PROPOSED METRIC SNOW SAMPLERS

by

WESTERN SNOW CONFERENCE METRICATION COMMITTEE:

Phillip E. Farnes, Barry E. Goodison, Ned R. Peterson, and Robert P. Richards[1]

INTRODUCTION

Canada started reporting snow survey data in metric units in 1978 and the United States is scheduled to make this change in 1982. Recognizing the need to coordinate the design or modification of snow sampling equipment to facilitate a complete changeover to the International System (SI) or metric system of measurements, the Western Snow Conference established a four-member working committee in 1978 to prepare designs and specifications of metric snow sampling equipment, to evaluate the accuracy of new and existing equipment, and to develop procedures for changing from English to metric units. Committee members represented Canadian federal and provincial agencies and United States federal and state agencies.

In addition to the change to metric units, there has been a renewed interest in quantifying snow sampler accuracy, largely because snow samples are the basic reference for comparing other snow sensors. Often the snow water equivalent (SWE) determined by other means varies from that determined with snow samplers and any change in the method of observation requires an understanding of such differences.

Manufacturers of snow sampling equipment are also interested in adopting standard specifications to reduce tool-up costs. Also, seemingly insignificant modifications can significantly affect sampling accuracy.

In July 1978 the committee met in Portland, Oregon, to develop criteria for unified development of metric procedures and equipment and to plan for evaluating the accuracy of snow samplers currently in use and those proposed. Besides developing these criteria and evaluation plans, the committee proposed two new metric designs for snow samplers and a proposed modification of the Federal sampler.

Criteria and Plans

The following criteria and plans were developed by the committee:

* Develop two standard cutter sizes. The first, identified as WSC-10, has a 10 cm^2 area and is comparable with the Federal snow sampler used in the deeper snowpacks of the west. The second size, identified as ESC-50, has a 50 cm^2 area and is comparable to the larger diameters used in the east for shallower snowpacks.

* Calibrate the scales to weigh in grams.

* Mark the depth on the outside of the snow tubes in metric units.

* Use existing equipment as much as possible to reduce conversion costs.

* Use a glacier-type sampler (a stainless steel cylinder 40 cm long with 10 cm diameter) as the standard. Data obtained parallel to a pit wall with this sampler would be considered as true snow water equivalent.

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[1] Phillip E. Farnes, Soil Conservation Service, Bozeman, Montana
Barry E. Goodison, Atmospheric Environment Service, Downsview, Ontario
Ned R. Peterson, Department of Water Resources, Sacramento, California
Robert P. Richards, Ministry of the Environment, Victoria, British Columbia

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* Use identical test equipment and sampling procedures. Use standard procedures to reduce data.

* Conduct field tests in different snow areas and snow types to evaluate accuracy under as many conditions as possible.

* Obtain samples at each test site with the glacier sampler and various cutters. As a minimum, tests would include the standard Federal, 37.7 mm diameter; sharpened Federal, 37.7 mm diameter; and metric, 35.7 mm diameter.

* Submit specifications and drawings for proposed metric snow samplers to the Western and Eastern Snow Conferences for approval. A complete report of all tests and evaluations would also be submitted.

* Recommend that approved specifications and drawings be provided to agencies and groups conducting snow sampling and to manufacturers of snow sampling equipment.

<u>Proposed Metric Design WSC-10</u>

* Cutter: 4130 Aircraft Moly steel, heat treated, 10 cm^2 area, 35.68 mm diameter, 16 teeth, sharpened to inside

* Tubing: 45 mm diameter aluminum 6061-T6 stock similar to present Federal sampler, each section 75 cm long, marked every 1 cm, numbered every 5 cm

* Couplings: aluminum stock similar to couplings on present Federal sampler except with modified Acme 3 threads per cm

* Scale 4 m: (similar to present 12½ ft.) marked every 2 cm SWE, numbered every 10 cm SWE

* Scale 6 m: (similar to present 20 ft.) marked every 5 cm SWE, numbered every 20 cm SWE

* Other components and configurations similar to present Federal sampler

<u>Proposed Metric Design ESC-50</u>

* Cutter: 4130 Aircraft Moly steel, heat treated, 50 cm^2 area, 79.78 mm diameter, 36 teeth, sharpened to inside and similar in shape and taper to teeth as on the WSC-10.

