Proceedings of the 1947 Conference on Snow and Ice

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40001166
Technical Memorandum (National Research Council of Canada. Associate Committee on Soil and Snow Mechanics), 1947-09-17

NATIONAL RESEARCH COUNCIL OF CANADA

Associate Committee on Soil and Snow Mechanics

Associate Committee on Geodesy and Geophysics

PROCEEDINGS OF THE 1947 CONFERENCE ON SNOW AND ICE

(Technical Memorandum No. 10 of the Associate Committee on Soil and Snow Mechanics)

This is a record of a conference of many of those Canadians actively interested in problems of snow and ice, held in Ottawa on the 17th and 18th of September, 1947.

Ottawa, Canada

October, 1947.

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NATIONAL RESEARCH COUNCIL

ASSOCIATE COMMITTEE ON SOIL AND SNOW MECHANICS

ASSOCIATE COMMITTEE ON GEODESY AND GEOPHYSICS

Conference on Snow and Ice

Ottawa, 17-18 September, 1947

This is a record of a Conference of many of those Canadians actively interested in problems of snow and ice, held in Ottawa on 17th and 18th September, 1947, under the joint auspices of the Associate Committee on Soil and Snow Mechanics and the Associate Committee on Geodesy and Geophysics, and conducted jointly by the Chairmen of these Committees, Mr. R.F. Legget and Dr. J.T. Wilson, respectively. The main function of the Conference was to pay tribute to work already done in Canada on snow and ice and make it better known, to stimulate interest in problems which were to be discussed, and to devise some means of both encouraging complete interchange of available information on the subject and promoting further research work in Canada.

2. Introduction of Special Guests

The Chairman welcomed those present, and two ladies whose interest in some of the problems to be discussed was already known to many of the delegates, were introduced: Mrs. E.W. Manning, who with her husband Mr. T.H. Manning, has spent some years living among and studying the habits of the Eskimos of Northern Canada; and Mrs. Diana Rowley, formerly a member of the Committee of the British Glaciological Society.

A special guest of honour was Sir Charles S. Wright, glaciologist of the Scott "Terra Nova" expedition to the Antarctic in 1912-1914, and author, jointly with Raymond Priestley, of the first book in English on the subject of "Glaciology". Sir Charles had recently retired as Chief Scientific Adviser of the British Admiralty and was fortunately in Ottawa at the time of the meeting.

Following the introduction of these special guests, a self-introduction was made by all those present (70 persons in all); a list accompanies this report as Appendix A.

3. Function of Associate Committees

Rather than having a fixed agenda, it was suggested by the Chairman that the course of the meeting might somewhat naturally include an outline of the general background leading up to the Conference, a factual survey consisting of statements from all those present of relevant work done on problems faced by their organizations, and finally the establishment of working arrangements for continuing, co-ordinating and expanding this work.

The Chairman explained that the function of Associate Committees of the National Research Council was to bring together interested authorities on particular problems, and to use funds available through the Council to the best advantage in their solution. The usefulness of such an arrangement was amply demonstrated during the war years.

Of the two Committees sponsoring the Conference, that on Soil and Snow Mechanics was initially established in 1945 to deal with a military problem related to the performance of tracked vehicles under various ground conditions. Since that time, its interests had expanded to include related work in Civilian Soil Mechanics, Muskeg, Permafrost, and problems of Snow and Ice. Its active interest in the latter work was manifested by this meeting.

The Associate Committee on Geodesy and Geophysics had sections (i.e. subcommittees) on five various phases of geophysical work. A section on Meteorology and Hydrology was under consideration. This work was intimately connected with snow and ice problems, particularly as affecting run-off. This Associate Committee also acted as the National Committee for Canada of the International Union of Geodesy and Geophysics and is thus in touch with hydrological and glaciological work in other countries.

Both Associate Committees offered their services; their members anticipated a successful Conference. A chart which was distributed showed the interrelation of Divisions and Committees of the National Research Council with the corresponding work of outside organizations, and corresponding contacts. A copy accompanies this report as Appendix B.

Factual Survey of Snow and Ice Problems

4. Major R.C. Farrow, Comptroller of Water Rights of the Department of Lands and Forests, British Columbia, commenced the factual survey of problems and work done in snow and ice. The British Columbia snow survey system had been developed empirically since 1935 and now consisted of some 48 courses extending across the southern part of the province, from the coast to the summit of the Continental Divide and as far north as latitude 53°. A number of courses had been located and laid out this year. Forecasts were tied in with the Dominion Water and Power Bureau survey in Alberta, and with American surveys to the south. Forecasting of spring run-off consisted of measuring the amount of water in snow fields in various basins, and correlating this with stream flow. Forecasting was undertaken for the benefit of the City of Vancouver, pulp and power companies on the coast, and for power companies and irrigationists in the interior.

In some areas, forecasts were consistently good with annual errors ranging from 1% to 10%. In others, they were not so consistent, yielding errors in occasional years of 7% to 20%. In a few areas, no satisfactory forecasts had been obtained. Aside from distorting factors and variables which could subsequently be traced, it was believed there were others which could be isolated and allowed for in forecasting and which would yield to research. Some of these were:

(1) What might be called "the soil priming factor", one of the most important factors affecting the relationship between snow-melt and run-off. Its greatest effect would be manifested on watersheds with deep alluvial or glacial detritus cover, and it represented the amount of water necessary to bring the soil up to capacity before surface run-off could occur. It was related on some watersheds to the ground water levels and to infiltration rates. Its evaluation might be attempted through ground water well studies or by one of the electrical resistance methods of measuring soil moisture. Condition of the ground water might also be indicated by stream volume during winter.

(2) Snow evaporation during the melting period, particularly in "Chinook" areas.

(3) Effect of forest cover on the snow pack in arresting evaporation and as a stabilizer in delaying run-off, and on the other hand, its toll on the snow-melt through interception, transpiration, and plant use.

(4) The physics of snow-melting.

5. Mr. W.A.D. Munday, Western Vice-President of the Alpine Club of Canada, Vancouver, mentioned the natural interest of the Club in finding out more about the characteristics of snow and ice, particularly as affecting the safety of climbers and skiers who, he noted, learned with experience a considerable amount about the changeable nature of snow and ice.

Due to heavy rainfall, enormous glaciers were found in the Coast Range of British Columbia. These acted as natural reservoirs tending to equalize stream flow over long periods of time. To the best of Mr. Munday's knowledge all British Columbia glaciers were shrinking, and there was a corresponding rise in the level of snow-line and tree-line in the mountains. Annual measurements of these shrinkages were being arranged by the Alpine Club of Canada.

The Chairman emphasized the reference which Mr. Munday had made to a book which was the most complete treatment of snow in English: G. Seligman, "Snow Structure and Ski Fields", McMillan & Co., 1936. Other references mentioned were: R. Haefeli, "Schneemechanik mit Henweisen auf die Erdbaumechanik", Technische Hoschule Zurich, 1939; and Wright and Priestley, "Glaciology" (now out of print).

6. Mr. Victor Meek, Controller of the Dominion Water and Power Bureau of the Department of Mines and Resources, Ottawa, told of the important work of this long-established organization in measuring and predicting run-off in Canada. The Bureau had a natural interest in snow as a source of run-off. Some 700-800 measuring stations were distributed across the country and snow surveys were carried on, particularly on the eastern slopes of the Rockies, which included the St. Mary and Bow River watersheds where predictions were urgently needed for irrigation purposes. Forecasts of run-off were made in cooperation with the United States Geological Service, and an accuracy of $\pm 10\%$ was obtained in the west. In eastern Canada, predictions were not as accurate, errors sometimes being of the magnitude of 40%. Three years ago, the Bureau had started annual measurements of the rate of shrinkage of representative glaciers.

7. Professor B.W. Currie of the Department of Physics of the University of Saskatchewan, Saskatoon, spoke regarding the Prairie Provinces where snow raised many important problems. Although comparatively little snowfall occurred, a wide range of temperatures was encountered and hence a considerable variety of snow conditions prevailed.

The specific gravity of freshly-fallen snow had been investigated during the past few years, and the relative weight of equal volumes of water and snow was found to be nearer 14:1 on the Canadian prairies than the established ratio of 10:1. Spectral sensitivities and reflectivities of snow were studied last winter to find out how absorption of solar heat affects the melting process of snow. Many difficulties were encountered in this investigation which also included a study of the structure of snow. Professor Currie listed the following as problems urgently in need of investigation:

(1) In estimating crop yield, the effect of infiltration of snow-melt into semi-frozen or frozen soil, as well as a knowledge of evaporation from snow surfaces;
(2) a study of the electrostatic charges on snow flakes;
(3) the placing of snow fences and wind breaks for highest efficiency; and
(4) a rapid method of detecting the thickness of ice ahead of tractor trains.

8. Mr. T.A. McElhanney, Superintendent of the Forest Products Laboratories, Department of Mines and Resources, Ottawa, reported that his organization had become interested in snow and ice when a request had come to them in 1936 for an investigation of the tractive effort required to draw logging sleighs. This problem was of importance in Canada since most timber was cut during the winter and hauled out over snow.

