

NRC Publications Archive Archives des publications du CNRC

Method of measuring the significant characteristics of a snow-cover
Klein, G. J.; Pearce, D. C.; Gold, L. W.

Publisher's version / Version de l'éditeur:

Technical Memorandum (National Research Council of Canada. Division of Building Research); no. DBR-TM-18, 1950-11-01

NRC Publications Archive Record / Notice des Archives des publications du CNRC :
<https://nrc-publications.canada.ca/eng/view/object/?id=54650980-94c4-4810-b8f9-7ffb54006ef2>
<https://publications-cnrc.canada.ca/fra/voir/objet/?id=54650980-94c4-4810-b8f9-7ffb54006ef2>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at
<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site
<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at
PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

NATIONAL RESEARCH COUNCIL OF CANADA

Associate Committee on Soil and Snow Mechanics

TECHNICAL MEMORANDUM NO. 18

METHOD OF MEASURING THE SIGNIFICANT CHARACTERISTICS
OF A SNOW-COVER

by

G. J. Klein, D. C. Pearce and L. W. Gold

ANALYZED

This Report supersedes T.M. No. 5 and
Division of Mechanical Engineering
Reports MM-192 and MM-202

Ottawa

November 1950

Price, 50 cents

N.R.C. No. 2269

guidance, in the newly formed Soil and Snow Mechanics Section of the Division of Building Research by Messrs. D. C. Pearce and L. W. Gold. A general paper has been prepared and will later be published.

As this work has proceeded, and as the Committee looks forward to an extension of the survey to sheltered areas, it has become very clear that a revision of the original "snow survey report" was not only desirable but essential. In the revision could be consolidated the several interim supplements. This report is the consolidated revision. As indicated on its cover, it supersedes all the previous reports on the snow survey technique. It includes details of a proposed international system of snow classification.

Although much of the work of revision has been done by Mr. Pearce and Mr. Gold, the report is still primarily the work of Mr. Klein under whose personal direction the revision has been carried out. It is a pleasure to record the appreciation of the Associate Committee of the work of these members of the Council's research staff. And it is a further pleasure to point out that publication of this joint report as a Technical Memorandum of the Committee is further evidence of the close co-operation which exists in this, as in other fields of work, between the Council's Divisions of Mechanical Engineering and Building Research.

Ottawa
7 November 1950.

R. F. Legget,
Chairman,
Associate Committee on
Soil and Snow Mechanics.

TABLE OF CONTENTS

	<u>Page No.</u>
Summary	1
Introduction	1
Tests of the Snow-Cover Survey	2
Instruments	7
Snow Classification	12
Test Procedure	12
General Instructions	18
Daily Observations	18
Snow Profile Observations	19
Observations at Sheltered Areas	20
Information to be Furnished by all Stations	21
Conclusion	22
Acknowledgments	22
Appendix A. General Notes on Snow	
Appendix B. Nomenclature for Snow	
Appendix C. Explanation of Form B	
Appendix D. Tentative Snow Classification	

Figures

1. Balance
2. Snow Sample Cutter (Soft Snow)
3. Snow Sample Cutter (Hard Snow)
4. Snow Hardness Gauge (N.R.C. Type)
5. Magnifying Glass, Graduated Cup and Spatula.
6. Complete Kit
7. Balance
8. Form B (Daily Observations)
9. Form A (Profile Observations)

METHOD OF MEASURING THE SIGNIFICANT CHARACTERISTICS
OF A SNOW-COVER

SUMMARY

The report describes the instruments and the current methods used in the Snow-Cover Survey which has been conducted in Canada since 1946. It is a revision of National Research Council of Canada, Division of Mechanical Engineering, Reports MM-192 and MM-202. Some general information concerning snow and a nomenclature for snow are given. The report also includes the "Tentative Snow Classification" proposed by a committee of the International Association of Hydrology.

INTRODUCTION

1. In winter, snow presents a great number of problems many of which are related to transportation. There are, for example, the problems of snow clearance on highways, railways and airports, the performance of over-snow motor vehicles, aircraft skis, logging sleighs and many miscellaneous snow problems. There is also the problem of avalanche control which has received so much attention in Switzerland. Such problems are not new and yet it is only in the last twenty years that snow mechanics research has been taken seriously. Although snow is often regarded as a nuisance, the successes that have resulted from snow research amply demonstrate that many of the undesirable effects of snow can be controlled or lessened considerably.

2. The properties of snow vary widely. New snow is different in many respects from old snow and the snow common to temperate climates is again different from that usually found in the Barrens. Experienced skiers are well aware of this peculiarity of snow and have found that a fair number of ski waxes are required to cope with the range of skiing qualities of the many types of snow. It is because snow properties vary so widely that designers of winter equipment require a more complete description of a snow-cover than merely its total depth which is often the only information provided.

3. The solution for many snow problems may be found by means of two separate lines of research which must be properly correlated if they are to be effective. The first deals with

the properties of different types of snow and should be carried out in a well equipped laboratory where conditions are under the control of the research worker. The second, which is the subject of this report, deals with the collection of snow-cover data at a number of observation stations with a view to establishing a reasonably reliable picture of the average and extreme conditions which occur in different localities. Over a period of many years, the meteorological services of different countries have collected considerable data on the amount of snowfall at a great many weather stations. In recent years, hydrological snow surveys have been conducted in many countries, usually in mountainous areas, for the purpose of predicting the amount of spring run-off and its effect on irrigation and water power developments. However, neither of these supply the kind of data needed for those problems related to winter transportation.

4. The Associate Committee on Soil and Snow Mechanics of the National Research Council of Canada has realized the value of collecting snow-cover data and it is due to their efforts that standardized instruments and methods have been developed in Canada. The instruments are not new - similar instruments have been used in various snow researches - but they have been redesigned so as to be as portable and as convenient to use as possible. Many sets of these instruments have been used in Canada and other countries since 1946.

5. In 1946 the Associate Committee on Soil and Snow Mechanics, with the close co-operation of the Meteorological Service of the Department of Transport, initiated the snow-cover survey in Canada. The venture was quite successful and much valuable information was gathered.

TESTS OF THE SNOW-COVER SURVEY

Purpose of the Tests

6. The aim of the snow tests is to describe any particular snow-cover by means of measurements (or photographs) in order that the problems associated with it - such as snow performance of vehicles, skis, snow-clearance equipment, etc. - can be fully appreciated by the designer or user of such equipment. The tests, therefore, deal with the significant features of the various layers of snow on the ground, and are concerned with falling snow only because of its relation to the snow in the surface layer. In certain winter problems the contours of the snow surface may become important; for example, the drifts or waves of hard wind-packed snow found in the Barrens present

problems to designers of over-snow vehicles, and designers of aircraft winter landing gear. For this reason the tests also deal with the shape of the snow surface. The observer should always keep the aim of the tests in mind and should be continually on the lookout for unusual conditions which may affect the design or performance of winter equipment. While snow in its various forms is an interesting material from a purely scientific point of view, the tests are primarily intended to fulfil a practical purpose.

Basis on which the tests have been chosen

7. An outline of the reasoning which determined the choice of tests should give the observer a better appreciation of their value. Snow tests, unless well planned, can consume a great deal of time; therefore only the essential tests have been chosen and they have been made as simple and convenient as possible.

8. Snow is very porous and therefore contains a considerable volume of air. At times it may be wet so that water in the liquid state may also be present. In general then, we can consider snow to be a mixture of ice, water and air. The relative amounts and the physical properties of each constituent will therefore affect the physical properties of the snow. The only one of the constituents whose properties vary appreciably with temperature is ice, since water can only be present at one temperature, i.e., the melting point of ice, and the main temperature effect on air is that it determines its moisture content. Near the melting point the properties of ice vary considerably with the temperature.

9. The shape and size of the ice crystals also influence the physical characteristics of snow; long slender forms are more fragile than more compact forms and cause the snow mass to be structurally weak. In new snow there are structural effects produced by the interlocking of the crystal branches and these too depend on the size and shape of the crystals. Size and shape of the grains have another important effect - the cohesion of wet snow is due largely to surface tension forces which, as explained in paragraphs (110 to 113) are most effective when the snow texture is very fine.

10. Changes which take place during ageing or "firnification" of the snow often cause the grains to grow together to form a miniature ice network. This bonding, which is usually present to some degree in all forms of dry snow, can add greatly to the strength of the snow.

11. From the above discussion it follows that the fundamental features upon which the properties of snow depend and which distinguish one form of snow from another are:

- (a) snow temperature;
- (b) relative proportions of ice, water and air;
- (c) shape and size of the individual grains or crystals, and
- (d) degree of bonding between the grains.

12. The methods for obtaining (a) and (b) are obvious if (b) is expressed in terms of specific gravity and percentage free water content. Snow temperature can be measured with a thermometer, specific gravity can be found by weighing a known volume of snow, and free water content can be determined by a simple calorimetric method.

13. There are alternative methods for obtaining (c). These are: (1) measurements of airflow permeability as adopted by the Institut für Schnee- und Lawinenforschung, Switzerland, (2) macrophotography of samples of snow grains, and (3) observations with the aid of a magnifying glass using a ruled background and a standardized scale of grain shape. The first of these methods, while excellent for laboratory tests, requires apparatus that cannot easily be made portable. The second is also a good method but is not as simple as the third. The third method is very convenient and has been found to give sufficiently accurate results for most practical purposes. Therefore the third method has been adopted in this report.

14. The most direct measure of the degree of bonding between grains, (d) above, is the tensile strength of the snow. Although tensile strength tests have been carried out in the laboratory, they present a number of difficulties for routine use in the field. The next best method, although somewhat indirect, is a test of snow hardness or firmness - a form of compression test of snow in situ.

15. Two types of instruments have been used for snow hardness tests: (1) the conical ram (Kegelsonde) developed by the Institut für Schnee- und Lawinenforschung, and (2) the National Research Council of Canada snow hardness gauge.

16. The conical ram was designed for a particular purpose - that of routine tests in the Swiss Alps with a view to estimating the avalanche tendencies of deep snow on steep slopes. Its outstanding feature is that it can measure the firmness of any layer down to depths as great as three or more meters without the necessity of digging a test trench in the snow. Although it is not a direct indicating instrument, only a very simple calculation is required to obtain the firmness of the snow. In Switzerland, where avalanche research is considered essential to safety in the mountains, the conical ram has been used extensively and is regarded as a standard snow testing instrument.

17. The National Research Council snow hardness gauge measures essentially the same quality of the snow as does the conical ram although the numerical results are not identical. It is similar to an instrument developed in Switzerland and referred to by Seligman in "Snow Structure and Ski Fields". Its main features are that it is simple and compact, it indicates snow hardness directly, and it covers a very wide range. However, it does require the digging of a test trench, but this is only a disadvantage when snow hardness measurements alone are taken. In most snow research - avalanche research being an exception - the trench is required for other tests.

18. The shape of a snow surface is not easily described by simple field measurements alone. In most cases a word description will suffice, but when the surface is such that it has a definite bearing on the problem under consideration, its shape may be most conveniently described by means of a photograph.

19. A snow-cover can therefore be completely described by the methods outlined above. The various tests are given in the table below. Air temperature, although not essential, is also included since it is often used as a convenient reference.

20. The various tests tabulated in this table are not without a few inter-relations. Snow of very low specific gravity will have crystals of slender dendritic form and will generally contain no free water. Dry snow of moderately

high specific gravity will be rather hard and its grains will be of compact form. Very wet snow will have compact grains and very high specific gravity. When the snow temperature is equal to the melting point of ice, free water will be present, but at all other temperatures there will be no free water.