* Tubing: 90 mm diameter fiberglass or plastic tubing with driving handle, 100 cm to 150 cm length, marked every 1 cm, numbered every 5 cm

* Scale 1 m: marked every 5 mm SWE, numbered every cm SWE. This would be the same scale as the 4 m except for the location of SWE markings. Units for both the 4 m and 1 m scales could be marked on opposite sides of the same scale where both WSC-10 and ESC-50 samplers are used.

<u>Proposed Modification of the Federal Sampler</u>

* Cutter: same as the proposed metric design for WSC-10

* Tube sections: knurl-out inch depth markings and restamp depths in metric units, marked every 1 cm and numbered every 5 cm.

* Scale 12½ ft.: discard shell on inner tube of scale and replace with shell marked every 2 cm SWE and numbered every 10 cm SWE. This scale will be similar to and interchangeable with the metric 4 m scale.

* Scale 20 ft.: discard shell on inner tube of scale and replace with shell marked every 5 cm SWE and numbered every 20 cm SWE. This scale will be similar to and interchangeable with the metric 6 m scale.

* Another option would be to sharpen the standard Federal cutter to the inside at 45° angle and replace the shell on the scales with a metric conversion. Even though this option would be less costly, it could create problems if scales were mixed or if cutters were changed, since the area of the standard Federal cutter is about 11 percent greater than the area of the proposed metric cutter.

Pre-1978 Tests

Before formation of the metrication committee, many independent evaluations were conducted. The Soil Conservation Service (SCS) compared the Federal snow sampler with various other cutter and snow sampler designs and with volumetric water equivalents determined by weighing all of the snow from a 150 cm X 180 cm pit. The results were reported in Cold Regions Research and Engineering Laboratory (CRREL) Technical Report #163, "Accuracy of Field Snow Surveys." (1) California Cooperative Snow Surveys conducted extensive tests on snow sensors and accuracy of snow measurements. This information is published in "Snow Sensor Evaluation in the Sierra Nevada." (2) Results of experiments conducted in shallow snowpacks have been reported in "Accuracy of Snow Samplers for Measuring Shallow Snowpacks: An Update." (3) There are many other references to similar work, including work done in 1977-78 in British Columbia, Ontario, Montana, and California using small diameter, short and long metric cutters.

It became apparent when analyzing these early test results that variations in cutter styles and designs and the tooth thickness of standard cutters could induce a significant variation in the SWE results. Variation of results and lack of continuity between tests made it impossible to evaluate the true accuracy of existing equipment or to predict the accuracy of the proposed metric equipment.

1978-79 Field Tests

Because of time constraints, only the small diameter equipment, WSC-10, was tested this season, although preliminary manufacturing and material investigation was started on the ESC-50. Five identical standard Federal cutters, five sharpened cutters, five 1979 metric cutters, and five glacier samplers were procured. Each was measured to determine its exact diameter so that measurements could be corrected to a common base. Each cutter was inserted in a separate cutter tube section, but the rest of the snow sampling tubes were common and used with each cutter section. Silicone was baked on all sampling sets to prevent snow from sticking to tubes and to make sampling easier. All scales were calibrated. Sampling procedures were standardized and computation forms developed. These are shown in the appendix. Calibrated scales and beam balances were used for weighing samples.

Several other tests were performed in conjunction with the metric evaluation, but on a limited scale. These include the effect that a broken cutter tooth will have on the results; comparison between water equivalents determined with snow sampling scales and with gram balance; comparison between water equivalent obtained with glacier sampler and a large pit volume; comparison between the glacier sampler and a sharpened 10 cm diameter aluminum irrigation tubing, accuracy of a sharpened cutter with no teeth; accuracy of the McCall snow sampler; and accuracy of the portable profile snow gage. These special tests will be described and discussed in the final report presented to the Western and Eastern Snow Conferences.