Mr. W.E. Wakefield, Chief of the Timber Mechanics Section of the Forest Products Laboratories, then described this investigation of a problem on which very little work had previously been done. Due to the vast variation of snow in Canadian woods and the great changes which took place in this snow on the ground, a trial and error procedure was necessary, and representative conditions and simplifications were assumed. Models and full scale sleds with steel shoeing were used, and both starting and sliding resistances were measured for unit loads of up to 1000 pounds per square foot, velocities up to 10 miles per hour, and temperatures down to -10°F. With increasing slenderness ratio of runners, tractive effort and penetration were both found to decrease and the type of friction obtained was found to vary with the amount of pressure applied. Details of the work are to be found in the publication by W.E. Wakefield: Final Report on Project 107, "The efficiency of logging sleighs for pulpwood operations in different types of terrain", Forest Products Laboratories of Canada, Department of Mines and Resources, April 1938.

9. Dr. Andrew Thomson, Controller of the Meteorological Service of the Department of Transport, Toronto, reviewed the work of that Service, under the administration of which 850 weather observation stations were operated, located from Eureka Sound in the Arctic to Pelee Island, and from Victoria to Newfoundland. The problem of obtaining staff to make snow observations at distant stations was considered a very practical one, and it was suggested that meteorologists who have a special interest in hydrology should be kept on such work. Requests by the Highway Departments of various provinces for forecasts of snowfall and snow drifting took a considerable part of the time of the meteorological staff.

Dr. Thomson considered it most important to co-ordinate the efforts of hydrologists and meteorologists.

10. Mr. W.G. Dyer, Engineer of Track of the Canadian Pacific Railways, Montreal, stated that little research had been done by his Company, but considerable practical knowledge had been gathered with regard to getting snow and ice off the track - their main problem - and the drifting of snow in flat areas. The actual amount of snow falling had no great effect on operations. Prediction of snow slides in mountainous areas was a serious problem.

A second interest was in snow as affecting maximum run-off and creating occasional flash floods. The present maintenance equipment was simply deployed in the field so that wash-outs could be handled if and where they occurred.

Storage of large quantities of ice for refrigeration purposes all across the country was an important problem and improved methods of refrigeration were continually under investigation.

11. Dr. George Hanson, Chief Geologist of the Geological Survey of Canada, which was organized in 1842 and is the third oldest such survey in the world, spoke next. Measurements of snow and ice were quite incidental to the general work of the Survey, although permanent glaciers had been mapped. However, it was of interest to know how much of the melt-water from snow got into the ground. Dr. Hanson offered the assistance of the Survey in the solution of any of the problems discussed at the Conference.

12. Messrs. J.A. Racicot and J.A. Lenoir, District Engineers of the Quebec Department of Highways, spoke briefly on their problems, which were generally:

(1) To stop snow from reaching roads, by means of controlling snow drifts;

(2) to remove snow from the roads; and

(3) to remove ice.

13. Mr. M.C. Hendry of the Hydraulic Department of the Hydro Electric Power Commission of Ontario, presented some of the snow and ice problems which concerned that organization. The Commission operated a large number of storage basins of various capacities, and since water from snow formed a large part of the supply to these basins, forecasts of run-off to be expected from that source were of great value in estimating available storage from time to time. The Commission, in close cooperation with the Dominion Water and Power Bureau, and other private utilities, established a number of snow survey stations throughout the northern part of the province, which had now been in operation for several years. During the coming season, the number of stations would be added to, so that in time, records would be available regarding the accumulation of potential run-off in the form of snow throughout the province of Ontario.

No definite conclusions had been reached as yet on a correlation between snow accumulation and run-off. Many variables entered into such predictions and seemingly identical amounts of snow might yield quite different run-off. Run-off depended upon a number of variables involving not only the snow, but conditions and features of the ground. The effect of individual factors was difficult to assess. It would appear however, that some progress could be made if more was known of the characteristics of snow cover, and it was hoped that investigations of snow-melt and its influence on the related question of ground water storage could be made.

The effect of ice pressure on structures and methods of computing it, a knowledge of the different types of ice with their properties and the conditions under which they were formed, how best to reduce or eliminate the formation of ice on structures, and problems of frazil ice caused by lack of ice cover behind water-controlling structures, were all in need of study if the best use was to be made of potential water power.

14. <u>The Chairman</u> noted Mr. Hendry's mention of the serious problem of ice pressure against dams, usually empirically taken as five tons per lineal foot at water level, and reported that the American Society of Civil Engineers had recently reconstituted a Committee to study the matter, the Chairman of which was Mr. R.L. Hearn, General Manager and Chief Engineer of the Hydro Electric Power Commission of Ontario.

In reply to a question by Mr. Hendry regarding any studies of means of reducing the strength of ice against dams, Mr. Baird mentioned that work had been done by a Dutch scientist on chemical methods of reducing ice formation with particular reference to keeping canals clear.

15. <u>Mr. A.E. Davison</u>, Transmission Engineer of the Hydro Electric Power Commission of Ontario, Toronto, reported on the transmission problems of the Commission and associated studies and activities. He was Chairman of a Committee of the American Institute of Electrical Engineers on studies of steel towers, wood poles and conductors. This Committee was charged with the problem of de-icing conductors and of the phenomenon of "galloping" which brought wires together in a high wind when weighted with sleet.

There were two other Committees concerned with this latter work; the Edison Electrical Institute had a Committee of which Mr. Davison was a member, and there was an unsponsored international group of engineers from sleet areas of the United States and Canada specifically assembled to study the problem which, in general, was to find ways and means of separating or eliminating the extraordinary motions caused by wind upon ice-coated conductors.

During the past year, a considerable step forward had been made by a group of engineers in the Chicago area, which had succeeded in creating "galloping" synthetically. The studies were progressing, but there was no solution as yet available other than keeping sleet off the conductors by internal heat, an expedient which was not always feasible.

Other studies reported by Mr. Davison as receiving attention by individuals and groups were:

(1) The fundamental problem of forebay coverage in winter in operation of large hydro-electric units in northern watersheds;

(2) The fundamentals of frazil ice and the critical nature and conditions governing its formation;

(3) The merits of metal versus other types of materials for racks, methods and economics of keeping frazil ice clear of racks (furthering of the studies of John Murphy and associates, as found in the statement before the International Joint Commission, Montreal, October 9th, 1920);

(4) The pressures exerted by large ice sheets, still intact, upon objects thought to be fixed, such as transmission towers during expansion periods of rising temperatures and prior to break up, specific studies of which are being done in Burlington Bay;

(5) The value of snow cover as sought by agriculturists: first, as a blanket and protection against frost penetration and heat; second, as promoting the slow absorption of water by soil; and third, as a fertilizer, as originally suggested by F.T. Shutt in "Nitrogen Compounds in Rain and Snow", before the Royal Society of Canada in December 1925;

(6) The importance of cyclic trends of solar radiation as affecting ice formation according to studies currently being made in the laboratories of the National Bureau of Standards, Washington, D.C. (as announced in their Technical News Bulletin, September 1947);

(7) Fundamentals and data regarding the existence of super-cooled liquid particles in air at sub-zero temperatures, and their characteristics when encountered by moving objects. The need for such data was felt in study of sleeting problems. Information on the study of this had been obtained from the weather observatory on Mount Washington in the eastern United States, and the cooperation of this station in dealing with such enquiries was emphasized.

From a discussion of Mr. Davison's remarks, it was established that some films taken by Dr. Howard T. Barnes in his early investigations of ice physics, one showing ice conditions on the St. Lawrence river from the air, and another on frazil ice, were now located in the library of the Hydro Electric Power Commission of Ontario.

16. Dr. A.L. Washburn, Director of the Arctic Institute of North America, Montreal, was then introduced. He explained that the Institute was organized on an international basis, with offices in Montreal and New York City, which were headquarters for national groups which might work individually or together on single projects. The work of the Institute provided a splendid example of scientific cooperation. Current work being done by means of Institute Fellowships was as follows:

(1) The identification of permafrost areas from aerial photographs was being investigated at Cornell University by Professor D.J. Belcher;

(2) An observer, Mr. R.A. Hemstock, was engaged in the study of permafrost at Norman Wells;

(3) Botany in the far north, as well as other scientific fields were under investigation.

Dr. Washburn offered the full assistance of the Institute to the two Committees sponsoring this meeting.

17. Mr. Walter A. Wood, Director of the New York Office of the Arctic Institute of North America, reported that the Institute hoped to establish northern research stations (one during the coming winter) which could be used for snow and ice studies and investigation of mountain travel. He hoped that those present could give thought to how such stations could best serve their purpose.

18. Mr. P.D. Baird, Director of the Montreal Office of the Arctic Institute of North America, reported on Exercise "Musk Ox". This exercise, held in northern Canada during the winter, 1945-46, was directly concerned with snow as affecting the mobility of oversnow vehicles, and methods of air supply to a slow-moving force under various conditions encountered in the far north. Snow and ice measurements were taken as often as possible en route with a testing kit designed by Mr. G.J. Klein (see paragraph 55). All the snow measurements were made on settled snow. The surface of the snow cover in the barren lands generally had a specific gravity between 0.3 and 0.4 and consisted of a layer of small rounded grains. These grains became progressively larger and more angular as the bottom of the snow layer was approached. In bush country, the snow was more loosely packed and lacked the surface layer of rounded grains. The average snow depth here in April was about 22 inches of settled snow with a specific gravity of 0.2 to 0.3.

Ice thickness was measured by scooping holes or by means of explosives. A hot rod device constructed by the National Research Council for rapid determination of ice thickness was not carried because the vehicle batteries were not considered adequate for the power which the rod required. An acoustic device for measuring ice thickness had been tried unsuccessfully. However, it was hoped to carry out investigations of economic importance in the near future on the thickness of sea ice.