TABLE I

Test	Apparatus	Remarks
Air temperature	Thermometer	Taken 1 to 3 feet above snow surface (See paragraph 51)
Snow temperature	Thermometer	Taken at least once every 6 inches through snow profile. (See paragraph 53)
Specific gravity of snow	Balance, snow cutters, snow knife	Observations in each distinct layer. (See paragraphs 64 and 66)
Free water content	Snow classification	See paragraphs 62 and 63
Grain shape and size	Magnifying glass, graduated cup, spatula, International classification	Observations in each distinct layer (See paragraphs 57 and 58)
Snow hardness	Snow hardness gauge or conical ram	Observations in each distinct snow layer (See paragraphs 54, 55 and 56)
Form of snow surface	Any photographic camera	See paragraphs 69 and 70

INSTRUMENTS

Choice of Instruments

21. The instruments which have been chosen are simple, compact and reasonably durable. No special skill is required to use them. All are graduated in metric units to facilitate comparison with the comprehensive Swiss researches in snow mechanics. A photograph of the complete set is shown in Fig. 6.

Care and Maintenance

22. All components of the instruments are rustproof with the exception of the balance knife edges which are made of hardened steel. Should the knife edges show signs of rusting, some very light oil may be applied and then wiped off, but oil should not be used on any other part of the instruments. If the snow cutters or snow knife begin to rust they may be protected with a thin coating of wax.

23. The interior of the carrying case should be kept as free of snow and water as possible; any snow or water adhering to the instruments should be removed before the instruments are put back into the case.

24. All instruments should be kept free of dirt or grit and may be oiled or waxed before they are stored for the summer. However, if oil is used it should be removed before they are put into service again.

25. It is advisable to keep the instruments in their carrying case in an unheated shelter so that the instruments, at the time they are used, will be at approximately the same temperature as the snow.

26. If the liquid column of a thermometer becomes separated, as may happen during shipment, it may be reunited by one of the following methods:

- (1) Mercury thermometer with separation near bulb. Immerse the bulb in a freezing mixture* until all the mercury has been drawn into the bulb. Tap the thermometer to dislodge gas bubbles in the bulb.

* Freezing mixture (parts by weight)
 3 parts snow at 0°C. added to 1 part NaCl.....=20°C.
 1 part snow at 0°C. added to 1 part alcohol.....=30°C.
 .70 parts snow at 0°C. added to 1 part CaCl₂.....=55°C.

(2) Mercury thermometer with separation near top. Hold the thermometer at a considerable height over a low flame and by moving it back and forth, apply heat gently until the broken place in the thread has moved upward into the reservoir.

CAUTION: This method is more likely to result in breakage and extreme care should be used.

(3) Red liquid thermometer. Securely fasten one end of a strong cord about 3 feet long to the thermometer by binding it tightly with cellulose tape along the full length of the thermometer, the thermometer bulb being opposite the free end of the cord. Securely hold the free end of the cord and rapidly whirl the thermometer in a horizontal plane over head.

(4) Red liquid thermometer. Use a method similar to (2) but apply the heat by immersing the bulb in water being heated on a stove. Stir the water continually and do not let the thermometer come in contact with the vessel containing the water.

The above methods have all been used successfully. If column separation occurs frequently it may be advisable to remove the thermometers from the kit and store them in a heated building.

27. If reasonable care is taken, damage to the instruments or loss of any of their parts can be avoided.

Balance

28. The beam type balance shown in Figs. 1 and 7 is ideal for snow measurements. It is more accurate than a spring type balance.

29. The balance frame A carries two riders B and C of equal weight. Moving either rider B or rider C from extreme left to extreme right is equivalent to 500 grams so that measurements up to 1,000 grams can be made by utilizing both riders. Rider B carries a vernier which reads directly to 2 grams. Measurements to the nearest gram can be made without much difficulty.

30. Rider C contains a spring clamp which prevents accidental movement of the rider when the frame is at an extreme angle. The clamp must be released by pressing on button D whenever it is necessary to move rider C.

31. Hook E is for hanging the balance on any convenient support. A balance support, which springs on to the edge of the carrying case, is provided with each set of instruments. Hook F is for hanging the weighing bucket on the balance.

32. The balance has been adjusted to read zero when the empty bucket is in place on hook F and riders B and C are in their extreme left position.

33. The sensitivity of the balance can be altered without disturbing the zero adjustment by changing the vertical position of the counterweight G. If the balance has to be used exposed to the wind, it is advisable to decrease the sensitivity. Generally, the balance should be as sensitive as conditions will permit. Frequent adjustment of sensitivity should be avoided. To change balance sensitivity loosen the clamping screws H, move the counterweight G (downward to decrease, upward to increase sensitivity) and securely tighten both screws H.

34. The condition of balance is indicated when the pointer J, which forms part of frame A, swings an equal amount on each side of the knife edge plates K.

Snow Sample Cutters

35. Each set of instruments contains two snow sample cutters which are used to cut snow samples of known volume for specific gravity measurements. The internal volume of each cutter is 250 cc.

36. The cutter shown in Fig. 2 is for soft snow conditions. Its cylinder A has a thin cutting edge and its handle is bent so that the axis of the handle coincides with that of the cylinder. The removable back cover plate C has hooks which engage pins D on the cylinder.

37. The soft snow cutter is always used horizontally. During the cutting of the sample, the cutter is rotated about its handle axis in order to avoid compressing the snow sample. A knife is used to trim the sample level with the forward and rear edges of the cylinder.

38. The back cover plate may be used to prevent very slippery samples from sliding out of the cutter before they can be placed in the balance bucket. It is also useful when determining the specific gravity of loose grains such as hail.

39. The snow sample cutter shown in Fig. 3 is for hard snow conditions. Its cylinder A has a saw-tooth cutting edge C and a simple handle B. The internal volume between the planes X-X and Y-Y is 250 cc. This cutter may be used either horizontally or vertically. To determine the specific gravity of a thin crust, cut sufficient discs of the crust to fill the length of the cylinder. The method of use is obvious.

Snow Hardness Gauge (N.R.C. type)

40. The snow hardness gauge is a push-type spring balance on which any one of several pressure discs can be mounted. The gauge is shown in Fig. 4.

41. The end of the push rod E is arranged so that the two smallest discs are permanently attached to the push rod. The area of the smallest disc A is 0.1 cm^2 , and the area of the annular shoulder B is 0.9 cm^2 , so that the area of A and B taken together is 1.0 cm^2 . Two separate discs C and D (D is not shown in Fig. 4) have areas of 10 and 100 cm^2 respectively. Disc C (or disc D) is held in place on the end of the push rod by the friction of a rubber washer which is cemented to the disc. Whenever a disc is fitted to, or removed from the push rod, the disc should be rotated to avoid pulling the rubber washer off the back of the disc.

42. The opposite end of the push rod carries a scale graduated from 0 to 10. Since 10 on the scale corresponds to a push rod force of 1,000 grams, one division of the scale corresponds to 100 grams. Thus, when the largest disc D is used, the push rod scale indicates the pressure directly in grams per cm^2 . Therefore this disc has engraved on it "x 1" to show that the snow hardness number is the scale reading times one. Similarly, disc C is marked "x 10" to indicate that the hardness number is the scale reading times 10. The factors by which the scale reading must be multiplied in order to obtain the hardness number, are given in the following table.

TABLE II

Disc	Area (cm ²)	Factor
A	.1	1,000
B	1.0	100
C	10	10
D	100	1

43. All snow kits have been provided with an additional snow hardness gauge which has a spring ten times stiffer than that provided in the low-range gauge. Since the scale of this gauge is graduated from 0 to 100 - instead of 0 to 10 as in the case of the low-range gauge - the factors given in the table above apply to both.

Graduated cup, magnifying glass, and spatula

44. These are shown in Fig. 5 and are used for observing the size and shape of the individual grains or crystals.

45. The cup B has a flat bottom on which are engraved a number of concentric circles whose radii vary by one millimeter steps. These circles form a scale for measuring grain size.

46. The spatula C is used to place and arrange the granules in the cup. Aggregates may be broken up with the flat end of the spatula.

Thermometers

47. Each kit contains laboratory grade thermometers graduated in degrees centigrade. Other suitable centigrade thermometers of reasonable accuracy may be used.

SNOW CLASSIFICATION

48. It has been pointed out in paragraph 9 that the structural properties and cohesion of a snow layer depend to a large extent on the shape of its individual grains. Grain shape also has a marked effect on both the static and sliding resistances of skis, and on the internal friction of snow. These effects are so pronounced that skiers often divide snow into: (a) new snow, which has crystals of dendritic form, and (b) old snow, which has roughly spherical grains and which includes the various kinds of crusts.

49. The question of snow classification was examined by a special committee of the International Association of Hydrology in 1949. The committee divided snow on the ground into five classes according to grain shape. These classes, described in paragraph 138 of Appendix D, replace the "grain-form density scale" given in National Research Council of Canada Reports No. MM-192 and MM-202 and are now used in the snow-cover survey.

TEST PROCEDURE

Accuracy of Measurements

50. Although the tests should be made with reasonable care a high degree of accuracy is not required. Even in flat open country the snow-cover is not entirely uniform and tests made in one place will not yield exactly the same results as similar tests made in another place only 10 or 20 yards away. In general, the observer should try to obtain as near average results as possible and this applies not only to the different tests but also to the location of the test trench which should be chosen with a view to obtaining a reasonably typical section through the snow-cover.

Air Temperature

51. Air temperature should be taken from 1 to 3 feet above the snow surface at the time of observation. The thermometer must be sheltered from the sun's rays and should be given sufficient time to reach a constant reading.

When snow tests are made within a short distance of a weather station (as in the snow-cover survey) air temperature as measured at the weather station may be used even though they are usually taken at a somewhat greater height above the snow surface.

52. When the facilities are present, the maximum and minimum temperatures of the preceding day should also be recorded.

Snow Temperature

53. For this and most of the following tests a trench must be dug in the snow cover to disclose the different snow layers. The temperature measurements should be carried out immediately after the trench has been dug in order to minimize errors due to exposure to air and sun. Snow temperatures should be taken close to the surface of the ground, within 1 inch of the snow surface and approximately every 6 inches through the profile. Thus snow depths of less than 12 inches will have a minimum of 3 temperature measurements. The thermometer should be given sufficient time to reach a constant reading.

Snow Hardness Tests

54. Snow hardness readings should be taken in each distinct snow layer. The hardness gauge is used horizontally against the wall of the trench. Care should be taken in cutting the face on which the test is to be made so as to obtain as flat a surface as possible and to avoid disturbing the snow. The reading is obtained by slowly pressing the gauge squarely against the snow and noting the value on the scale at which the disc begins to enter the snow. While the manner in which the disc enters the snow varies somewhat with snow conditions it is usually fairly sudden. Very slight compression of the snow should be disregarded. Readings to the nearest half division are sufficiently accurate.

55. The gauge may be used vertically to measure the hardness of a thin layer at the surface. When used vertically a correction for the weight of the moving parts must be added to the observed reading. The correction can be found by reading the scale when the gauge is held vertically with the disc end uppermost. It is approximately one-third of a division for disc C and three-quarters for disc D when the low-range hardness gauge is used.

56. Each snow kit contains a high-range and a low-range gauge. The low-range gauge should be used for hardness up to 1,000 i.e. with discs B, C and D only, and the high range gauge for hardnesses above 1,000, i.e. with disc A and B only. In recording hardness, care must be taken to get the right number of zeros. If the observer finds this difficult, it is suggested that in his rough field notes he record a reading of say 4.5 with the low-range gauge and disc C as 4.5 C, or a reading of say 30 with the high range gauge and disc B as 30B. Since the low and high range gauges are graduated 0, 1, 2, 10 and 0, 10, 20, 100 respectively, these notations indicate which gauge and disc were used. The hardness numbers corresponding to the above examples are:

$$4.5 \times 10 = 45 \quad \text{and} \\ 30 \times 100 = 3,000 \quad (\text{see paragraphs 42 and 43}).$$

However, only the hardness numbers should be entered in the report.

Average Grain Size and Shape

57. Observations of grain size and shape should be made in each distinct layer. Grain size is taken as the maximum dimension of a single grain or crystal. In a layer formed by a fall of compound snowflakes, only the separate crystals which make up the flakes should be considered. A fair number of grains should be examined and an estimate made of their average size. Estimates to the nearest 0.2 mm. are sufficiently accurate. When the grains are bonded together the aggregate must be broken up before the measurement can be made, but grain fragments must not be mistaken for individual grains. In cases of extreme bonding or in very wet snow, grain size and shape begin to lose their meaning and need not be recorded.