Table I summarizes the results from 71 field measurements made in the 1978-79 season. Dimensions of equipment used in these tests are tabulated in Table II. The raw data for these measurements are shown in Table III. Snowpack sampled varied from 26 to 332 cm in depth and from 57 to 1,493 mm SWE. Density ranged between 21 and 52 percent.

The largest overmeasurement error was with the standard Federal, followed by the 1979 metric cutter. The sharpened Federal cutter had the smallest error. As expected, the data have a high degree of correlation.

The sharpened Federal was the easiest cutter to sample with. The smaller diameter metric cutters had noticeably more resistance and required more effort to drive the sampler through the snowpack. They also had shorter cores. The glacier sampler is difficult to use in snowpacks that are dense or that have ice layers. The glacier sampler should not be considered an operational snow sampler, but more of a research tool.

Additional analysis will be made to see if overmeasurement errors are related to density, snowpack temperature, or type of snow being sampled.

1979-80 Season Tests

The WSC-10 metric cutter was redesigned for the 1979-80 season to incorporate better ice-cutting performance. The number of teeth and inside diameter remained the same, and the cutter teeth were sharpened to the inside.

1979-80 tests are still in progress and the results have not been analyzed. However, it appears the data are very comparable with the 1978-79 data and that the 1980 metric cutter performs almost identically to the 1979 metric cutter.

A prototype of the ESC-50 sampler was received in April 1980. It is hoped that some data can be obtained in the remainder of the 1979-80 season to evaluate its performance and to incorporate any necessary design changes prior to next season's tests.

Future Work

Data obtained with the 1980 metric cutters will be evaluated at the end of the 1979-80 season. It will be determined if additional modifications in the cutter design are needed, if scales are to be calibrated to account for overmeasurement, and if additional controlled tests are required. More extensive tests will be conducted with the larger diameter ESC-50 equipment and its performance will be compared with the smaller diameter cutters and the glacier sampler.

Additional work needs to be done on comparing the glacier sampler with volumetric measurements to verify the assumption that the glacier sampler measures near-true snow water equivalent.

The committee will prepare a final report to the Western and Eastern Snow Conferences. This report will compare different cutter styles and designs; provide detailed drawings and specifications for proposed metric snow sampling equipment; contain all basic data obtained (including snow profiles, snow sampling notes, computation sheets); and all other related data and information.

Conclusion

Based on limited volumetric tests, the glacier sampler does measure near-true snow water equivalent. Data that have been analyzed indicate all small diameter cutter designs with areas of 10 to 11 cm^2 overweigh true snow water equivalent up to 10 percent. Sharpened cutters have less overmeasurement than flat-tooth or nonsharpened cutters such as the standard Federal. Smaller diameter cutters have more overmeasurement than larger diameter cutters of similar design. The development of metric snow sampling equipment may require that scale or cutter be calibrated to account for overmeasurement if measurements are to represent near-true snow water equivalent.

Acknowledgements

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REFERENCES

1. Beaumont, R. T., Freeman, T. G., Stockwell, Homer J., and Work, R. A., "Accuracy of Field Snow Surveys, Western United States, Including Alaska," Technical Report 163, USDA Soil Conservation Service and U.S. Army Cold Regions Research & Engineering Laboratory, August 1965.

2. State of California, Department of Water Resources, "Snow Sensor Evaluation in the Sierra Nevada, California," March 1976.

3. Goodison, B. E., "Accuracy of Snow Samplers for Measuring Shallow Snowpacks: An Update," Proceedings, Eastern Snow Conference, 35th Annual Meeting, February 1978, pp. 36-49.