Afternoon Session, 17 September

19. To continue the discussion, Sir Charles S. Wright was called upon to speak. He expressed his pleasure at being present and on hearing mention of such familiar and interesting problems, and emphasized the importance of a study of the fundamentals of snow and ice. He believed that physics was behind most of the phenomena of these substances and gave interesting examples from his experience to illustrate this.

20. Professor George H. Kimble, Chairman of the Department of Geography, and Director of the Meteorological Observatory, McGill University, Montreal, testified to the close liaison existing between his department and the Arctic Institute, with whose cooperation a forum on problems of the north had been held this past summer.

Problems which he felt were in need of attention were the development of an effective anti-slip treatment for roads or sidewalks; seasonal forecasting of snowfall, even if only to indicate whether above or below average; and maps showing snow cover and its seasonal variations.

21. Dr. Norman W. Radforth, Professor of Plant Morphology and Palaeobotany and Head of the Department of Botany of McMaster University, and Director of the Royal Botanical Gardens, Hamilton, reported on problems coming to his attention as Chairman of the Subcommittee on "Muskeg" of the Associate Committee on Soil and Snow Mechanics. In preliminary studies of this committee, uncertainty of the meaning of "Muskeg" was encountered, and material called by that name in various parts of the country was found to have differences in physical structure, vegetational cover, etc. The purpose of the committee was to interpret various physical properties of "Muskeg"

in scientific terms, and so establish a background for the study of relevant problems, ranging from the trafficability of "Muskeg" to uses of the material itself. One of the variables in such studies was frost in both permanent and active forms, and any information discovered regarding the properties of ice, particularly in relation to organic materials, would be very useful.

Aerial photographic work was done at Churchill this summer in an attempt to recognize "Muskeg" from characteristics of the surface cover.

22. Dr. P.O. Ripley, Dominion Field Husbandman of the Experimental Farms Service of the Department of Agriculture, Ottawa, pointed out that the importance of snow in agriculture was evident from instances already cited. For example, the use of snow as a fertilizer due to its absorption of atmospheric nitrogen while falling had been mentioned, as had its uses in irrigation considerations. In dry farming areas, it was important that all possible moisture be preserved, and at Scott, Saskatchewan, experiments in drift control had been done in an attempt to increase the depth of snow remaining on fields for this purpose. Wind breaks, while protecting homesteads, also controlled the amount of moisture retained for gardens and crops. Soil conservation work involved snow studies in connection with preventing excessive spring run-off and consequent floods, which affected urban as well as rural dwellers. Snow characteristics were also of interest to the agriculturalist from the point of view of investigating traction and trafficability of farm vehicles.

23. **Dr. A. Leahey, Soil Specialist of the Experimental Farms Service of the Department of Agriculture, Ottawa,** added that frost action was of vital interest in problems of land clearing as well as in those of laying service pipes. Some work had been done on the great effect of Permafrost on crops and plant growth, but a great deal more needed to be done in order to discover where it lay, the nature of the soils in which it occurred and how its level might be lowered.

In connection with "Muskeg", Dr. Leahey noted that this material was known to be a good insulator from its action in retaining frost, but enquired if such was the case, how frost came to be in the "Muskeg" in the first place.

24. Mr. W.E. Griffiths of the Chief Engineer's Department of the Canadian National Railways, Montreal, stated that the problems of his organization were similar of those already mentioned by Mr. Dyer (see paragraph 10). Three points however were worthy of emphasis:

(1) Snow removal entailed considerable expense and tied up all traffic. The usual mechanical or hand labour was the only means of removal so far found. Frozen switches also caused delays in train routings, and this kept as many as 600 to 1000 men busy at one time in the Montreal terminal. Hundreds of miles of snow fences were used every winter in attempts to keep tracks free of snow.

(2) An additional source of expense was keeping tracks level in winter. This was due to frost heaving, which was prevented by drainage, when possible.

(3) Washouts caused most damage in June when the ground was saturated and water from snow melting at high levels was therefore flowing down on the ground surface. Deforestration added to flood effects.

Mr. Griffiths observed that the railroads will watch with great interest any investigations which result from this Conference.

25. Mr. J. Sicard, President and General Manager of Sicard Limited, Montreal, told of the development of snow blowers by his company, commencing with the original idea of his father who used a threshing machine blower to clear snow on his farm in 1902. He expressed the hope that the Conference would lead to the solution of many of the problems discussed, and kindly offered the use of any records which the company possessed that might be of help.

The Chairman mentioned that Sicard snow blowers were now being manufactured under license in Europe.

26. Mr. H.S. Rees, Chief Aeronautical Engineer of the Department of Transport, Ottawa, noted that problems of snow and ice encountered in his work fell into two classes: (1) those involved in taking off and landing, in which Mr. Klein's work in investigating aircraft skis had been helpful, although it was now found that snow friction depended on speed, calling for a new set of tests, and (2) those involved in the air due to ice formation on wings or carburetor. When planes were picketed out at night, frost was frequently found to form on wing surfaces, destroying lift. A program was now under way to find the load under planes during taxiing and take-off with various snow conditions; much work has yet to be done.

27. Mr. J.W. Lucas, Acting Director of the Testing Laboratories of the Department of Public Works, reported that most of the ice problems encountered by his department were in connection with winter construction work. These included damage to small wharves due to ice movements, and the clearing of ship channels, usually carried out with explosives.

28. Superintendent D.J. Martin, Officer Commanding "G" Division, Eastern and Western Arctic, of the Royal Canadian Mounted Police, spoke of travel conditions in the Arctic. In the Eastern Arctic, travel was over bare ground in the summer, and over ice and snow during the winter. Several mechanical snowmobiles and motor toboggans were used, but these were not very successful, and their operation was handicapped by the lack of staff and the scarcity of summer caches for the vehicles. Dog sleighs were therefore generally used, with steel runners which were iced in the winter and left bare in the spring. In the Mackenzie and Yukon areas, where snow was soft and deep, toboggans were used. On patrols packing was difficult since all supplies had to be carried.

Experiments on insulation and clothing had made housing and living fairly comfortable in the north. Information collected on freezing and break-up periods, thickness of ice, and other data had been passed on to interested organizations. The Royal Canadian Mounted Police now had an Aviation Section in charge of flying and it was expected that their ship patrols would be expanded.

29. Mrs. E.W. Manning expressed her keen interest in anything providing additional comfort to travellers in the far north. No satisfactory substitute had yet been found for fur clothing in which the Eskimos were now largely lacking, and she considered that an effort should be made to provide comfortable clothing for those who must spend much time under Arctic conditions.

30. Mrs. Diana Rowley, formerly a member of the Committee of the British Glaciological Society, brought to the attention of those present the "Glaciological Journal" published by the Society, which fulfilled a very real need in providing information on new discoveries in connection with ice, and expressed the hope that it might be of interest to Canadians. (See also paragraph 61)

31. Mr. Matthew Balls, Manager of the Water Resources Department of the Shawinigan Water and Power Company, Montreal, was particularly interested in the prediction of run-off available for power development. From as far back as 1928, attempts had been made by his company to correlate the amount of snow with spring run-off. In recent years, additional information on run-off had been obtained from ground water levels in wells, and more data was sought to evaluate variables encountered in such estimates. An endeavour to find the time of run-off from investigation of the latent heat of fusion had not been too successful.

32. Mr. H.M. Finlayson, Hydraulic Engineer of the Shawinigan Water and Power Company, Montreal, mentioned various problems of interest. The occurrence and distribution of snow affected various means of winter transportation. The problem of the collection of sleet on conductors was now materially assisted by accurate predictions of the Meteorological Services. The occurrence of frazil, anchor and slush ice influenced the design of hydro-electric installations. Frazil ice was now melted on racks by electrical means. The crushing strength of ice against dams had been considered. It was intended to prevent ice formation against dams and so eliminate ice pressure on such structures altogether.

33. Mr. C.H. Pigot, General Assistant Engineer, Generating Stations and Hydraulic Division of the Quebec Hydro Electric Commission, Montreal, reported that their problems were similar to those of other power companies. Ice coming down the St. Lawrence river caused floods in the lower section of the river and much money had been spent in opening channels in the ice in attempts to prevent this. Frazil ice problems were not serious since the ice cover on Lake St. Francis formed early. The effect of snow on ground water conditions on farms adjacent to rivers was of interest.

34. Messrs. J.C. Chagnon and A. Marien, Chief Engineer and Hydraulic Engineer respectively of the Quebec Streams Commission, Montreal, noted their interest in meteorology and hydrology and the desirability of a link between the two sciences. The increasing importance of soil conservation work had emphasized the significance of snow surveys and these were to be extended in Quebec with the establishment of snow courses.

35. Mr. John Walter, Materials Engineer of the Ontario Department of Highways, Toronto, emphasized that problems of snow and ice are of very vital importance in the work of the Department. The yearly expenditure in the province on snow removal and skid-proofing of King's Highways alone was approximately three million dollars, i.e., exclusive of costs to counties, townships and municipalities. If the total cost were considered throughout Canada, the economic importance of this problem would be appreciated.

Problems encountered fell into three classes:

(1) Control of snow drifting was at present accomplished by snow fences, snow hedges and improved highway design. Snow fences and hedges were placed at various distances from the highway and at locations where experience had shown that excessive drifting occurred. Features of recent highways designed to be self-cleansing involved the construction of three to five-foot fills, rounded and flattened backslopes in cuts, and wider cuts to facilitate snow storage.