58. Frequently the grains in a single layer of snow are not all of the same form although most layers which have passed the settled stage are fairly uniform both as to shape and size of grains. The average shape and size of crystals determine to some extent the physical characteristics of the layer. Therefore the observer should record the average shape and size of crystal under "grain shape and size" and if other shapes are prominent, a record of these should be made in the "remarks" column.

59. A few observers have found it difficult to distinguish between forms "c" and "d" of old snow. Type "c" snow is a product of melting whereas type "d" snow is produced by the process of sublimation. The crystal facets of form "d" are not always easy to recognize, especially since the grains of both forms are somewhat similar odd distorted shapes. When an aggregate of grains has to be broken up for examination, the fractures have some of the general aspects of facets and this adds to the difficulty. A method which will serve to demonstrate the difference between the two forms is to observe the amount of sparkle when direct sunlight falls on a sample of snow. The flat facets produce a definite sparkle effect and indicate that the form is "d", whereas fractures, which are seldom flat, do not produce such clear cut reflections. With experience the observer will be able to identify forms "c" and "d" without using this simple test.

60. Drifting can cause loose grains of old snow at the surface to become rounded by abrasion. If they have lost all traces of their facets they are of form "c" even though no melting has taken place. But if they retain some of their facets they are of form "d". Whenever drifting has occurred, a note to that effect should always be included in the "remarks".

Wet old snow is always of type "c".

Surface Layer Grain Shape and Size

61. The most rapid changes usually take place in the surface layer because it is of fairly recent origin and the one most exposed to the action of the weather. Grain samples should be taken about 1 inch below the surface except when the surface layer is less than 1 inch thick; they should then be taken near the midpoint of the layer thickness. Record average shape and average size and, when necessary, give more details in the "remarks".

Free Water Content (F. W. C.)

62. Free water content need only be reported when the snow is wet, i.e.: when the snow temperature is 0°C.

63. The difficulty in obtaining an accurate value for the free water content when in the field is very great.

For the purpose of this survey it is sufficient to use the terms given in paragraph 138 of Appendix D. If a more accurate value is required, one is referred to a standard laboratory procedure which makes use of a reliable calorimeter.

Specific Gravity Measurements

64. Measurements of specific gravity should be made at approximately 6 inch intervals. However, this spacing may be varied somewhat to permit taking a sample in a uniform layer. The height of the centre of the sample above ground should be recorded.

65. The density of thin hard crusts need not be found provided their hardness has been measured. If a group of thin similar layers occur together in settled old snow, a representative single sample may be used to determine the density of the group. The results thus far show that, once the snow has settled, its specific gravity can be estimated fairly accurately if its hardness, grain shape, and free water content are known. This is not the case for new or settling snow.

66. The measurements are made by weighing a known volume of snow. When the snow is moderately dense, 2 samples cut with one of the snow sample cutters should be weighed at a time; when it is light, 4 samples may be weighed. The specific gravity is then simply the weight divided by the volume. Volumes of 500 to 1000 cc. are the most convenient since the calculations then become extremely simple.

67. Soft snow samples should be very carefully cut to avoid compressing the snow and any snow samples which do not completely fill the internal volume of the cutter should be discarded.

68. In cutting samples, it is advisable to first cut them from the top layer and then the next layer down and so on until the lowest layer from which samples are to be cut is reached. Frequently a considerable amount of digging is required to obtain the snow samples and the procedure suggested above tends to minimize the amount of digging.

Form of Snow Surface

69. The condition of the snow surface should be described by the terms given in the "Tentative Snow Classification" (see Appendix D). When unusual conditions exist, the terms of the snow classification may be augmented by short descriptions in the "remarks" or by photographs. A few simple measurements such as average height and spacing of drifts may aid in the description. If drifting has occurred since the last observation, a note describing it as either light, medium or heavy should be included in the remarks.

70. When photography is used, consideration should be given to the effects of shadows, as these can often be employed to good advantage since they emphasize the irregularities of the snow. It is often desirable to add a few simple dimensions to the photograph; the photograph should include an object of known size for comparison. If photographs are taken, the observers are asked to send 2 prints of each photograph and to lightly mark in pencil the station and date on the back of each.

Wind Velocity

71. The average wind speed since the last observation should be recorded because it is more significant than a single measurement. Practically every one of the exposed area stations is equipped with an anemometer which produces a stepped record, each step representing one mile of air movement. Knowing the period of time in hours and the total number of steps corresponding to this period, the calculation of average wind speed becomes very simple. For example, if daily observations were taken at 10.30 on January 4 and at 10.30 on January 5, and 156 miles of air movement took place during the intervening period, then the average wind speed which should be entered for January 5 is $156/24 = 6.5$ or 7 m.p.h. The nearest m.p.h. is sufficiently accurate.

72. If a recording anemometer is not available, several readings taken at regular intervals throughout the period may be averaged. If no method of obtaining average speed is feasible, a single reading taken at the time of observations should be entered for the date of the observation.

73. The prevailing wind direction for the 24-hour period should be recorded.

GENERAL INSTRUCTIONS FOR SNOW-COVER SURVEY

Snow-Cover Survey Tests

74. These tests will be conducted at a number of observation stations over a period of several winters. Therefore it is highly desirable that a uniform procedure be adopted. Uniformity of methods will also simplify the the analysis of the many observations.

75. The amount of shelter from wind and sun has an important bearing on the form of the snow-cover. It is rather difficult to evaluate the effect of different degrees of shelter, therefore areas that provide either one of the two extremes of shelter, i.e.: flat unprotected areas or heavily wooded areas, are the most suitable from the point of view of uniformity. During the initial years of the survey the majority of the stations were exposed. In order to make the survey more complete sheltered areas were introduced in the winter 1950-51.

Choice of Area

76. An area of at least 500 sq. ft. is required for the test trenches. If possible it should be located on a slight rise to avoid flooding with water in spring. A snow-cover depth gauge in the form of a post marked off in inches should be set up at one edge of the test area in a convenient location.

77. For sheltered test areas, a relatively flat location exposed to precipitation but well sheltered from the wind by fairly closely spaced trees should be chosen. Shelter from the sun is also desirable but is not as important as shelter from the wind. Ease of accessibility may dictate the choice. The observer can only use the above as a guide and make the best selection local conditions permit.

Daily Observations

78. Daily observations should be taken when conditions are fairly close to average i.e.: 10.30 or 15.30 (3.30 p.m.) hours local standard time. Morning readings are preferred. Once the survey has commenced the readings should be taken at the same time each day. Observations should be recorded on Form "B" (see Fig. 8 and Appendix C).

Snow Profile Observations

79. A detailed study of the profile of the entire snow-cover should be carried out periodically. Changes in the snow-cover are usually quite slow and it has been found that two profiles taken each month are sufficient. These observations should be taken on the first and fifteenth day of each month.

80. The test pits should be dug according to some plan so that every profile is taken in an undisturbed region adjacent to the profile studied 15 days earlier. Each trench should be no larger than necessary for carrying out the measurements, 2 feet 6 inches by 3 feet 6 inches should be ample. It is a good idea to dig the first trench at the down-wind edge of the test site and as new trenches are required they should be located so as not to disturb the normal drifting of the snow over the unused part of the area. On completion of a set of measurements, the trench should be filled and the snow surface roughly levelled off.

81. It is wise to mark the location of all the old trenches with stakes or by any other suitable method in order to avoid digging two trenches in the same place.

82. Unless the depth of snow is excessive the trench should be dug right to the ground. One face of the trench should be vertical and clean cut.

83. Previous tests have shown that the most prominent features which distinguish one layer of snow from another are hardness and grain size. Rough preliminary measurements of hardness and grain size should therefore be made merely as a guide to locating the boundaries of the principal layers. Do not record the preliminary measurements of hardness and grain size. After the boundaries have been determined, more accurate measurements should be made and recorded. When temperatures are persistently low, as in the Barrens, a section through the snow-cover appears to be fairly uniform and it is difficult to distinguish one layer from another unless the preliminary measurements are made.

84. More or less continuous ice crusts within the snow-cover should be recorded as a separate layer. Sometimes several of these lie quite close together in which case the group should be regarded as a single layer. In no other case, however, should two distinctly different layers be grouped together as a single layer. Ice layers isolate one snow layer from another by acting as barriers to the flow of air and

seepage water and thus affect the changes which take place in the different snow layers. If an air space occurs in the snow-cover it should be recorded.

85. The order of the tests for the profile observations should be as follows:

1. Snow Temperature
2. Mark Layer Boundaries (see paragraph 83)
3. Average Grain Size and Shape
4. Snow Hardness
5. Specific Gravity
6. Free Water Content (see paragraph 62)

86. The results of these tests should be recorded in form "A" (Fig. 9). The "remarks" column may be used to describe any unusual conditions such as dust present in a layer.

87. Layers should be recorded in order from the ground up (see example Fig. 9). Profile observations and daily observations should be taken during the same period of the day.

Observations at Sheltered Areas

88. Since accessibility may not always be easy, it is proposed to limit the observations at sheltered stations to the bare minimum consistent with obtaining worth-while results.

89. Profile observations should be made according to the instructions given in paragraphs 79 to 87.

90. Daily observations should include at least

Column No.

(see Fig. 8)

1. date,
 2. time (local standard time),
 3. total snow depth,
 5. shape of crystal at snow surface,
 6. size of crystal at snow surface,
 8. depth of new snow since last observation,
 9. air temperature,
- and 17. kind of precipitation since last observation.

91. A sheet of heavy white cotton, about a yard square, may be used as a snow gauge. The sheet should be anchored to the snow by means of stakes. It should be approximately flush with the snow surface and in a location which is relatively free from drifting. The depth of any new snow on the sheet can be measured very easily. The snow should be shaken off after the depth has been measured.

INFORMATION TO BE FURNISHED BY ALL OBSERVATION STATIONS

92. While the Meteorological Stations taking part in the snow-cover survey have all the desirable facilities, some of the other stations may not be so well equipped and for this reason it may be necessary to use an alternative method for some of the measurements. When the results of all the stations are analysed, the methods used at each station and other general information should be known. The following is a list of the information required. Items III, IV and V do not apply to completely sheltered stations.

- I Test Area: is it (a) completely exposed, (b) slightly sheltered, or (c) completely sheltered?
- II Daily Observations: are they taken at (a) the test area, or (b) some other place?
- III Wind Velocity: is it (a) the average taken from anemometer records, (b) the average of several measurements (give number of measurements per day), or (c) a single measurement?
- IV Hours of Sunshine: is it obtained (a) from a sunshine recorder, or (b) by estimate?
- V Mounting Height of Meteorological Instruments: what is the approximate height above the ground of (a) the anemometer, and (b) the sunshine recorder?
- VI Map: a map showing the general features of the surrounding country and on which the location of the test area has been marked would be very helpful. The scale of the map should be not less than 1 inch to the mile; 2 inches or 4 inches to the mile would be better. It may be either a printed map, a blue-print, an air photograph, a pencil tracing of either of these, or a pencil sketch reasonably to scale.

- VII Test Area Photographs: a few photographs of the test area are very desirable. These should show the entire test area with its limits marked by stakes or flags, and the trees, fences, buildings, etc. which are closest to the test area. The station, date and approximate direction in which the photograph was taken should be lightly marked in pencil on the back of each photograph.

CONCLUSION

93. Snow is of such vital importance to the economic life of Canada that research into its properties is a national task of significance. A proper understanding of the properties of snow must be based upon accurate knowledge as to the variety of forms in which it occurs throughout the Dominion. The observations suggested in this publication, therefore, simple though they may appear to be, will and have provided fundamental information essential for the future progress of "snow mechanics" studies in Canada. The Associate Committee on Soil and Snow Mechanics of the National Research Council of Canada will be indeed grateful to all observers assisting with the work herein described. It is hoped that observers may find interest in the observations and some return for their activities by a new appreciation of the wonder and beauty of what will always be one of the most remarkable of all materials - snow.

