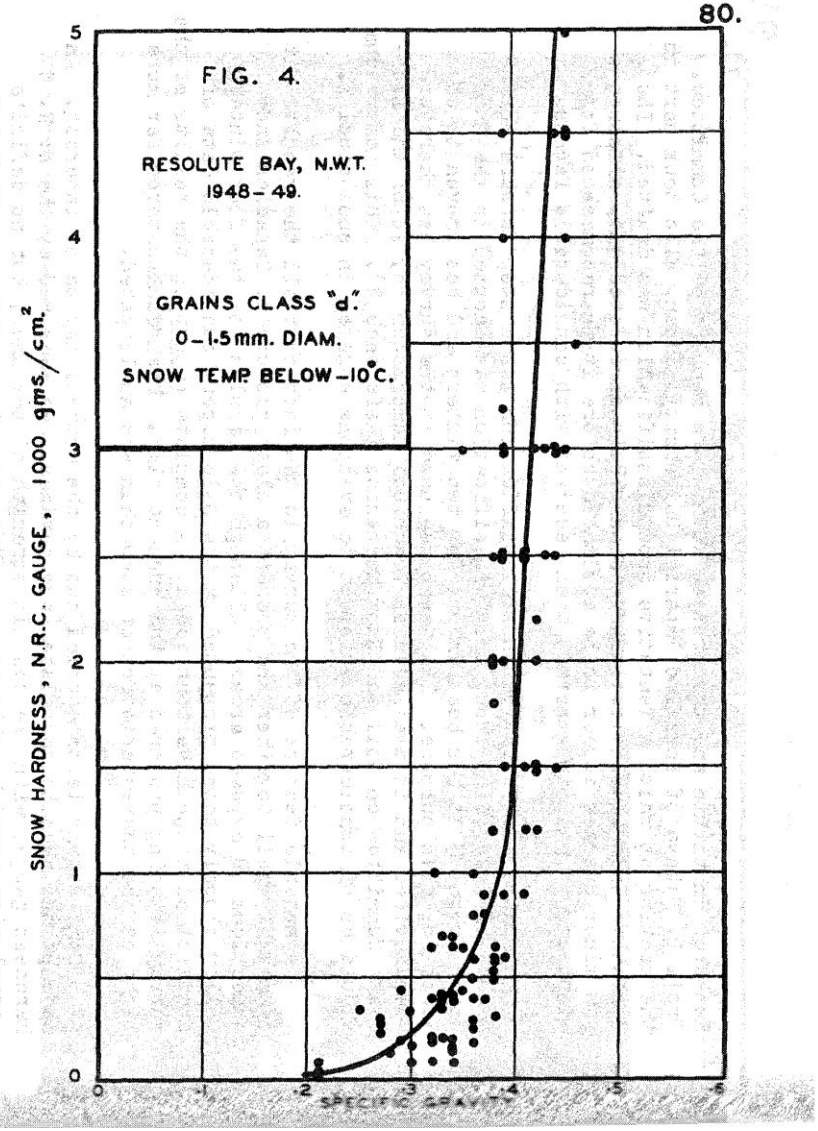
FIG. 4.
RESOLUTE BAY, N.W.T.
1948 – 49.
GRAINS CLASS "d."
0 – 1.5 mm. DIAM.
SNOW TEMP. BELOW –10°C.
SNOW HARDNESS, N.R.C. GAUGE, 1000 gms./cm.²
0
1
2
3
4
5
SPECIFIC GRAVITY
0
.1
.2
.3
.4
.5
.6

given a clear picture of snow conditions on exposed areas across Canada.

Since sufficient data have now been obtained from exposed areas, many of these stations can be discontinued. However, the value of the survey will be substantially increased by the addition of a number of carefully selected sheltered stations and plans in this direction are going forward.

The snow studies undertaken by the National Research Council of Canada have clearly shown the value of research into the problems associated with one of the most remarkable of all materials -- snow.

REFERENCES

1. Canadian Survey of Physical Characteristics of Snow-Covers - G. J. Klein. Technical Memorandum No. 15, Associate Committee on Soil and Snow Mechanics, National Research Council of Canada.

2. Method of Measuring the Significant Characteristics of a Snow-Cover - G. J. Klein, D. C. Pearce and L. W. Gold. Technical Memorandum No. 18, Associate Committee on Soil and Snow Mechanics, National Research Council of Canada.

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DISCUSSION

by

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Mr. Klein's paper is a progress report on a survey of the Canadian snow cover begun in 1947 and should be read in supplement of his paper presented to the International Commission of Snow and Ice at Oslo in 1948 on "Canadian Survey of Physical Characteristics of Snow Covers" published by the International Association of Hydrology and reprinted from Glaciers and Climate (Geografiska Annaler 1949, H. 1-2). Otherwise many of the details will be lacking.

The original purpose of snow surveys as developed in the United States and Canada was the forecasting of streamflow, as in the Shawinigan Basin in Quebec, the Bow Basin and Columbia on the Great Divide and in British Columbia under the initiative of Balls, Hoover, and Dick Farrow in whose honor we are meeting at Victoria.

But inevitably the researches of Klein on efficient skis for airplanes even before 1939 has led Canada to a nationwide survey of the surface characteristics of her snow cover.