(2) The removal of snow and ice was accomplished by mechanized equipment such as snow plows, snow blowers, under-body planers and graders, and bulldozers. Chemicals and chemically treated sand were used to provide traction to vehicles and to facilitate the removal of snow and ice. Approximately 200,000 cubic yards of sand and 40,000 tons of chemicals were used per year, of which 70% of the latter was imported from the U.S.A.

The Department was very appreciative of the excellent service rendered by the Meteorological Service of the Department of Transport which permitted advance preparation for adverse weather and re-routing of equipment to affected areas.

(3) Efficient control of the run-off resulting from spring melting conditions was of major importance in relation to the resultant flooding of low-lying areas, the infiltration of water into the roadbed, and erosion. The solution of these problems was related to many highway design features.

Improvement was required in combating snow and ice problems for the following reasons:

(1) Present methods were excessively expensive.
(2) The amount of sand available for spreading was limited or exhausted in some areas.
(3) The use of chemicals was generally injurious to concrete pavements, automobile under-carriages, and trees and shrubs.

In conclusion, it was felt that research was most essential in order to study the fundamental properties of snow and ice as related to the problems outlined.

36. Mr. A.K. Laing, Assistant Chief of the Aids to Navigation Branch of the Marine Services, Department of Transport, Ottawa, told of some trouble encountered in their winter operations. The date of taking in buoys and lightkeepers was always a problem. Anything which would lengthen the navigation season would be of economic importance to the Dominion. The forecasting of iceberg seasons and tracing the paths of icebergs, with the cooperation of the International Iceberg Commission, also came under the work of the Department.

37. Mr. E.G. Cameron, Chief Engineer of the National Harbours Board, Ottawa, referred to problems related to construction in the far north. Some structures built on piles driven to the permafrost level were subject to considerable seasonal variations in elevation, which were thought due to the alternate freezing and thawing of the soil beneath.

Another problem was the choice of materials and design for permanent housing units at locations such as Churchill.

38. Commander C.V. Green, Deputy Director of Naval Construction of the Royal Canadian Navy, Ottawa, discussed problems of icing encountered in keeping ships at sea, in decreasing order of importance as follows:

(1) Safety of the ship itself was sometimes endangered by excessive accumulation of ice formed from wind and spray resulting from storm or speed, and raising the center of gravity due to increased weight of the superstructure.

(2) Ability of the ship to fight was jeopardized by the presence of ice on weapons, many of which were delicate instruments, and the removal of such ice was necessary before they could be used.

(3) Maintenance of course and speed was rendered difficult by the additional resistance due to the increased weight of superstructures, ice along the water-line, and clogging of intakes.

(4) Economy of operation was reduced by the additional fuel necessary.

Steam jets as used in World War I against ice were not found successful. Jets of warm salt-water were found better since the water did not freeze again. Ice was generally removed from mountings by heating, for which purpose steam was found better than electricity. A coating such as grease made for easier ice removal, particularly on plane surfaces. Further experiments on these problems were to be carried out during the coming winter and the advantage of using Canadian ships in conducting such studies was pointed out, since in the course of their duties they operated in extremes of heat and cold.

39. Lieutenant Colonel G.W. Rowley of the Defence Research Board of the Department of National Defence, Ottawa, reported that his organization was interested in all Canadian work with possible military applications. This included that of snow and ice, "Muskeg" and Permafrost, particularly where practical needs were fulfilled. It was felt that the development of the whole north of Canada was dependent on transportation, and in the solution of this problem, the work of the Conference should be of importance.

40. Wing Commander K.C. Maclure, Director of Arctic Research of the Defence Research Board of the Department of National Defence, Ottawa, reported their interest in all information of use to any of the armed forces. For their purpose, desirable information involving snow and ice might be grouped as follows:

(1) In transportation, those properties affecting oversnow travel; values of the bearing strength of sea ice and methods of establishing them; and the movement of snow and ice under wind, and methods of controlling it;

(2) In communications, the effect of snow on aircraft; the effect of blowing snow and ice crystal haze on navigation and communication and on the attenuation of ultra-high frequency radio waves;

(3) In living conditions, the effects of cold weather on buildings and shelters; and

(4) In physiological and psychological considerations, the effect of proper clothing and food and the development of survival methods.

The Board was in the process of organizing projects and acquiring personnel in order to keep in touch with all current Arctic research and to persuade existing establishments to carry out advisable research. In addition they would sponsor directly certain such programmes and carry out some projects in their own right. A research laboratory was being built at Churchill and work was being commenced.

41. Wing Commander C.H. Cotton, Director of Equipment of the Royal Canadian Air Force, Ottawa, spoke of several of their problems which could only be solved completely by a study of snow and ice:

(1) The question of airborne machinery with which modern runways on rolled snow, ice-covered lakes, or "Muskeg" must be built;

(2) Frost and ice on standing aircraft, for which alcohol treatment of surfaces gave effective but slow results;

(3) Means of transporting and storing fuel in the north, for which storage in snow or the use of collapsible containers held interesting possibilities; and

(4) The problem of precipitation static in communications.

All these were connected with snow and ice research, and it was considered that the grouping of problems into basic types for research might assist in obtaining a start at critical points.

42. Dr. A.H. Woodcock, Research Scientist with the Defence Research Board, Department of National Defence, Ottawa, asked for more fundamental information on snow and ice. They were interested in:

(1) Clothing, in connection with which it was believed that the phenomenon of condensation from breath was related to that causing icing of aircraft;

(2) Sliding properties of snow which influenced runner and aircraft ski design;

(3) Permafrost, in particular with regard to its thermal conductivity; and

(4) Snow drifting, which filled in snow fences rather rapidly in the north.

43. Lieutenant Colonel Charles Ballard of the Directorate of Armament Development, M.G.O. Branch, Department of National Defence, Ottawa, reported that Army problems in snow and ice were very varied. Little was known of the effect of these materials on armament, and in this regard they were interested in the "stopping power" and fragmentation effect of snow and ice on bombs and shells, and the penetration of weapons.

44. Mr. W.N. Chater, Acting Director of Vehicle Development, M.G.O. Branch of the Department of National Defence, Ottawa, explained that his Directorate was responsible for the design and provision of Canadian Army vehicles. Hence their interest in snow and ice was from the point of view of its effect on the movement of vehicles, which must be designed to operate at any time and regardless of weather. The Canadian Snowmobile was developed by trial and error during the war, and its performance had been gratifying in spite of many faults. Some of these faults were now being analysed and improvements considered. Track studies were proceeding under the direction of the Associate Committee on Soil and Snow Mechanics, and more was known of the physical properties of snow than two years ago. The investigation would be pushed on and progress to date had been hopeful.

45. Major Scott Lynn of the Directorate of Engineering Development of the Department of National Defence, Ottawa, told of work done to investigate the action of snow fencing. Drifting snow filled in the usual snow fencing rather rapidly in the north and alternative methods of deflecting wind were now being tried, along with various heights and angles of standard fences. Photographs of some of these test installations were shown and it was hoped that tests would continue this winter.

46. Major F.G.B. Maskell of the Directorate of Weapons and Development, Department of National Defence, Ottawa, pointed out that Army problems fell between those of the meteorologist and the hydrologist who were interested respectively in falling snow and run-off. The Army must be prepared to move under any type of snow and ice on the ground, and it could not choose which. It was believed that basic research into characteristics of snow and ice, applied research into particular problems, and snow surveys, were the most pressing needs and much more information would be required before many problems could be solved.

47. In closing the discussion of the day Dr. D.A. Keys, Vice President (Scientific) of the National Research Council, spoke in interesting fashion of his association with Dr. Howard T. Barnes when both were on the staff of McGill University. Dr. Barnes was a pioneer in ice engineering. It was he who suggested thermite as a means of breaking up ice jams in power channels and rivers, and Dr. Keys gave a brief talk on some of the interesting aspects of this development.

48. The Chairman expressed the hope that the meeting by now had been fully justified in the minds of all those present. Although the work of the National Research Council in snow and ice had not yet been mentioned, that was suggested as an appropriate starting point for the session of the following day.

The Chairman requested that those present review what they had heard and give consideration to how continuing and new work on snow and ice could be integrated and directed most efficiently.

Morning Session, 18th September

The Chairman suggested that the factual survey of work being done might now be completed, commencing with the part played by the National Research Council.

49. Dr. F.H. Sanders, Scientific Assistant to the President, and formerly of the Division of Physics and Electrical Engineering, National Research Council, was called upon and described how the action of ice and snow in impeding electro-magnetic waves was of use at sea in the detection of icebergs and ice flows. On land, a possible application of a similar principle was the determination of the depth of snow. Detection of snow storms and other data by similar means is found to depend on the electrical properties of snow, size of the particles, and other factors.

50. Dr. C.D. Niven, Head of the Heat Section, Division of Physics and Electrical Engineering of the National Research Council, enquired how the Heat Section could help to solve problems which had been raised. They had already dealt with several projects. These included

the "Habakkuk" project, which, although dropped, had provided information which would yet be of use, including much not formerly known about the physical properties of ice. A suggested civilian application was the use of ice bridges in the far north, to be kept cold by refrigeration in summer. However, solutions to problems of the strength of ice solved in the laboratory were found difficult to apply in the field, due to cracking and other vagaries of nature. Other properties of ice were in need of investigation as well as strength, the forecasting of frazil ice formation had so far been unsuccessful. Little was known of the effect of rain on ice.

Difficulties were also found in snow tests as compared with those of ice because of the problem of reproducing standard conditions. Further investigations were needed of the effect of heating runners on snow friction.