ACKNOWLEDGMENTS

The Associate Committee on Soil and Snow Mechanics of the National Research Council of Canada wishes to thank all who have contributed to the success of the snow-cover survey, and particularly the observers who have been so enthusiastic, and have faithfully carried out the many observations, often under difficult and uncomfortable conditions. The Committee will be grateful indeed to all who help continue this valuable work.

Appendix A

GENERAL NOTES ON SNOW

94. The fact that water becomes solid either by freezing or by sublimation is of fundamental significance in all snow studies. Sublimation is the transition from vapour to solid (and from solid to vapour) without passing through the liquid state.

95. When water freezes the shape of the resulting ice is approximately that of the water prior to freezing, but when the solid is formed by sublimation its shape is that of a crystal. Freezing produces ice and rime while sublimation produces the beautiful crystals of snow and hoar. Actually all solid forms of water have a crystalline structure but only those formed by sublimation show evidence of this in their external shape.

Formation of Snowflakes

96. When air is cooled its relative humidity rises. The most common way in which air is cooled is by expansion due to the air mass rising to a height where the atmospheric pressure is reduced, but cooling may take place in several other ways. If the cooling continues beyond the saturation point, the excess moisture will be deposited on any solid object such as dust particles which are generally present in the atmosphere. At temperatures above freezing the moisture will condense and form fog, while at temperatures below freezing the saturation point with respect to ice will occur before the saturation point with respect to water and consequently the moisture will sublime and form snow.

97. The pattern of a snowflake depends mainly on the rate of growth of the flake. Slow growth produces the more solid forms such as hexagonal columns and thin hexagonal plates, while very rapid growth results in plane crystals of very slender proportions and open pattern. Generally the rate of growth is not constant and as a result, flakes of complex patterns are produced. Sometimes the flakes have astonishing forms; a symmetrical combination of a short column and two or more plane crystals is not uncommon. A twelve ray flake is simply a very short column with six rays attached to each end and even some six ray flakes have their rays in two planes separated by a very short column. Not all snowflakes are perfect, - various circumstances produce some surprising forms.

98. All flakes which consist of a single crystal are called "simple snowflakes" to distinguish them from "compound snowflakes" which are composed of several partially melted flakes that have become stuck together during their fall to earth.

99. The rate of growth of a flake depends largely on the temperature at the altitude at which the flake is formed, the lower the temperature the less the amount of moisture available for snowflake growth. At very low temperatures the flakes are therefore small and of hexagonal plate or column form, at moderate temperatures the flakes are larger and mostly of complex patterns, while at temperatures above freezing they are large compound snowflakes or "sleet".

100. Frequently, snowflakes fall through a cloud layer of water droplets and become coated with rime. The thickness of the coating varies considerably. When the coating is fairly thick the flakes become roughly spherical and are called "graupeln" or "soft hail". A layer of graupeln has a dull chalky white appearance, and is the only form of freshly fallen snow that has good skiing qualities.

101. Snowflakes suspended in the atmosphere are often carried to higher altitudes by rising air currents. Sometimes a flake falls to a warm level where it is partially melted and is then carried upwards to a cold level where it freezes again. When flakes pass through a series of melting and freezing stages with the addition of moisture between the stages, they become coated with successive layers of ice and are called "hail". Some authorities on snow use a separate term "ice pellets" to describe frozen rain drops, but in snow-cover measurements there is no reason for making this distinction and both forms should be described as "hail".

Changes that Take Place in Fallen Snow

102. Immediately after the snow has fallen, changes begin to take place in its structure. The points and slender branches begin to evaporate and sublime again on the more solid parts of the crystals which gradually become small irregularly shaped grains. As the crystals change shape they become more compact and the snow settles.

103. The settling of snow usually takes place in two fairly distinct stages. The principal difference between the two is that the rate of settling is much greater in the first than in the second stage. In the first stage the crystals

lose all their feathery structure and become small and granular. Snow is said to be settled when the end of the first stage has been reached. In the second stage the grains grow in size and become bonded together. Sun, rain and thawing conditions generally play a part in the second stage.

Changes due to Wind Action

104. Most of the bulk of fallen snow is air,- dry new snow contains about 90 per cent air by volume, and hard crust about 50 per cent. A snow layer is therefore very porous and contains a great many interconnected passages through which air may flow. A wind blowing over the snow surface induces air flow within the snow layer and in this way greatly accelerates the settling of snow.

105. The changes in snow structure due to wind action depend upon the temperature, relative humidity, strength and duration of the wind. Whenever the air temperature is below freezing, wind accelerates both evaporation and sublimation without causing melting. When the wind is dry, evaporation predominates and the snow settles with very little tendency for the grains to become bonded together - in fact, a very dry wind tends to loosen grains that have previously been bonded. But when the humidity of the wind is high, sublimation predominates and causes bonding of the snow grains, and thus toughens or hardens the snow. The hardening of snow by wind action is called "wind packing". Prolonged wind packing forms very hard "wind crust" in which skis and even hob nailed boots make little or no impression.

106. When new snow is compressed its crystals become broken and the fragments lie more closely together than originally. Very little wind action is then required to bond the grains and considerably harden the snow. This property of snow has been utilized at many airports when freshly fallen snow is compacted by rolling. Immediately after rolling, the snow is still fairly soft but it hardens sufficiently in only a few hours to permit landings with wheel landing gear even when there is only a slight wind.

107. Whenever the wind velocity is great enough to cause drifting of old snow, the grains become rounded by friction with the snow surface and thus lose all traces of their crystalline facets. If the rounded grains of old snow are deposited in an area of complete calm, a drift of loosely lying snow grains will form. However, if they are deposited

in an area of low wind velocity and the humidity is high enough to cause wind packing, "wind slab" will form. The feature which distinguishes wind slab from wind crust is that the anchorage of wind slab to the snow beneath is very weak. Settling of the underlying snow often forms an air space below wind slab. Generally wind crust forms on areas exposed to the wind and its surface is often considerably eroded, whereas wind slab forms in sheltered areas and for this reason its surface is only slightly wind rippled. Wind slab is usually found in patches and can be easily recognized by its dull white appearance. When wind slab is broken by a vertical load, it breaks suddenly with long cracks radiating outward in all directions. This peculiarity is due to the brittleness of the slab and the presence of a space directly below the slab. If part of a large area of wind slab on a steep slope is broken by the weight of a skier or vehicle, the slab will in most cases break up into blocks and initiate a dangerous avalanche.

108. Wind also changes the shape of the snow surface by forming erosion ridges, drifts and snow cornices.

Changes due to Melting and Freezing

109. The changes in snow structure caused by melting and subsequent freezing differ from those due to evaporation and sublimation. Sublimation always produces forms that have crystalline facets, while melting followed by freezing produces forms devoid of facets. The amount of melting determines the extent of the change - if a small amount of melting occurs, only the sharp ends of the crystal branches will melt and become rounded; if a greater amount of melting takes place, the crystals may become coated with water and on freezing, form a network of miniature ice bridges; but if considerable melting occurs, an icy crust or ice will be formed.

110. The repeated thawing and refreezing which usually occurs in late spring, when the temperature is above freezing during the day and below freezing at night, produces a very coarse type of snow. During the thawing period, the smaller grains melt more readily than the larger grains. If a moderate amount of melting occurs, there will be no appreciable run-off and nearly all the thaw water will be distributed in a fairly even coating on the remaining grains, so that, when freezing takes place, the size of the larger grains will be greater than at the beginning of the cycle. Thus the larger grains grow at the expense of the smaller grains. In its thawed condition this coarse type of snow is called "spring snow"; when it is frozen it is called "spring crust".

Wet Snow

111. The molecular attractions which occur at the surface of contact between two liquids, or between a liquid and a gas, produce effects which appear to be due to a tension in the surface of contact. This phenomenon is known as surface tension. It acts at the air-to-water surfaces of water drops and causes them to cling to solid objects wetted by the drops. When a water drop wets several small grains, such as grains of sand, the forces due to surface tension draw the grains together. In wet snow, there are a large number of air-to-water surfaces, with the result that surface tension has considerable effect on the properties of the snow and is largely responsible for the cohesion of wet snow.

112. The moulding properties of sand afford a good example of surface tension effects. Dry, very fine sand cannot be moulded, but when it is dampened and pressed together, it has considerable cohesion which gives it excellent moulding properties. However, if all the air in the sand is expelled by flooding with water, there will be no air-to-water surfaces at which surface tension can act. Sand flooded with water has no cohesion but tends to flow like a liquid. Thus there is a certain proportion of sand and water which gives maximum cohesion and optimum moulding properties.

113. Grain size also affects the cohesion. If we consider two equal volumes of sand, each wetted to give maximum cohesion but each of different grain size, the sand of finer grains will contain a greater number of surface tension bonds and will therefore have greater cohesion. For instance, there is practically no cohesion in a pile of small pebbles no matter what amount of water is used to wet the pebbles.

114. The surface tension effects in snow are very similar to those in sand. Loose dry snow has very little cohesion, in other words it is difficult to make a snow ball of dry snow. On the other hand, slightly wet new snow composed of crystals which have a large number of slender branches, has high cohesion, but if its feathery structure is destroyed by further melting it will have considerably less cohesion. Coarse spring snow has relatively low cohesion, and slush has practically none.

115. When slightly wet to moderately wet new snow is pressed together, the crystals become broken and lie much closer together. This greatly increases the number of surface tension bonds with the result that the cohesion becomes very much greater.

116. When moderately wet snow is subjected to high pressure, most of the air and some of the water is forced out, and the remaining water becomes a thin film between the snow grains. On release of the pressure, the film of water freezes and the snow becomes very hard and icy. Ice may form in this way between the wheels and tracks of track type vehicles and often precludes their use on fairly wet snow. In some cases, the ice causes excessive stretching or breakage of the tracks. This difficulty may be eliminated by the use of a flexible track - such as a rubber track - which frees itself of the ice by flexing.

117. It should be noted that the rate of seepage of thaw water through snow is very low. In most cases the rate is between 0.3 and 2 inches per minute.

Hoar

118. Hoar crystals are similar to snow crystals, the main difference being that hoar grows on fixed objects while snow grows on dust particles floating in the atmosphere. Since hoar grows on objects that are usually fairly large, the presence of the object and of adjacent hoar crystals has an influence on the manner in which the crystals grow and gives them their characteristic form.

119. Hoar which grows on objects above the snow surface, such as trees, is called "air hoar". Its crystals are usually hollow hexagonal prisms when it grows slowly, and slender needles arranged in a haphazard manner when it grows rapidly.

120. A common form of hoar, "surface hoar", grows on the snow surface. The conditions that promote its growth occur on clear nights with little or no wind when the humidity of the air is high and the air temperature is higher than that of the snow. It often grows near open water. Its crystals are flat hexagonal plates or almost flat hexagonal cups and can easily be mistaken for freshly fallen snow. Surface hoar crystals are often as large as 1/2" and in a few cases crystals several inches in diameter have been observed. If it is formed during a light wind, the two sides most nearly parallel to the wind direction will be slightly longer than the other sides.

121. Hoar also grows in cavities within the snow-cover and is then called "depth hoar". It is generally found in air spaces directly below a hard old crust after a long moderately cold period without thaws. Since its crystals grow very slowly they always have solid surfaces and are either plates or hollow hexagonal cups.

122. There are some crystals of old snow which are analogous to hoar, although they are not hollow like most depth hoar crystals. They occur in the deeper parts of the snow-cover and reach full development only after a fairly long period in which the lower layers have not been subjected to melting. These crystals are fairly coarse and rather weakly bonded together. They may or may not have crystalline facets; in the Barrens where temperatures are quite low and calm conditions are rare, crystals with facets are the most common.

Rime

123. Rime deposits are found not only on snowflakes but also on vertical objects above the snow surface and occasionally on the snow surface.

124. Rime is an accumulation of frozen water droplets which generally requires a moderate to strong wind to promote its formation. For this reason, rime deposits are usually heaviest near the top of vertical objects whereas hoar deposits, which are more fragile and grow in little wind, are heaviest near the snow surface. When rime is deposited during a snow storm, some of the snowflakes become entrapped in the deposit and give it the appearance of hoar.

Appendix B

NOMENCLATURE FOR SNOW

125. The snow nomenclatures which have been used at various times by meteorologists, glaciologists, skiers and others have not been in complete harmony. Occasionally the same term has been used by different groups, or in different localities, to describe entirely different forms of snow and this has led to a certain amount of confusion.

126. The use of radio for reporting ski-ing conditions has greatly emphasized the desirability of a standardized nomenclature for snow and an appreciable advance has been made in this direction. The present trend among skiers and specialists in snow mechanics is to adopt the terminology used by Seligman in his book* "Snow Structure and Ski Fields" or some modification of it.

127. The nomenclature given below follows Seligman's classification very closely. Although it is not a complete list of commonly used snow terms it covers all ordinary snow conditions and employs terms which have been widely used by specialists and skiers. Many of the terms are more or less self explanatory and therefore are less likely to be misinterpreted. Since each term refers to a fairly wide range of generally similar forms of snow it is often necessary to add qualifying words such as: slightly wet new snow, moderately wind toughened snow, very coarse spring snow, sun crust beginning to thaw, etc. The figures for specific gravity and free water content are only approximate and are given merely as a guide.

I SOLID FORMS OF WATER

(a) ICE

The term "ice" has frequently been used in a broad sense to cover all solid forms of water. In a strict sense "ice" refers only to the solid produced by the freezing of water, e.g. the ice on rivers and lakes, icicles, etc.

* "Snow Structure and Ski Fields" by Seligman, The MacMillan Co., 1936. This excellent reference book contains many photographs of snow and snow surfaces and a great deal of practical information on snow.

Glacier ice is not a true product of freezing - it is formed mainly by plastic deformation of a snow mass - but since it resembles the product of freezing in every respect, it too is called "ice". The generally accepted value for the specific gravity of ice is .917.

(b) RIME

A coating of very small water droplets which have frozen immediately upon deposition onto a solid object. Its pebbly surface of fine texture gives it a dull chalky white appearance. Snowflakes coated with rime are quite common and some of the ice deposits on aeroplane wings are similar to rime. Wind greatly assists the growth of rime. (See paragraphs 100, 122 and 123)

(c) HOAR

Crystals formed by sublimation of water vapour onto any fixed surface. The terms "air hoar", "surface hoar" and "depth hoar" refer respectively to hoar growing on objects above the snow surface, on the snow surface, and in cavities within the snow-cover. (See paragraphs 118 to 120)

(d) SNOW

Crystals which form in the atmosphere by sublimation of water vapour onto solid nuclei (dust particles) and fall to earth. The term "snowflake" should be limited to snow in the act of falling.

II SNOWFLAKES

(a) SIMPLE SNOWFLAKE

A snowflake consisting of a single crystal.

(b) COMPOUND SNOWFLAKE

A collection of partially melted simple snowflakes which have become stuck together during their fall to earth. They are often quite large.

(c) SLEET (See U.S. definition in Appendix of Appendix D)

Snowflakes which reach the ground in a very wet condition. The free water content of sleet is above 25%. Rain which freezes when it comes in contact with an object is not sleet although sleet often freezes upon falling. The ice coating formed by either rain or sleet is called "glaze ice".

(d) GRAUPEL (plural Graupeln) or SOFT HAIL

A snowflake which has fallen through a cloud layer of water droplets and has become thickly coated with rime. It may retain some of the shape of the original snowflake or it may be approximately spherical. A layer of freshly fallen graupeln has no sparkle.

(e) HAIL

Snowflakes which have become coated with layers of ice. (See paragraph 101).

III FALLEN SNOW (General Classes)

(a) NEW SNOW

Snow made up of crystals which retain all or most of their dendritic structure.

(b) POWDER SNOW

A dry snow composed of crystals or grains which lie loosely, e.g., new powder snow, settling powder snow, and settled powder snow. Settled powder snow is the ideal snow for skiing.

(c) SETTLING SNOW

Snow made up of crystals which have lost a good deal but not all of their dendritic structure.

(d) SETTLED SNOW

Snow which has lost all traces of dendritic structure. It is the early stage of old snow, and its grains are smaller than those of old snow. Generally there is not a great deal of bonding between grains. (See paragraph 103).

(e) OLD SNOW OR FIRN

Snow which has settled beyond the "settled snow" stage. Its grains have approximately spherical proportions and may lie fairly loosely or they may be bonded together. In moderate climates old snow generally has a dull appearance, but in cold climates, such as in the Barrens, old snow may have as much sparkle as new snow since its grains have many crystalline facets. Old snow has frequently been called "granular snow" but since the term "granular" has also been used for other forms of snow it should be avoided. (See paragraph 103).

(f) CRUST

Any fairly hard layer of snow lying on a softer layer. A crust may be at or near the surface or at a considerable depth.

IV NEW SNOW (Distinct Types)

(a) WILD SNOW (Wildschnee of Alpine nomenclature)

A dry, extremely light new snow which is very fluffy and unstable. It falls only when there is complete calm. Scooped up in the hand it may be blown off like feathers. This term has sometimes been used incorrectly for all forms of dry powdery new snow. Its specific gravity is below .03.

(b) DRY NEW SNOW

A dry, fluffy snow which has fallen in little or no wind. Its crystals are more solid than those of wild snow and on bright days it has considerable sparkle. Its specific gravity is .03 to .08.

(c) WET NEW SNOW

A wet snow composed of crystals which still retain some of their dendritic structure. It contains up to about 15 or 20 per cent free water and usually has very little sparkle. It has considerable cohesion and very poor skiing qualities. Skiers sometimes call it "clog snow" or "sticky snow". Its specific gravity is about .1 to .3.

(d) SAND SNOW

A dry new snow, usually found only in polar regions, which has fallen at a very low temperature (below -25°C) during little or no wind. Its crystals are fairly small and lie loosely. Its principal characteristic is its extremely poor ski-ing quality. It is somewhat similar to dry sand.

V OLD SNOW (Distinct Types)

(a) WIND TOUGHENED SNOW (a type of settled snow)

A dry snow that is firm but has no appreciable crust. Its grains are similar to settled powder except that they are lightly to moderately bonded together. Its specific gravity is about .2 to .35.

(b) DRY OLD SNOW or DRY FIRN

A dry granular snow which has been compacted by the combined action of sun, wind and temperature changes. Its grains are moderately coarse and are generally firmly bonded together. Its specific gravity is about .3 to .55.

(c) WET OLD SNOW or WET FIRN

Old snow containing up to about 20 per cent free water. It differs from spring snow in that its grains are appreciably smaller. It may be considered to be an early stage of spring snow. Skiers sometimes call it "telemark snow". Its specific gravity is about .35 to .65.

(d) SPRING SNOW

A coarse granular wet snow which generally occurs in spring. It resembles finely chopped ice and contains up to about 20 per cent free water. (See paragraph 110) Skiers sometimes refer to it as "corn snow", "granular snow" or "sugar snow". In its frozen state it should be called "spring crust". Its specific gravity is about .5 to .7.

(e) SLUSH

Very wet snow containing over 25 per cent free water. Its specific gravity is about .6 to .85.

NOTE: There are also "dry settling snow", "dry settled snow", "wet settling snow" and "wet settled snow".

VI CRUST

(a) WIND SLAB

A dry moderately hard and somewhat brittle layer of wind packed snow, usually found at the surface, which is not anchored to the snow beneath. (See paragraph 107). Its specific gravity is about .25 to .35.

(b) WIND CRUST

A tough or hard crust formed by the action of a wind of high relative humidity. It differs from wind slab in that it is anchored to the snow beneath. Wind crust forms on areas exposed to the wind and its surface generally shows considerable wind erosion. (See paragraphs 105 and 107). Its specific gravity is about .25 to .45.

(c) SUN CRUST

A crust formed by melting of the surface snow due to radiation from the sun, followed by freezing. Sun crust is usually fairly thin and its surface is generally smooth.

(d) RAIN CRUST

A crust formed by freezing after a rainfall. It is frequently very hard and icy.

(e) SPRING CRUST

A crust formed by the freezing of spring snow.

(f) FILM CRUST

A very thin layer of clear ice which is separated from the snow beneath. It is formed by the sun's radiation which passes through a thin transparent sun crust or rain crust without melting it and, being absorbed by the snow beneath, causes the snow to settle and form the air space.

Appendix C

128. Explanation of Form B (Fig. 8)

(Form 2370 of the Meteorological Division of the
Department of Transport)

Daily Snow and Weather Observations

1. Date
2. Time
3. HS - Total snow depth measured in inches at the snow depth gauge (See paragraph 76)
4. Q - Estimated ratio of area covered with snow to total area. Express in tenths and only recorded when ratio has a value of 9/10 or less.
5. F - Average grain shape (See paragraph 63 and Appendix D).
6. D - Average grain size in millimeters.
7. O - Surface condition. Note code letters given in Appendix D.
8. NS - Depth of new snow, measured in inches, that has been deposited since last observation.
9. At - Air temperature at time of observation, measured in degrees centigrade.
- 10, 11 - Maximum and minimum temperatures since last observation.
- 12, 13 - Average wind speed and direction since last observation (in m.p.h.).
14. Humidity - average relative humidity of air since last observation.
15. Extent of cloud-cover at time of observation expressed in per cent.
16. Average number of hours of sunshine since last observation.
17. Kind of precipitation that has occurred since last observation.

The standard symbols: * snow, Δ hail, \circ rain, \circ drizzle should be used. The symbol should be followed by the amount that has fallen since the last observation (snow and hail to the nearest 0.1", rain and drizzle to the nearest 0.01"). When only a trace is observed (less than 0.1" snow or hail; less than 0.01" rain or drizzle) the symbol alone should be given. When one form of the precipitation precedes another the symbols should be given in the order of their occurrence - *.5 \circ .02 indicates .5" of snow followed by .02" of rain. When two forms occur together brackets should be used - (\circ .04" Δ) indicates

.04" of rain with a trace of hail. When precipitation cannot be described by this notation, notes may be used.

18. Remarks - Any additional information the observer feels necessary to give a sufficient description of the observations.

APPENDIX D

TENTATIVE SNOW CLASSIFICATION

COMMISSION ON SNOW AND ICE
of the
INTERNATIONAL ASSOCIATION OF HYDROLOGY

COMMITTEE ON SNOW CLASSIFICATION

TENTATIVE SNOW CLASSIFICATION

The following is the tentative form of a classification being developed by the Committee on Snow Classification in the hope that its final form will be generally acceptable to scientists and others interested in snow. The aim is to promote uniformity in the method of describing snow and to simplify the correlation of data obtained by different groups.

The Committee invites comments or suggestions for improving the proposed classification.

Snow research groups are urged to give the classification a trial and to report their assessment of its suitability to the Committee.

All communications should be addressed to: The Snow Research Section, Division of Building Research, National Research Council, Ottawa, Canada.

ACKNOWLEDGEMENT

The Committee wish to thank Professor U. Nakaya of Hokkaido Imperial University, Japan, who was able to attend the meeting of the Committee at which the Tentative Snow Classification, presented herein, was drafted. His kind co-operation and his experience in snow research was of real value.

Committee on Snow Classification

V. J. Schaefer, Schenectady, New York, U. S. A.

M. R. de Quervain, Davos/Weissfluhjoch, Switzerland.

G. J. Klein, Ottawa, Canada.

GENERAL REMARKS

Definitions of terms, as they are used herein, may be found in the Appendix.

Each class and basic feature of snow has been designated by a code symbol with a view to making the classification international, i.e., independent of language. Most letter symbols have been chosen from an international term, for example: F(form in English, forme in French, form in German) has been chosen for "grain shape". The small letters a, b, c, d and e have been used to indicate: very low, low, medium, high, and very high respectively, in describing the degree of a snow feature. The code is also suitable for teletype messages although this was not the primary reason for adopting a code.