51. Mr. P.M. Pfalzner, Physicist in the Heat Section of the Division of Physics and Electrical Engineering, National Research Council, described experimental attempts to increase and decrease the friction of ice. Coefficients of friction with various substances and at various loads and temperatures were found. Model sleighs were built and certain advantages were found with heated runners, but not sufficient to compensate for the energy used, except possibly at very low temperatures.

Rubber companies were interested in the gripping rather than sliding qualities of their products on ice, and such problems involved surface physics and chemistry. Means of increasing the friction of synthetic rubber tires on ice, to compensate for their decreased gripping power as compared with tires of natural rubber, were investigated, and various synthetic rubber samples were tested for static and dynamic friction. Surface conditions comparable to natural icy roads were found difficult to determine. Good dynamic friction would not always follow from good static friction and vice versa.

52. Mr. George J. Klein, Research Engineer of the Division of Mechanical Engineering, National Research Council, reported on the work of that Division, which was chiefly interested in aeronautical problems and associated researches. A testing program to find the friction of aircraft skis on snow was initiated in 1934, using large models (up to one-half scale) of many different materials, and shapes and loads up to 1000 pounds per square foot.

A large number of tests were made and a considerable knowledge of significant properties of snow accumulated. At the conclusion of two winters' work, there appeared to be no correlation between ski performance and snow conditions, but a theory was evolved which considered the ski resistance to be due to:

(1) The energy spent in compacting the snow;
(2) Dry mechanical friction, mostly at the toe;
(3) Viscous drag in the water film under the ski; and
(4) Surface tension drag in particular.

Each of these varied with snow conditions, unit loads and other features. The important effect of surface tension was verified by experiments with other materials.

The theory accounted for the results of all the many tests and led to the satisfactory use of smaller skis with higher unit loads in all but soft snow. In 1934, the maximum load used for aircraft skis had been 200 pounds per square foot. Tests were now still giving consistent results at loads of 1000 pounds per square foot. Other important features of the improved ski were a high slenderness ratio, relatively fine entrance angle, central loading of the sliding surface, and completely polymerized laminated bakelite shoeing. Full-scale landing and take-off tests of various skis fitted with a force recording pedestal were being planned for the next winter. It was realized that more must be learned about the properties of snow, particularly with regard to changes taking place with temperature.

53. A large amount of work had been done and was continuing on the problem of <u>aircraft de-icing</u>. The first work on this problem was done about 20 years ago in the United States. More recently, several "icing tunnels" had been built in that country and one was under construction in the Low Temperature Laboratory of the National Research Council of Canada. Aircraft had been fitted out as flying laboratories in both countries to test anti-icing devices and make fundamental studies of the conditions which cause icing. Some interesting observations have also been made at the U.S. Weather Bureau Station on Mount Washington where extreme winds and snowfalls have been recorded.

The National Research Council had been active in this field of research. An ultra-high speed camera was used for photographing cloud particles during flight in order to measure their size and concentration. Propeller de-icing by means of pads cemented to the blades and connected to a generator mounted on the propeller hub was a recent development. Satisfactory methods of electrically heating wind screens and the leading edge of wings and control surfaces were now under investigation.

54. The first Canadian oversnow motor vehicle was Bombardier's "Auto-neige", of which about 600 had been manufactured near Quebec City. From this basis, the Canadian Snowmobile ("Penguin") was developed concurrently with the "Weasel", which was produced by the cooperation of the United States, Britain, Canada and Norway. The performance of oversnow vehicles had been found to depend on the type of snow. Poor icing qualities of steel tracks as compared with rubber parts had become very apparent, particularly in wet snow. Rubber had the advantage of flexibility, thereby breaking off ice before it accumulated.

55. An investigation of fundamental snow properties was recently sponsored by the National Research Council when it became apparent that very little was known of various types of snow and their characteristics. A program of collecting snow information was initiated and instruments were developed to make up a test kit. The apparatus was designed to be portable and simple, capable of use in extreme cold, yet yielding sufficiently accurate data to give a clear picture of the snow, and thus eliminate confusion resulting from the use of descriptive terms alone. In each snow layer, specific gravity, hardness (ranging from one to 10,000 units), temperature, free water content, and the size and shape of snow grains was measured. The metric system was used so that results might be compared conveniently with important work done by the Swiss. After minor changes resulting from initial use on Exercise "Musk Ox", the kits were used in a snow survey carried out last winter under the auspices of the Associate Committee on Soil and Snow Mechanics and with the generous assistance of the Meteorological Service and the Department of National Defence. Tests were made once per week and at ten locations in open country, giving a fairly good idea of snow conditions in unsheltered areas across Canada. Reports and data were encouraging and the technique of testing and recording results was shown to be satisfactory. Results had been plotted in graphical form without losing significant details.

Instruments of the snow testing kit, developed by Mr. Klein and made and distributed by the National Research Council, were shown and explained to the gathering, along with copies of the accompanying instructions. It was announced that anyone wishing to secure testing kits and instructions for use this winter should contact Mr. D.B. Nazzer of the National Research Council at an early date. Additional kits were being made for early distribution.

The Chairman told of the interest expressed by the Swiss in these instruments, to such an extent that they had adopted some of them in place of their own.

56. Mr. Klein was asked to tell of some of the early researches on snow and ice carried on in North America. He reported that from 1890-1931, Mr. W.A. Bentley of Vermont took micro-photographs of snowflakes, using transmitted light, and over 2400 of these were published in a book entitled "Snow Crystals", which is still recognized as the best existing collection of snowflake photographs.

The early contribution of Professor Howard T. Barnes of McGill University, who investigated the physics of ice in connection with problems of winter navigation, ice thickness, and others, was mentioned. In 1909 Professor Barnes presented a paper before the Royal Society on "The Physical Constants of Ice", which was a general survey of the more important work concerning ice which had been done up to that date.

At this point, Mr. Hendry suggested that the records left by Dr. Barnes and his associates, of considerable work which he did in and around the upper St. Lawrence, might still exist. As these were considered worthy of investigation, the Conference was assured that both the National Research Council and other organizations would attempt to trace such records with the assistance of Mr. Hendry and other interested persons.

Mr. Klein told of the recent development of dry ice seeding of storm clouds in order to produce precipitation of snow. It was in connection with these studies that Langmuir and Schaefer of the General Electric Laboratories had discovered an interesting process of making replicas of snowflakes which might have a number of useful applications.

57. In a question period at this point, Dr Keys related that in Montreal snow was sometimes placed on the streetcar tracks on excessive grades in winter, apparently

in an attempt to increase the friction. This procedure could not be explained by any of those present.

Sir Charles Wright mentioned his recollection of a great increase in the friction of sleighs on snow below certain temperatures, particularly on newly formed wet sea ice, over which runners would scrape as though on sandpaper. Sir Charles wondered if snow friction did not at one temperature establish a "wall", just as sound wave frequencies build up in aviation as the speed of sound is approached.

Mr. Klein gave data from his ski tests showing that dry mechanical friction did indeed increase very rapidly with decreasing temperature and that at very low temperatures it formed a large part of the sliding resistance.

58. Dr. Norman W. McLeod, Department of Asphalt Technology of Imperial Oil Limited, Toronto, and a member of the Associate Committee on Soil and Snow Mechanics, reviewed some of the problems found in the borderline between soil and snow mechanics, such as the harmful effect on highways of chemicals used for snow and ice removal; foundations on permafrost; the occurrence of frost boils and frost heaving which was tied up with snow cover; and the increase of moisture in subgrades of highways and airfields due to spring thaw, necessitating the reduction of heavy traffic to preserve pavements, with consequent economic losses. It was pointed out that the United States Army Engineers based the design of airport base courses in part on the number of degree-days of freezing. The cost of such runways may be as much as $1,000,000 per airport, demonstrating the economic importance of investigation of such designs. Run-off, when unusual, caused highway washouts, necessitating repair work and liberal allowances in culvert and bridge design. Ice jams caused destruction of engineering structures, such as the old Niagara Gorge bridge. In conclusion, it was mentioned that an Imperial Oil representative at Norman Wells was studying Permafrost and problems of winter clothing and housing.

59. Mr. Norman Marr, Assistant Controller of the Dominion Water and Power Bureau, Department of Mines and Resources, Ottawa, amplified the remarks previously made by Mr. Meek (paragraph 6) on the work of the Bureau.

60. Mr. W.L. Saunders of the Ottawa District Office of the Ontario Department of Highways, expressed his dissatisfaction with the current design of snowplows in this country. At present, he considered they were designed too much on the principle of the agricultural plow, turning the snow and ice over forward. Types had been designed on other principles but seemed to have been neglected.

61. The Chairman introduced a brief review on work in snow and ice done in countries other than Canada.

In Great Britain, much outstanding work had been done in this field, largely in connection with Arctic exploration, and not the least of which was that of Sir Charles Wright. Much work had been prompted by the dangers of skiing, and Seligman's book (see paragraph 5) on this phase was a classical work. The British Glaciological Society was founded under Mr. Seligman's guidance and it was recommended that all those particularly interested in the basic properties of snow and ice might well investigate membership in this Society and subscription to its Journal. Subscription to the Society (the only one of its kind in the world) is 15 s. per year, this including the Journal. Those interested were asked to communicate with Mr. Legget, c/o National Research Council, Ottawa.

62. Mr. Klein continued the review of work in other countries with a description of some of the researches by Nakaya in Japan from 1934 to 1939. He succeeded in making the most complete classification of snow crystals in existance, and was able to determine for each class of snowflake its probability of occurrence and size. He developed laboratory apparatus and a technique for growing snow crystals, and was able to verify by experiment the theory that the rate of growth had a considerable influence on the crystal form. Nakaya also developed apparatus for measuring the hardness and free-water content of fallen snow, conducted some very interesting experiments with skis, and measured the electrical charges on falling snowflakes.

In the U.S.S.R., a great deal of snow and ice research had been done, of which the major part had been on Permafrost which covers nearly one-half the area of the country and introduces serious problems in connection with construction. Russian papers on permanently frozen ground were the main source of information on this subject and many had been translated into English. Other problems which had received considerable attention in the Soviet

Union were frazil and other types of underwater ice, the strength of river and sea ice, navigation in Arctic drift ice, the construction of ice roads for tractor trains and the starting of such trains in cold weather, aircraft de-icing, and a wide variety of fundamental studies. Unfortunately, most of this valuable work had not yet been translated.

In Sweden, between 1929 and 1932, the first comprehensive investigation of the operating resistance of skis was made by Soderberg. Dr. Ahlman of the same country had made an extensive study of glaciers, dealing particularly with ablation (the removal of snow and ice by melting, evaporation and erosion) and the gradual transformation of snow into glacier ice.

Scientists of other European countries, particularly Scandinavia and Poland, had also made important contributions to our knowledge.

63. Major M.G. Bekker of the Directorate of Vehicle Development of the Department of National Defence, Ottawa, was then requested to tell of German work on snow and ice, which he had investigated during a visit to the country in 1946. It seemed that German wartime investigations had added to their previous knowledge of the subject. The construction of autobahns and the occupation of Austria and Czechoslavakia had made snow removal problems increasingly important. Hence an investigating body and a research station were established in 1938, to enquire into snow friction, moisture, strength, permeability and crystal structure.

In an effort to standardize and improve the design of snowplows, two contests of all current German types were sponsored, and results compared and assessed. As a result, the number of types manufactured was reduced from approximately 50 to 14 and the distance of snow throw diminished without reduction of speed. An institute then took over the problem and study of the movement of particles along the plow blade was initiated. A cycloid theory was developed and was to be published. In addition, a supposedly universal snowplow unit was devised.

All available types of snow blowers were investigated and it was found that mechanical losses in throwing snow amounted to 80% or 90%. Therefore, a long term program was initiated to study the elements of design, and theories such as those of centrifugal propulsion. Electrically driven models up to full scale were used and a new snow blower with 40% efficiency was said to be developed.

Snow fences were investigated using trial and error methods with carefully established meteorological and topographical conditions, and test results were obtained with respect to position, size, type and dimensions of fence. A new type of fence made of paper mesh was developed but work was incomplete when the war ended.

Avalanche studies of the Germans were based mainly on Swiss work and little new was added. Snow-going vehicles were studied in a very detailed fashion by an institute under the direction of Dr. Kamm, and records were made of what happened to both snow and vehicle. Static electricity, icing and hydrology were also studied but Major Bekker had no chance to follow up these investigations.

Though it was said that many of the records of investigations were burned, Major Bekker had succeeded in retrieving a certain amount of information from unburned portions which he discovered after an exciting search in the Austrian Tyrol. He also discovered some of the ingenious apparatus used by the Germans in their snow trafficability tests and arranged to have it shipped to Canada. However, very unfortunately, the equipment had been damaged beyond repair in transit.

64. Mr. R.F. Legget completed the review of work in other countries with an account of snow and ice research in Switzerland. With Major Bekker, he visited that country in the spring of 1946 and was greatly impressed with the progress of their studies and the cordial welcome which was extended. The Swiss had studied snow extensively and their cooperation in Canadian work would be most fruitful through contacts which were established by the visit. The country is small and well populated, and completely snow covered for a part of the year. The necessity for avalanche prevention initially focussed attention on snow, since the tourist trade and skiing are among the main businesses of the country; communications were often threatened and the conservation of natural resources, particularly forests, was considered of prime importance.

A Commission on Avalanche Study was set up after World War I, and it was suggested at that time by Dr. Meyer-Peter of the Zurich Technical School that the work might well begin with an investigation of basic snow properties. Dr. Haefeli was put on the work and employed some of the methods of soil mechanics, his first interest. The studies proved of such promise that the Commission was reorganized under the Department of Forestry, and an entire laboratory was set up on the Weissflujoch at an elevation of 8500 feet, solely for the study of snow mechanics, with a staff of 10 scientists and 4 laboratory assistants. Work was done nearby on the testing of snow removal and handling equipment. On the Jungfrau, the Institute for the Study of Life at High Altitudes was established, where work was done on meteorology and glaciology, among other things.

For the purpose of predicting avalanches throughout the country, penetrometer profiles were taken, sometimes daily, at 28 observation stations in the mountains. If records of these tests showed marked changes in the hardness of the snow at any particular level, it was known that slippage was likely to occur there, and warnings were issued in any district where, judging from experience and these records, avalanches seemed probable. Avalanches were also artificially precipitated under control at safe times, to remove subsequent danger, and avalanche rescue work was studied.

It was particularly emphasized that:

(1) All studies were based on a fundamental knowledge of snow properties and characteristics which were established, and

(2) The correlation of snow mechanics with soil mechanics was considered essential because of the many theories common to both.

The vast amount of information which was gathered during the visit and a realization of its importance to Canada and many other countries made it desirable to prepare much more than the usual report on what was seen. Hence as complete a digest as possible of the present status of snow studies in all the countries mentioned was now being compiled by Major Bekker, Mr. Klein and the Chairman. It was hoped that copies of this report would be available (through the National Research Council) early in 1948.

Open Forum

65. Upon the completion of this factual review, an open forum was held at the Chairman's suggestion, in which some of the problems previously mentioned were brought under discussion.

With regard to the suggestion of supercooled water which Mr. Davison had mentioned, Mr. Klein observed that the same phenomenon was of interest in aircraft icing and occurred most commonly when the air-suspended water particles were extremely small. German war experiments had shown that repeated freezing of water lowers its freezing point if the containing vessel is sizeable. Such experiments had been reproduced by the National Research Council and it had been found that impurities had a great effect. Sir Charles Wright added that there seemed to be two conditions under which condensation occurred from the atmosphere: (1) when supercooled water droplets gave a rapid accretion, and (2) when extremely fine ice particles fell giving a slow accretion.

Establishment of Continuing Committee

66. The Chairman suggested that the time had now come to decide what could be done to continue the co-ordination of the work which had been reported and suggested by the Conference. With the aid of a chart (accompanying this report as Appendix B) the present organization and integration of the Associate Committee on Soil and Snow Mechanics and that on Geodesy and Geophysics was explained. The proposal was placed before the Conference by the Chairman that existing machinery might best be used and resources best conserved by the establishment of one Subcommittee, to include all the aspects of the numerous problems dealing with snow and ice, under the two Associate Committees with the cooperation of the Department of National Defence, rather than by setting up a new independent committee. This Subcommittee could act as a clearing-house for the work which it was hoped would be carried out across Canada by various agencies.

After discussion, the Chairman asked for an indication of opinion on the advisability of setting up a joint Subcommittee on Snow and Ice under the two

Associate Committees, as proposed, and unanimous agreement to this was expressed.

The Chairman assured the gathering that the greatest care would be exercised in choosing the membership of the Subcommittee so that it might be free to give sufficient time and attention to the work, and so make its function as effective as possible. It was stated also that serious and careful consideration would be given to all the problems, and it was asked that suggestions for problems on snow and ice requiring immediate attention be submitted in writing to Mr. Nazzer.

Publicity

67. The advisability of publicizing the proceedings and decisions of this Conference was discussed, and general opinion was in favour. It was therefore announced that a record of the meeting would be prepared as a joint memorandum of the two Associate Committees concerned, and circulated to those present. Requests for extra copies of this record might be sent to Mr. Nazzer.

International Conference on Snow and Glaciers

68. It was announced that in August 1948, the International Conference on Snow and Glaciers would be held in Oslo, in connection with meetings of the International Union of Geodesy and Geophysics, and it was hoped that Canada would produce papers and representation at this gathering for the benefit of international cooperation in snow and ice research.

Coordinating Work in Hydrology and Meteorology

69. Dr. J.T. Wilson, co-chairman of the Conference, described those international and national organizations at present concerned with hydrology and meteorology. The International Union of Geodesy and Geophysics included seven sections dealing with related subjects and 35 national committees of which the American Geophysical Union was largest.

The Hydrological Section of the American Geophysical Union carried out a great deal of work, and in view of the importance of hydrology and the associated subject of meteorology in Canada, it was deemed advisable to have some Canadian body or bodies dealing with these subjects which could also cooperate with this section of the American organization. It was considered that the suggestion to set up such a body might well be made at this time in view of the approaching International Conference at Oslo, where it was expected that some Canadians would present papers on hydrology and meteorology.

Dr. Wilson explained that many organizations and individuals had been found to be interested in such problems. If a Committee was formed under the National Research Council to deal with them, the Council might assist in financing publications and meetings, and in rendering financial assistance in some degree to researches. A bulletin on geophysical subjects generally had already been published to indicate what was currently being done, and this bulletin could be made available for the publication of hydrological and meteorological work.

After some discussion on whether or not hydrology and meteorology should be dealt with by a single Subcommittee of the Associate Committee on Geodesy and Geophysics, or treated as separate subjects with two committees, it was decided that the two subjects could profitably be kept together and dealt with by a single Subcommittee or Section.