The classification for solid precipitation (falling snow, hail, etc.) has been based on the form of the crystal or grain, whereas that for deposited snow has been based on the fundamental features of the snow which determine its physical properties and distinguish one type from another, e.g., specific gravity, cohesion, etc. It does not consider the "genesis" of the snow.

Two parallel methods have been given for classifying deposited snow. The one is for the use of the scientist and employs measurements; the other which is for less precise work, employs terms and does not require the use of instruments of any kind. Since both methods are basically the same, except for the degree of precision, any reasonable combination of the two may be used to meet the requirements of a particular class of work.











No attempt has been made thus far to set up a nomenclature for snow.

Graphical symbols have also been given so that the class of precipitation or the vertical profile of a snow-cover may be presented in a standardized graphical form.





For those cases in which meteorological data are required, the standard international meteorological code may be used.

SOLID PRECIPITATION
(falling snow, hail, etc.)

Type of Particle Code symbol F

<u>Code</u>	<u>Graphic Symbol</u>	<u>Term</u>	<u>Remarks</u>
1		Plates	and combinations of plates with or without very short connecting columns.
2		Stellar Crystals	and parallel stars with very short connecting columns.
3		Columns	and combinations of columns.
4		Needles	and combinations of needles.
5		Spacial Dendrites	
6		Capped Columns	
7		Irregular Crystals	
8		Graupel	
9		Sleet	
0		Hail	

Additional Characteristics

m			broken crystals of type 1, 2, etc.
r			rimed crystals of type 1, 2, etc., but not sufficiently rimed to be classed as Graupel
f			Clusters of type 1, 2, etc. crystals
w			Wet or partially melted crystals of type 1,2, etc.

Size of Particle Code symbol D


The greatest extension of a particle (or average when many are considered) measured in millimeters. For a cluster of crystals it refers to the average size of the crystals composing the flake. The following symbols may also be used to express size:-


a	0	-	0.49 mm.
b	0.5	-	0.99
c	1.0	-	1.99
d	2.0	-	3.99
e	4.0 or larger		






Examples:

FlrD1.5

F2fw Dd

 1.5
















 d
HOAR AND RIME

<u>Code</u>	<u>Graphical Symbol</u>	<u>Term</u>
V1		Hoar
V2		Feathery Rime
V3		Dense Rime
V4		Opaque Glaze
V5		Transparent Glaze

DEPOSITED SNOWSnow-Cover Data

<u>Code</u>	<u>Graphical Symbol</u>	<u>Term</u>	<u>Remarks</u>
HS		Total Snow Depth	cm. measured vertically
HN		New Snow Depth	cm. snow deposited within 24 hours of obser- vation.
HW		Water equivalent of snow-cover	cm. of water
Q		Ratio of covered area	in tenths.
Z		Vertical coordinate	cm. measured from the ground (to locate a level in the snow-cover)

Condition of Snow - Surface

Op		—	Smooth
Or			Rain Erosion
Os			Sun "
Ow			Wind "
Ox			Sun or Rain Crust
Oy			Wind Crust
Oz			Film Crust
Ov			Surface Hoar

Basic Features

The minimum number of features which completely define a snow type are:

<u>Code</u>	<u>Feature</u>	<u>Units</u>	
G	Specific Gravity	nondimensional) Material
W	Free Water Content	% by weight	
P	Impurities (if any)	% by weight	
F	Average Grain Shape	(code symbol)) Structure
D	Mean Grain Size	millimeters	
K	Cohesion (tensile strength)	gms/cm ²	
T	Snow Temperature	°C (without the minus sign)	

For accurate work the snow type is classified by measurements, for example:

G.440 W15 Fc D3.0 K80. (obviously T=0°C)

G.320 Fd D2.2 K145 T23. (obviously W=0)

With a little experience an observer can classify a snow type without the use of instruments, for example:





G medium, Fc, D fine, K high.
Gc Fc Db Kd. (alternative)

The relation between terms, code symbols, and measurements, for each basic feature, is given below.

Specific Gravity

<u>Code</u>	<u>Range</u>	<u>Term</u>
a	0 - 0.099	very light
b	0.1 - 0.199	light
c	0.2 - 0.299	medium
d	0.3 - 0.499	heavy
e	0.5 and greater	very heavy.

Free Water Content

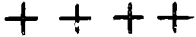




<u>Code</u>	<u>Graphic Symbol</u>	<u>Term</u>	<u>Remarks</u>
a		slightly moist	Very small amount of free water present.
b		moist	Greater than "a" but less than "c".
c		wet	Saturated but not flooded with water.
e		very wet	Flooded with water, i.e., practically no air present in the snow.

Runoff conditions depend, not only on the percentage of free water, but also on the snow structure. Code symbol "d" has been omitted because snow in a condition between "c" and "e" is virtually never found.

Impurities

Since these vary in kind and amount, and occur only occasionally, they are best described by words or measurements. The graphic symbol is

Average Grain Shape

<u>Code</u>	<u>Graphic Symbol</u>	<u>Remarks</u>
a		Stars or plates close to their original form. (see foot note)
b		Feltlike structure. Needles or columns close to their original form (see foot note) and snow in transformation with fragments of stars etc. present.
c		Rounded grains of settled snow, grains rounded by abrasion during drifting, grauple, sleet and hail.
d		Settled snow grains having crystal facets.
e		Depth hoar (generally cup shaped crystals)

Note: Deposited snow composed of crystals close to their original form may, as an alternative, be classed according to the classification for solid precipitation.

Mean Grain Size

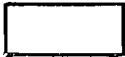

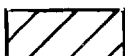



Code	Range	Term
a	0 - 0.49mm.	very fine
b	0.5 - 0.99	fine
c	1.0 - 1.99	medium
d	2.0 - 3.99	coarse
e	4.0 and larger	very coarse

The terms given in the last column apply only to the granular forms of snow.

Cohesion

In Soil Mechanics, which is an engineering science, cohesion is taken as shear strength and therefore has a frictional component. In snow, cohesion is the bond between grains due to welding, capillary and hooking effects. Further, shear tests of certain types of snow are difficult to carry out with accuracy whereas reliable tensile strength measurements may be obtained by means of a simple centrifugal apparatus. Therefore, it is proposed to adopt tensile strength as the reference for cohesion in snow.

For field work, a snow hardness instrument (or a shear strength instrument) may be more convenient. In this case the correlation between the instrument readings and tensile strength should be established.

Code	Graphic Symbol	Term	Remarks
a		very low)	The ease of penetration of a hand, pencil, etc. could be used as a rough scale. It is proposed to set up such a scale.
b		low)	
c		medium)	
d		high)	
e		very high)	
i		ice	

Rough values are given below for two types of hardness instruments. These values must not be regarded as a conversion table since correlation of the readings of the two instruments and correlation with tensile strength is at present incomplete.

	Swiss Kegelsonde		Canadian Plate type Hardness Gauge	
a	0	- 1	0	- 100
b	1	- 10	100	- 1,000
c	10	- 50	1,000	- 5,000
d	50	- 100	5,000	- 10,000
e	100 and greater		10,000 and greater	

Note: If hardness (or shear) measurements are used to describe cohesion, a code symbol other than K should be employed. The symbol R is suggested for hardness measurements.

Snow Temperature

For rough work snow temperature may be omitted, in which case the snow is considered to be below freezing except when free water is reported.

EXAMPLE OF REPRESENTATION BY CODE

HS 70/HN 8/HW 19/Q10/Op

Z 5 /Fde /D 3.5/G .290/R800 /T 2.5

Z20/Fd / D 2.0/G .310/R1500/T 4.5

Z35/Fc/ D 1.5/G .360/R3000/T 6.7

Z50/Fb/ D 2.0/G .280/R1200/T 8.2

Z65/Fa/ D 3.0/G .085/R 400/T 9.6

APPENDIX

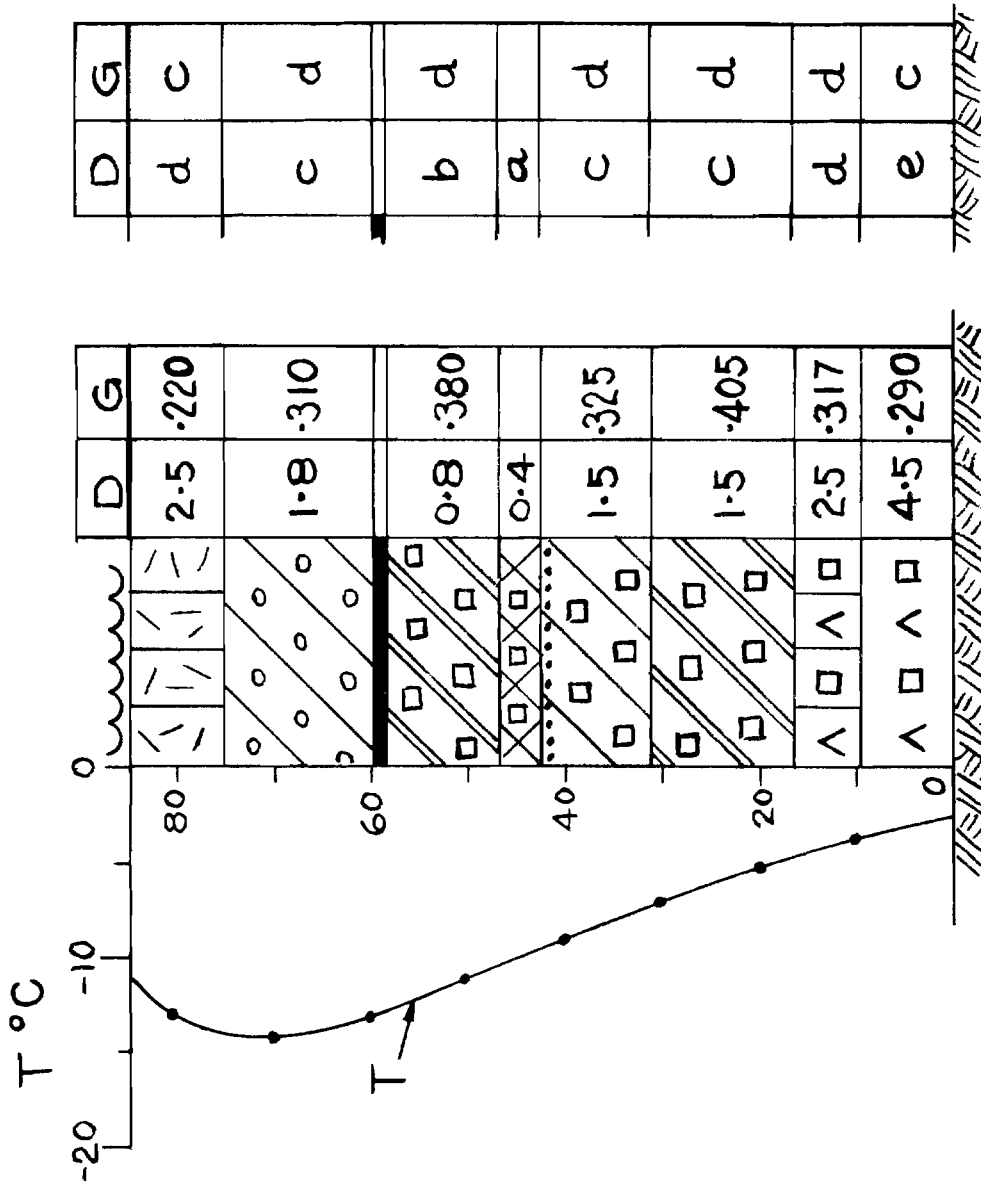
- Snow Solid precipitation formed in the atmosphere by sublimation of water vapour onto minute solid nuclei.
- Snow Crystal A single crystal, either regular or irregular, of snow.
- Snow Flake A cluster of snow crystals which have become stuck together while falling to earth.
- Graupel A snow crystal (or flake) thickly coated with rime. It may retain some of the original form of the crystal or it may be approximately spherical. Also called "snow pellet".
- Sleet (U.S. definition) Frozen rain-drops. They are usually fairly small and transparent. Also called "Ice Pellets".
- Hail Solid precipitation formed by the successive freezing of water layers and growing outward from a solid centre in semi-transparent layers.
- Column A snow crystal in the form of a short hexagonal prism with either plane, pyramidal or truncated ends. (Length/diameter less than 5).
- Needle A slender needlelike snow crystal usually having a structure consisting of needlelike components lying parallel and closely knit together. (Length/diameter greater than 5).
- Spacial Dendrite A feathery type of snow crystal having branches which are not in one plane. It may have a stellar base on which secondary branches which are not in the base plane have formed, or it may have branches radiating from its centre.
- Irregular Crystal A snow crystal which has grown in random directions. It may have the appearance of a combination of microscopic crystals or its structure may be concealed by a coating of rime which gives it an opaque appearance. It should not be confused with a fragment of a star. Nakaya has used the term "amorphous snow" and Schaefer, the term "asymmetrical crystal" to describe this form of snow.