It was therefore proposed and generally agreed that the Associate Committee on Geodesy and Geophysics, with representatives of other interested agencies and the Associate Committee on Soil and Snow Mechanics, would consult together and appoint a Subcommittee on Hydrology and Meteorology.

Snow Research Stations

70. Mr. Baird, in summing up generally the problems discussed at the Conference, said that need had been shown for:

(1) Research on the basic physics of snow and ice;

(2) Observation stations and snow surveys, and in connection with the latter, a correlation of and better distribution of uniform data;

(3) Research on snow fences and snow removal, perhaps financed by some of the vast amount of money now spent on these; and

(4) Research on sleighs and aircraft.

All of these items pointed to the need for snow research stations in Canada. The Northwest Territories Branch, Department of Mines and Resources, was already establishing a scientific station at Baker Lake, N.W.T. The Arctic Institute of North America had been considering the establishment of a snow research station in the near future, probably in the Rockies near a transportation route. Additional stations both in the northwest and in the glacial region of northeastern Canada would be considered. Some support for the proposal had already been shown and the official support of the newly formed Subcommittee on Snow and Ice would be most gratifying.

The Chairman assured Mr. Baird that the Committee would do all it could to support and assist such a plan when it commenced activities.

Future Conferences

71. At Dr. Woodcock's suggestion, the question of another similar Conference was taken up by the Chairman. It was generally agreed that such a meeting could most usefully be held in the fall of next year.

Concluding Remarks

72. Dr. R.W. Boyle, Director of the Division of Physics and Electrical Engineering of the National Research Council, (to whose long interest in snow and ice the Chairman paid tribute), directed the attention of those present to the fact that there were only four world nations with a special duty of responsibility to pursue northern researches -- Canada, United States and Alaska, Russia, and Scandinavia,-- and asked if Canada could be considered as pulling its weight when compared with any of these. He was strongly in favour of pursuing such research and cooperating with anyone, anywhere in the world, doing similar work. The complete support of the Division of Physics was assured on any problem of snow and ice touching the work of that Division.

73. The Chairman presented a summary of the work of the Conference. Seventy delegates had gathered from all parts of Canada to discuss their interest in snow and ice problems. Almost without exception, everyone had contributed to a factual survey which included numerous suggestions for investigation. (A list of suggested and continuing problems for research accompanies this report as Appendix C). It had been agreed that a joint Subcommittee, operating under the two Associate Committees sponsoring the Conference, should be set up to coordinate future work and that a similar Conference should if possible be held annually. A Section on Meteorology and Hydrology would be appointed under the Associate Committee on Geodesy and Geophysics. Long-standing problems had been aired and information exchanged freely. It was hoped that this Conference would be but the first step in a program of active research which would extend far in the future.

74. Dr. C.J. Mackenzie, President of the National Research Council, who was able to join the Conference only after attending concurrent important meetings, brought the meeting to a close by expressing the official interest of the National Research Council in the work of the Conference, and his personal pleasure at hearing of what had been accomplished.

Report prepared by
F.L. Peckover,
24 October, 1947.

Checked by
R.F.L., J.T.W., P.D.B.

APPENDIX A

LIST OF THOSE ATTENDING CONFERENCE
ON SNOW AND ICE

Ottawa, 17-18 September, 1947.

Dr. C.J. Mackenzie, President, National Research Council, Ottawa.
Dr. D.A. Keys, Vice-President (Scientific), National Research Council, Chalk River.
Dr. R.W. Boyle, Director, Division of Physics, National Research Council, Ottawa.
J.H. Parkin, Director, Division of Mechanical Engineering, National Research Council, Ottawa.

Sir Charles S. Wright, former Chief Scientific Adviser, British Admiralty.
Mrs. E.W. Manning, Ottawa.
Mrs. Diana Rowley, Ottawa, former member of Committee of the British Glaciological Society.

P.D. Baird, Director, Montreal Office, Arctic Institute of North America.
Matthew Balls, Manager, Water Resources Department, Shawinigan Water and Power Company, Montreal.
J.C. Chagnon, Chief Engineer, Quebec Streams Commission, Montreal.
C.G. Cline, Senior Assistant Engineer, Dominion Water and Power Bureau, Niagara Falls.
B.W. Currie, Professor of Physics, University of Saskatchewan, Saskatoon.
A.E. Davison, Transmission Engineer, Hydro Electric Power Commission of Ontario, Toronto.
W.G. Dyer, Engineer of Track, Canadian Pacific Railways, Montreal.
R.C. Farrow, Comptroller of Water Rights, Department of Lands and Forests, British Columbia. (Chairman, A.G.U. Committee on Snow)
H.M. Finlayson, Hydraulic Engineer, Shawinigan Water and Power Company, Montreal.
G.O. Grant, Maintenance Engineer, Ontario Department of Highways, Toronto.
W.E. Griffiths, Chief Engineer's Department, Canadian National Railways, Montreal.

M.C. Hendry, Engineer, Hydraulic Department, Hydro Electric Power Commission of Ontario, Toronto.
George H. Kimble, Chairman, Department of Geography; Director, Meteorological Observatory, McGill University, Montreal.
J.A. Lenoir, District Engineer, Quebec Department of Highways, Montreal.
A. Marien, Hydraulic Engineer, Quebec Streams Commission, Montreal.
Norman W. McLeod, Department of Asphalt Technology, Imperial Oil Limited, Toronto.
W.A.D. Munday, Western Vice-President, Alpine Club of Canada, North Vancouver, B.C.
C.H. Pigot, General Assistant Engineer, Generating Stations and Hydraulic Division, Quebec Hydro Electric Commission, Montreal.
J.A. Racicot, District Engineer, Quebec Department of Highways, Montreal.
Norman W. Radforth, Professor of Plant Morphology and Palaeobotany; Head, Department of Botany, McMaster University; Director, Royal Botanical Gardens, Hamilton.
C.A. Robbins, District Engineer, Ontario Department of Highways, Toronto.
J. Sicard, President and General Manager, Sicard Limited, Montreal.
Andrew Thomson, Controller, Meteorological Service, Department of Transport, Toronto.
John Walter, Materials Engineer, Ontario Department of Highways, Toronto.
A.L. Washburn, Director, Arctic Institute of North America, Montreal.
Walter A. Wood, Director, New York Office, Arctic Institute of North America.

From Ottawa

Charles Ballard, Lt.-Col., Directorate of Armament Development, M.G.O. Branch, Department of National Defence.
A.M. Beale, Executive Engineer, Dominion Water and Power Bureau.
M.G. Bekker, Maj., Directorate of Vehicle Development, Department of National Defence.
E.G. Cameron, Chief Engineer, National Harbours Board.
H.D. Cameron, Meteorologist, Department of Transport.

W.N. Chater, Acting Director of Vehicle Development, M.G.O. Branch, Department of National Defence.
C.H. Cotton, W/C, Director of Equipment, Royal Canadian Air Force.
C.V. Green, Cdr. (R.C.N.), Deputy Director, Naval Construction, Royal Canadian Navy.
George Hanson, Chief Geologist, Geological Survey of Canada.
D.B. Kennedy, Meteorological Adviser, National Defence Headquarters.
George J. Klein, Research Engineer, Division of Mechanical Engineering, National Research Council.
A.K. Laing, Assistant Chief, Aids to Navigation, Marine Services, Department of Transport.
James Lang, Maj., Directorate of Engineering Development, Department of National Defence.
A. Leahey, Soil Specialist, Experimental Farms Service.
J.W. Lucas, Acting Director, Testing Laboratories, Department of Public Works.
Scott Lynn, Maj., Directorate of Engineering Development, Department of National Defence.
K.C. Maclure, W/C, Director of Arctic Research, Defence Research Board, Department of National Defence.
T.H. Manning, Survey Engineer, Geodetic Service, Department of Mines and Resources.
Norman Marr, Assistant Controller, Dominion Water and Power Bureau, Department of Mines and Resources.
D.J. Martin, Superintendent, O.C. "G" Division, Eastern and Western Arctic, Royal Canadian Mounted Police.
F.G.B. Maskell, Maj., Directorate of Weapons and Development, Department of National Defence.
T.A. McElhanney, Superintendent, Forest Products Laboratories, Department of Mines and Resources.
Victor Meek, Controller, Dominion Water and Power Bureau, Department of Mines and Resources.
C.D. Niven, Physicist, Heat Section, Division of Physics, National Research Council.
P.M. Pfalzner, Physicist, Heat Section, Division of Physics, National Research Council.
H.S. Rees, Chief Aeronautical Engineer, Department of Transport.
P.O. Ripley, Dominion Field Husbandman, Experimental Farms Service, Department of Agriculture.
D.C. Rose, Chief Superintendent, Canadian Armament Research and Development Establishment, Valcartier, Que. (also National Research Council).
G.W. Rowley, Lt. Col. Defence Research Board, Department of National Defence.
F.H. Sanders, Scientific Assistant to the President, National Research Council.

W. L. Saunders, District Engineer, Ontario Department of Highways.
W.E. Wakefield, Chief, Timber Mechanics, Forest Products Laboratories, Department of Mines and Resources.
A.H. Woodcock, Research Scientist, Defence Research Board, Department of National Defence.

Associate Committee on Geodesy and Geophysics

J. Tuzo Wilson, Chairman; Professor of Geophysics, University of Toronto.
W.E. Grasham, Secretary; Assistant Research Physicist, Division of Physics, National Research Council.

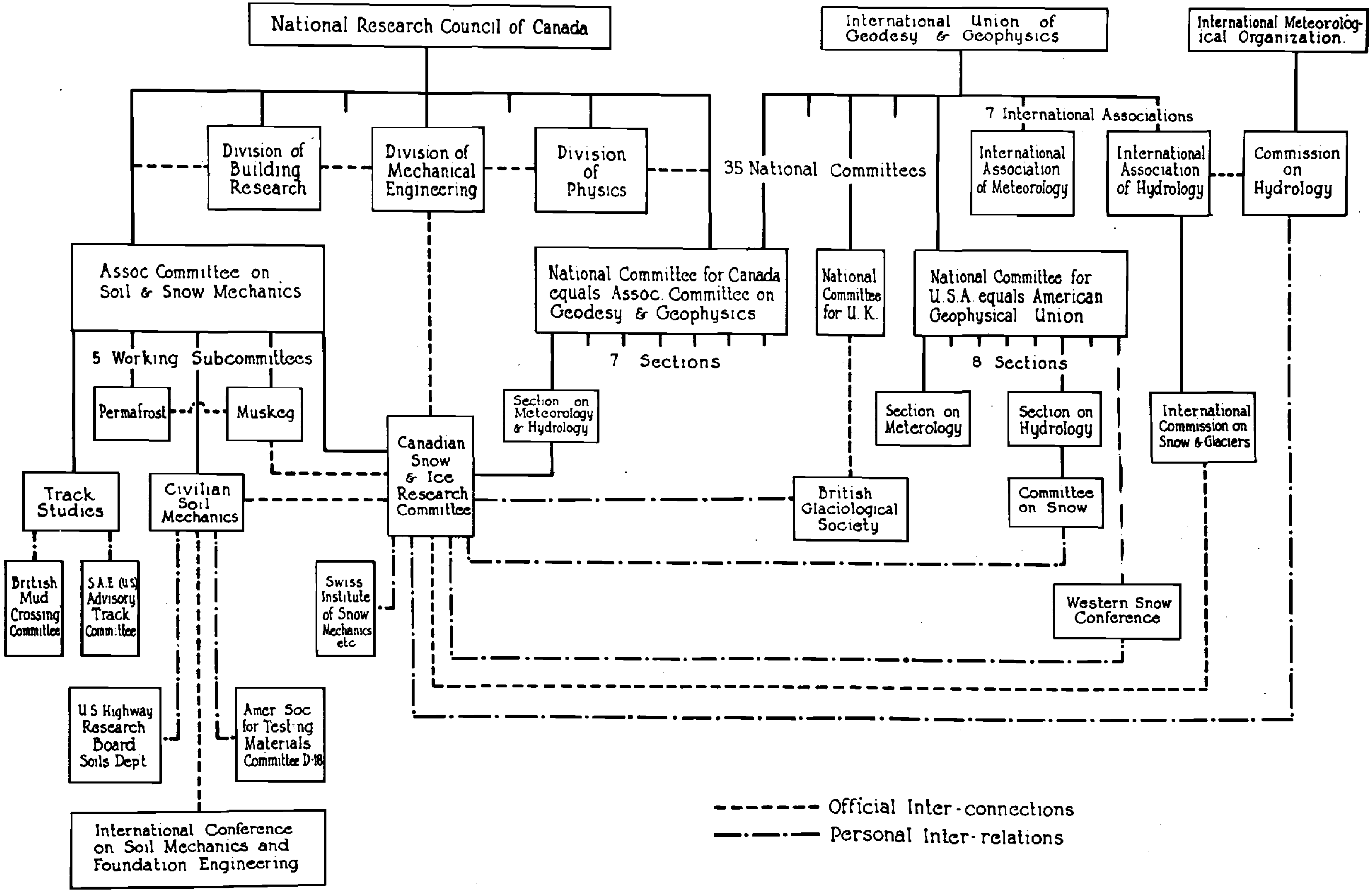
Associate Committee on Soil and Snow Mechanics

R.F. Legget, Chairman; Director, Division of Building Research, National Research Council.
D.B. Nazzer, Secretary; Assistant Research Engineer, Division of Mechanical Engineering, National Research Council.
F. Lionel Peckover, Assistant Research Officer, Division of Building Research, National Research Council.

Following the Conference, the following were named to serve as officers of the Joint Subcommittee on Snow and Ice:

P.D. Baird, Chairman,

D.B. Nazzer, Secretary.



Organization Chart of N.R.C. Assoc. Committee on Soil and Snow Mechanics showing inter-relation with Assoc. Committee on Geophysics, with special reference to Canadian and International studies of Snow and Ice.

APPENDIX C

List of Suggested and Continuing Research Projects on Snow and Ice Mentioned at the Conference

I. Fundamental Research

1. Establishment of observation and research stations.
2. Correlation and expansion of existing snow surveys, and standardization and distribution of data so obtained.
3. Maps of snow cover and its seasonal variation.
4. The physics of snow-melting, particularly as related to absorption of solar heat.
5. Knowledge of the properties of various types of ice, and conditions under which they are formed.
6. The importance of cyclic trends of solar radiation as affecting severity of weather.
7. Seasonal forecasting of snowfall.

II. Hydrology and Meteorology:

1. Correlation of snow accumulation and run-off, finding variables involved and their individual importance and effect.
2. Accurate prediction of run-off as affecting power development and flood conditions.
3. Influence of snow meltwater on ground water storage.

III. Snow Control and Clearance:

1. Location of existing types of snow fences and wind-breaks for highest efficiency.
2. Development of more efficient means of control of snow drifting.
3. Improvement of snowplow design.
4. Development of more efficient means of snow and ice removal.
5. Development of non-injurious chemicals for road treatment.
6. Development of anti-slip treatment for roads and sidewalks.
7. Design of self-cleansing highways.

IV. Oversnow Travel:

1. Properties of snow as affecting skis, sleds, or toboggans, and effect of heating sliding surfaces.
2. Design of oversnow tracked vehicles.
3. Starting of tracked vehicles in cold weather.
4. Take-off and landing with aircraft skis.

V. Agricultural Effects:

1. Evaporation from snow surfaces as affecting snow storage.
2. Amount of run-off available for irrigation purposes.
3. Preservation of moisture in dry farming areas by drift prevention.
4. Run-off as affecting erosion and soil conservation.
5. Value of snow cover (a) as a fertilizer, (b) as protection against frost penetration, and (c) as promoting the slow absorption of water by soil.
6. The effect of infiltration of snow meltwater into frozen or semi-frozen soil.
7. The effect of permafrost on crops and plant growth.
8. Frost action in problems of land clearing.
9. Snow mechanics as affecting the trafficability of farm vehicles.

VI. General Ice Problems:

1. Physical properties of ice, such as strength and friction.
2. Means of reducing or increasing such properties.
3. Conditions governing the formation of various types of ice, particularly frazil ice, and their critical nature.
4. Means of preventing the formation of ice, such as frazil ice or that against dams and other structures.
5. Pressure of large ice sheets on engineering structures.
6. Prevention of ice jams with consequent floods and structural damage.
7. Study of living glaciers.
8. Effect of rain on ice.
9. Rapid means of detecting thickness of sea ice.
10. Rapid means of estimating strength of sea ice.
11. Storage of ice for refrigeration purposes.

VII. Ice Problems Affecting Navigation:

1. Eliminating and controlling formation of ice on various parts of a ship.
2. Means of facilitating the removal of such ice after formation.
3. Means of predicting the close of the navigation season.
4. Means of lengthening the navigation season on the Great Lakes.
5. Means of clearing ship channels more effectively.
6. Movements of ice under wind, and controls for such movements.
7. Navigation in Arctic drift ice.
8. Forecasting of iceberg seasons.
9. Tracing the path of icebergs.

VIII. De-Icing Problems:

1. Data on super-cooled liquid particles in air, and their characteristics when encountered by moving objects.
2. Means of de-icing electrical conductors.
3. Elimination of "galloping" conductors.
4. Icing of aircraft propellers.
5. Icing of aircraft wings and fuselage on the ground.
6. Icing of aircraft wings in the air.

IX. Permafrost:

1. Identification and mapping of permafrost areas.
2. Determination of the nature of soils in which permafrost occurs.
3. Determination of the thermal conductivity of frozen ground.
4. Means of lowering the level of permafrost.
5. Foundations on permafrost.

X. Engineering

1. Frost boils and frost heaving of roadbeds.
2. Depth of frost penetration as affecting the depth of laying pipe services.
3. The validity of the use of the number of degree-days of freezing as a factor in runway design.

4. Airborne machinery necessary for the construction of airports on rolled snow or ice-covered lakes.
5. Construction of ice roads for tractor trains.
6. Means of transporting and storing fuel in the far north.
7. Damage to wharves caused by ice movements.

XI. Electromagnetic Effects:

1. Electrostatic charges on snowflakes.
2. Determination of snow and ice depth by electromagnetic waves.
3. Effect of blowing snow and ice crystal haze on ultra-high frequency radio waves, and on navigation and communication.
4. Detection of snow storms by electromagnetic waves.

XII. Comfort Problems:

1. Clothing in the far north.
2. Physiological and psychological effect of proper clothing and food.
3. Housing in the far north.
4. Development of survival methods.

XIII. Miscellaneous:

1. Prediction of snow slides in mountainous areas.
2. Effect of snow on penetration of weapons and fragmentation of bombs and shells.