Hoar Crystals formed by sublimation of water vapour onto any fixed object.

Depth Hoar Hoar crystals, usually of cup shape, which have grown in cavities within the snow-cover.

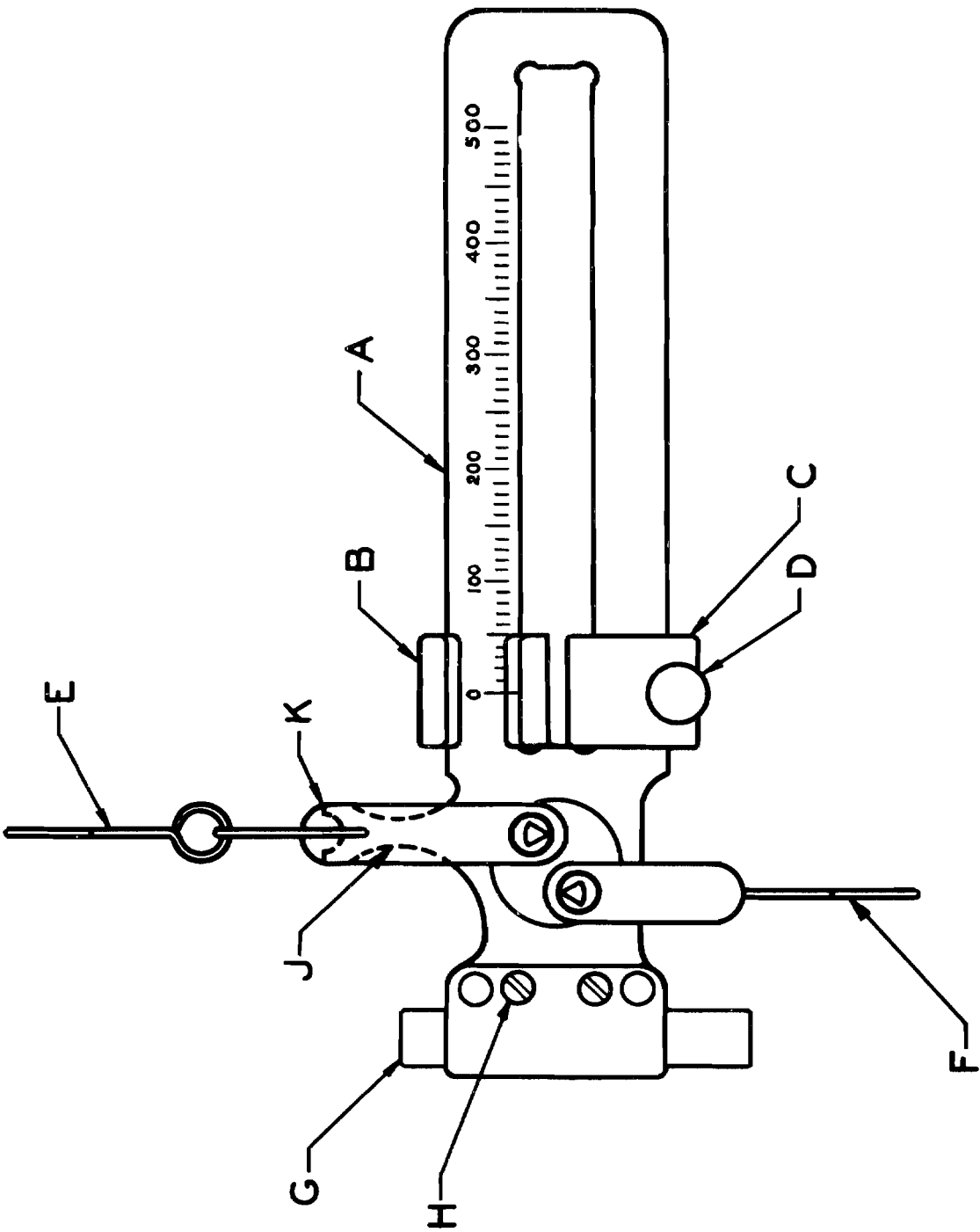
Rime An ice coating on solid objects formed by freezing of very small water droplets immediately upon deposition. In its commonest form it has a pebbly surface of fine texture and an opaque appearance.

Glaze An ice formation on solid objects formed by freezing of water droplets. Its surface is smoother than that of rime but there is no sharp separation between rime and glaze. A specific gravity of 0.87 may be accepted as the boundary, glaze being more dense than rime.



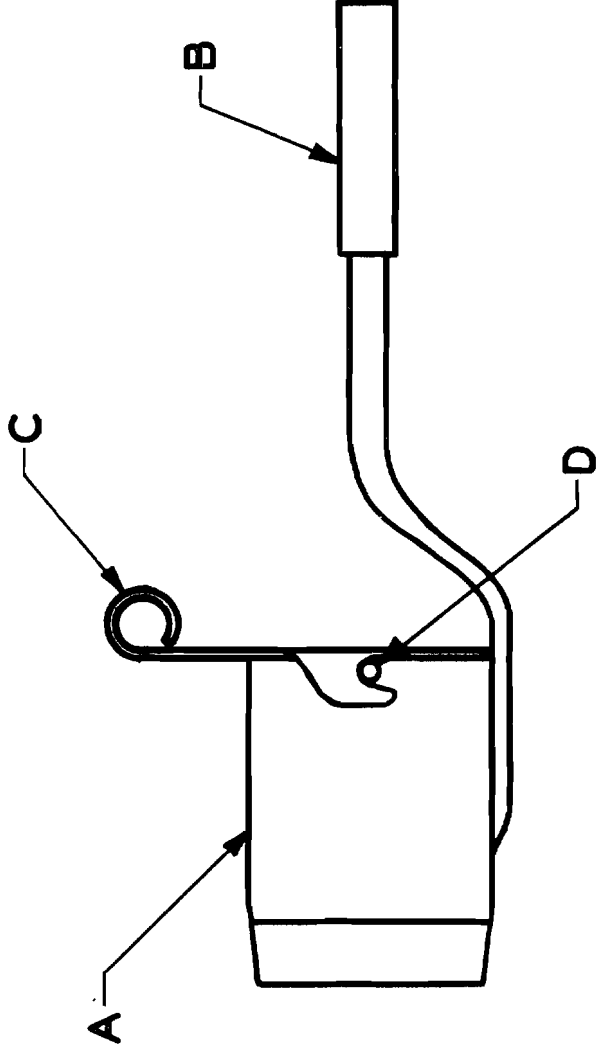
D and G
may also be
shown as
curves.

EXAMPLE OF PROFILE USING GRAPHIC SYMBOLS



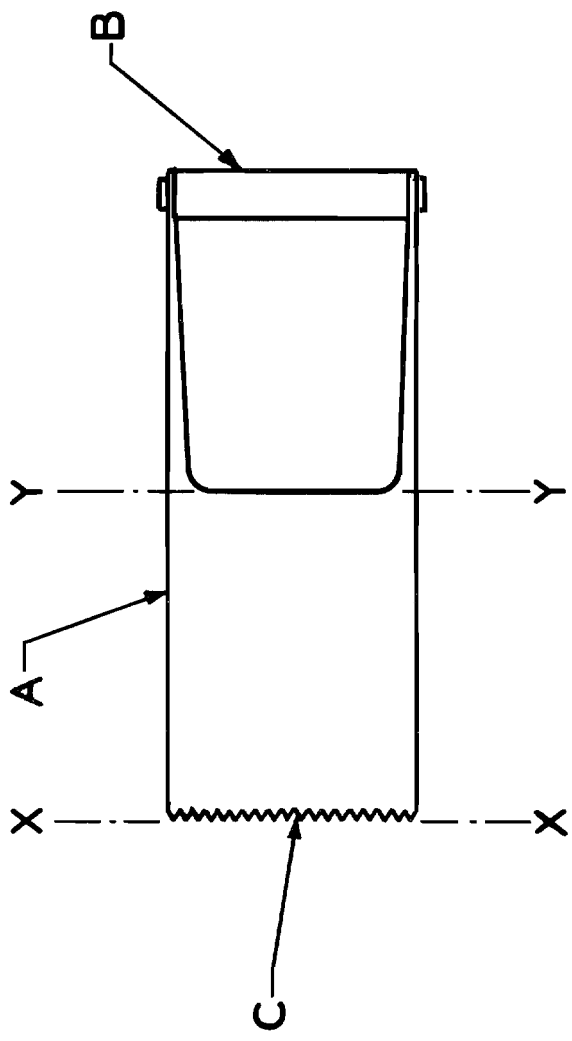
BALANCE

FIG. 1



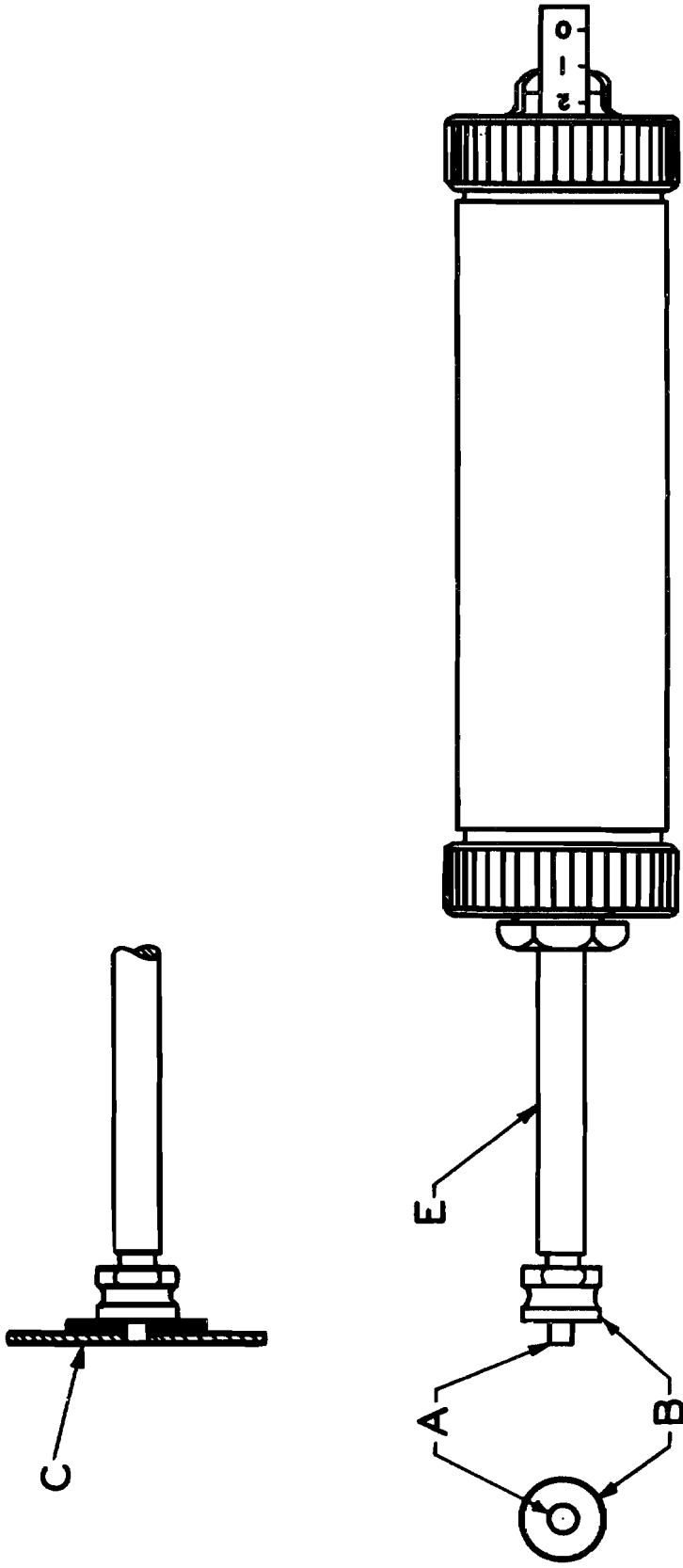
SNOW SAMPLE CUTTER
SOFT SNOW

FIG. 2



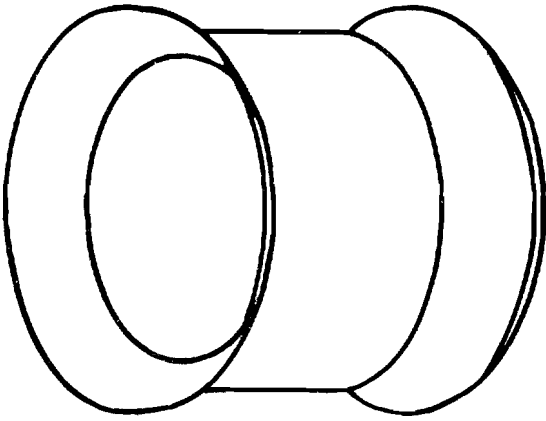
SNOW SAMPLE CUTTER
HARD SNOW

FIG. 3

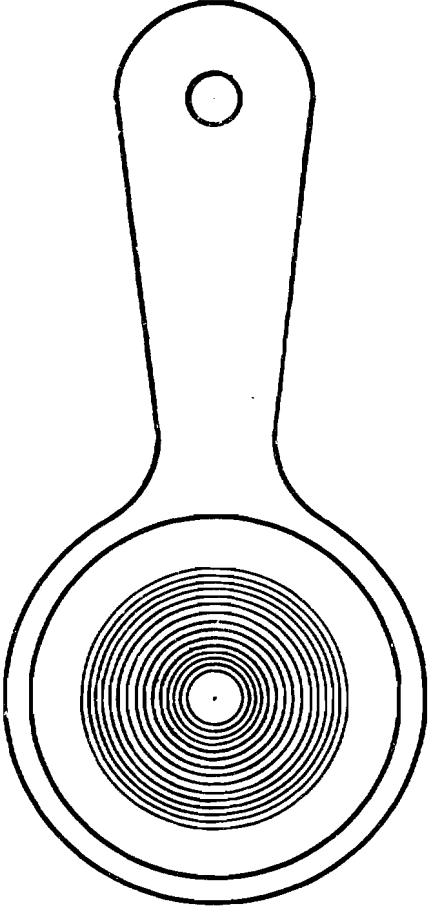


SNOW HARDNESS GAUGE
N.R.C. TYPE

FIG. 4



A



B



C

MAGNIFYING GLASS, GRADUATED CUP & SPATULA

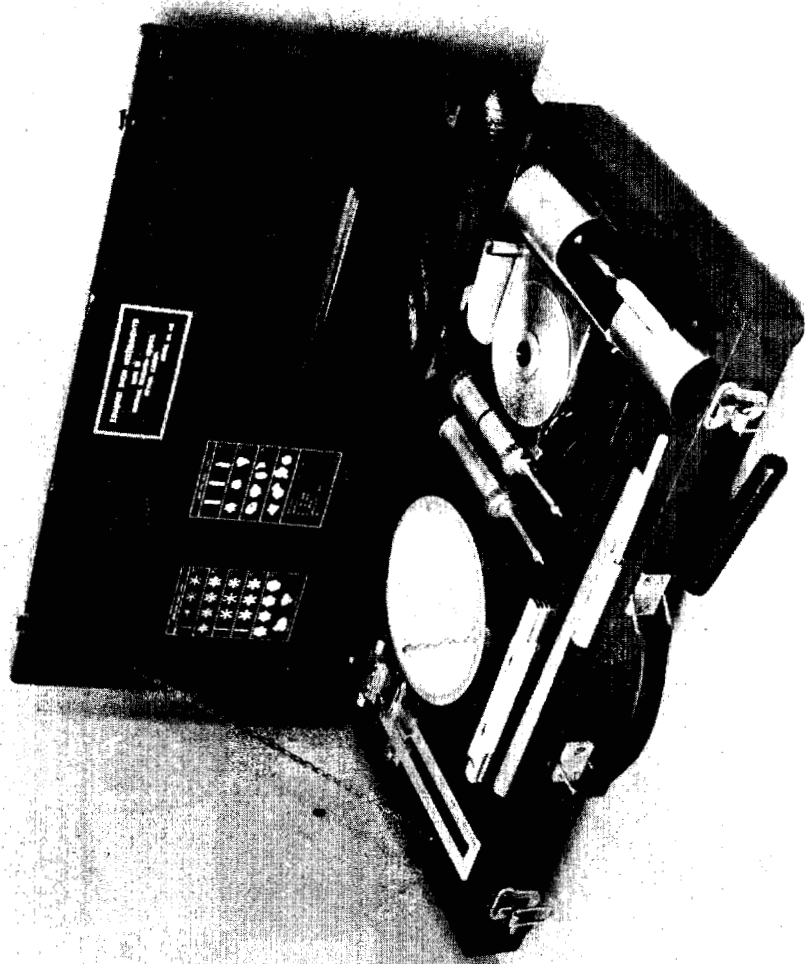


Fig. 6 Complete Kit

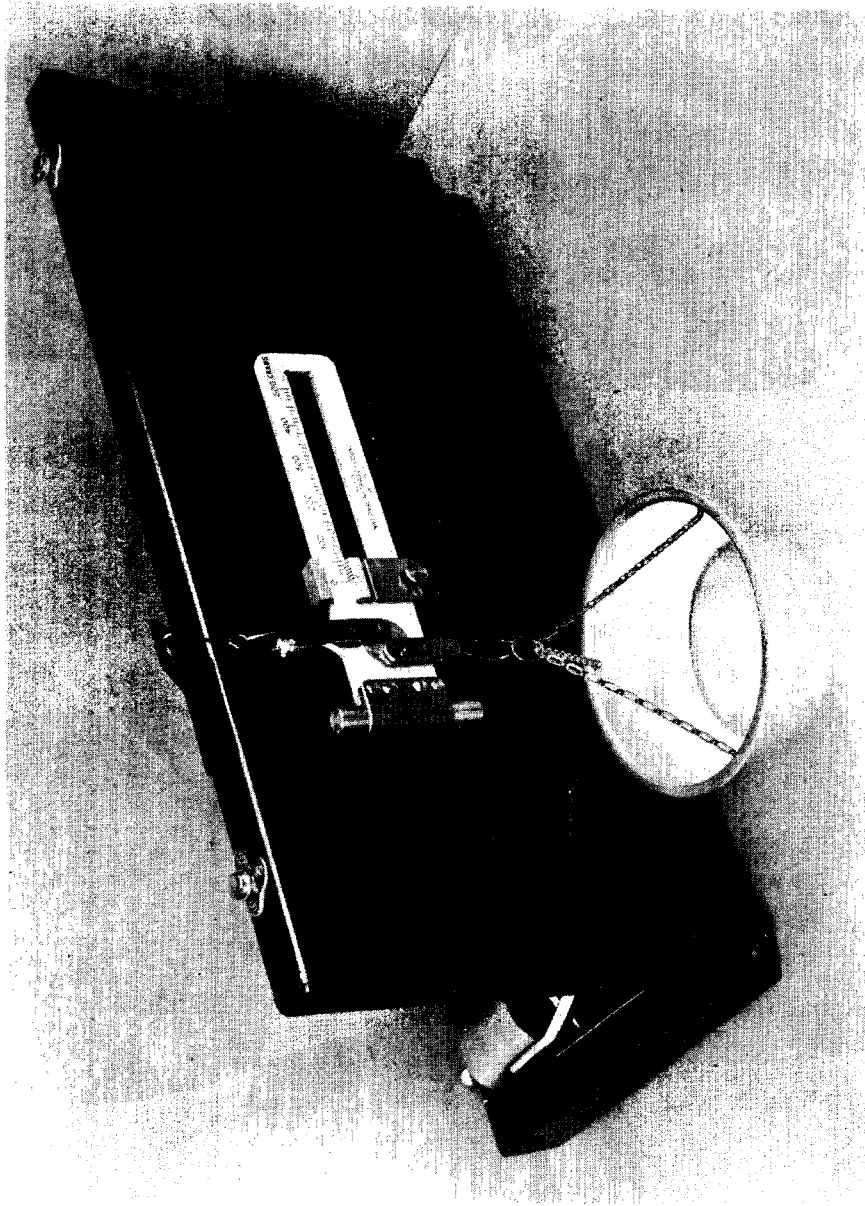


Fig. 7 Balance

NATIONAL RESEARCH COUNCIL
SNOW RESEARCH SECTION

Year 1950

Month Jan.

Station Montreal Road

Daily Snow and Weather Observations

Date	Time	Snow Cover		Snow Surface			Air Temperature		Wind		Humidity of Air	Cloudiness	Hours of Sunshine	Kind of Precipitation	Remarks		
		HS Total inches	Q Covered Area /10	F Shape of Crystals	D Size of Crystals mm	O Surface Code	HN Depth of Fresh Snow inches	At Time of Observation °C	Minimum °C	Maximum °C						Velocity Mph	Direction
1	2.	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	0930	16.0	-	c	1.5	0w	-	-18	-22	-15	12	N	96	3	4	-	-
2	0930	18.0	-	a	3.0	Op	2.0	-15	-20	-10	8	N	90	10	0	F2	-
3	"	17.5	-	b	2.0	Op	-	-9	-16	-6	6	N	92	8	1.5	-	-
4	"	17.0	-	c	1.5	Op	-	-7	-11	-4	5	N	91	2	2	-	-
5	"	17.0	-	c	1.5	Oy	-	-11	-13	-9	16	SE	85	1	5.0	-	-
6	"	21.0	-	a	4.0	Op	4.0	-8	-15	-5	4	W	81	10	0	F3	-
7	"	20.0	-	b	3.0	Op	-	-30	-33	-26	3	W	83	8	2.0	-	-
8	"	19.5	-	c	2.0	Ow	-	-22	-24	-18	18	SE	85	3	4.1	-	-
9	"	19.0	-	c	2.0	Ow	-	-20	-22	-16	16	SE	90	1	5.2	-	-
10	"	19.0	-	c	1.5	Ow	-	-5	-16	-2	8	S	92	1	5.8	-	-
11	"	16.0	-	c	1.5	Or	-	-1	-12	0	3	S	98	10	0	rain	0.5"

Example Fig. 9

NATIONAL RESEARCH COUNCIL

SNOW RESEARCH SECTION

FORM A

SNOW COVER OBSERVATIONS

Station Montreal Road Day 15 Month Jan. Year 1950

Total Snow Depth 21.0 inches Time: 0930 Z

Total Water Equivalent: _____ inches Observer: D. C. Pearce

Form of Snow Surface O_p Air Temp.: -18 °C

Layer from Ground Z (inches)	*F	*D mm	*W terms	Spec. Gravity		Hardness		Snow Temp.		Remarks
				Z ins.	G	Z ins.	R gr/cm ²	Z ins.	T °C	
21.0	a	2.0	-	2.0	0.25	2.0	150	0.5	-2.0	
18.0	c	1.5	-	8.0	0.32	8.0	950	6	-4.0	
11.5	d	2.0	-	15.0	0.30	15.0	1300	12	-10.0	
4.0	e	4.0	-	19.5	0.16	19.5	40	18	-20.0	
0.5	ice sheet							21	-17.0	

*F = Crystal shape; *D = Crystal size; *W = Free water content.