Table I - Summary of Analysis for 1978-79 Data

Type of Cutter Compared With:	Number of Observations	Percent Overmeasurement	Standard Error of Estimate cm	Correlation Coefficient
Glacier Sampler With:				
Standard Federal	71	9.3	1.72	.9986
Sharpened Federal	71	6.4	2.20	.9976
79 Metric	71	8.2	2.19	.9977
Standard Federal With:				
Sharpened Federal	71	-3.2	1.41	.9992
79 Metric	71	-0.8	2.67	.9972
Sharpened Federal With:				
79 Metric	71	2.3	2.91	.9964

Table II - Diameters of Cutters and Tooth Thickness of Standard Federal Cutter Used in 1978-79 Tests

Location	Glacier Sampler mm	Standard Federal mm	Tooth Thickness Standard Federal mm	Sharpened Federal mm	1979 Metric mm
Agricultural Research	102.2	37.7	1.3	37.6	35.6
British Columbia	102.1	37.7	1.5	37.7	35.6
California	102.4	37.7	1.8	37.7	35.6
Montana	102.1	37.7	1.6	37.7	35.6
Ontario	101.1	37.7	1.6	37.7	35.6

Table III - Basic Data 1978-79

Location	Snow Depth Glacier Sampler cm	Glacier Sampler SWE mm	Standard Federal SWE mm	Sharpened Federal SWE mm	1979 Metric SWE mm	Density Glacier Sampler Percent
AR 1	74	166	187	163	161	22
AR 2	205	640	694	684	667	31
AR 3	201	618	684	680	670	31
AR 4	195	618	691	669	664	32
BC 1	153	390	413	402	394	26
BC 2	319	1207	1315	1241	1294	38
BC 3	133	307	335	319	314	23
BC 4	58	119	104	104	117	21
BC 5	169	442	487	467	489	26
BC 6	103	365	399	386	396	35

Table III - Basic Data 1978-79 (cont.)

Location	Snow Depth Glacier Sampler cm	Glacier Sampler SWE mm	Standard Federal SWE mm	Sharpened Federal SWE mm	1979 Metric SWE mm	Density Glacier Sampler Percent
BC 7	161	511	555	532	545	32
BC 8	37	100	96	96	88	27
BC 9	332	1493	1630	1572	1612	45
BC 10	330	1388	1550	1478	1498	42
BC 11	130	434	476	454	483	33
BC 12	122	396	442	411	458	32
BC 13	156	534	587	564	580	34
BC 14	162	543	620	596	606	34
BC 15	200	976	1108	1057	1102	49
BC 16	226	1167	1271	1216	1239	52
CA 1	206	655	660	641	704	32
CA 2	211	713	761	721	810	34
CA 3	168	664	680	651	769	40
CA 4	146	651	693	676	749	45
CA 5	196	709	771	731	834	36
CA 6	55	215	227	214	244	39
CA 7	138	435	477	452	537	32
MT 1	99	275	275	277	297	28
MT 2	95	236	264	249	265	25
MT 3	90	199	236	208	226	22
MT 4	90	212	250	215	250	24
MT 5	86	189	229	209	214	22
MT 6	99	232	244	244	262	23
MT 7	100	227	251	242	270	23
MT 8	93	241	282	263	258	26
MT 9	91	223	243	232	247	25
MT 10	139	400	460	459	454	29
MT 11	133	376	425	431	432	28
MT 12	145	379	428	408	417	26
MT 13	141	360	414	392	404	26
MT 14	146	375	431	411	414	26
MT 15	254	885	986	993	1005	35
MT 16	252	871	984	966	970	35
MT 17	249	893	983	959	960	36
MT 18	248	882	988	973	968	36
MT 19	186	616	678	693	693	33
MT 20	195	667	725	725	739	34
MT 21	211	715	818	809	817	34
MT 22	208	703	798	793	805	34
MT 23	79	295	291	284	264	37
MT 24	81	281	296	285	276	35
MT 25	196	704	778	741	740	36
MT 26	195	671	757	731	739	34
MT 27	110	472	566	560	525	43
MT 28	113	531	593	571	543	47
MT 29	209	867	956	932	920	41
MT 30	213	892	998	974	943	42
MT 31	126	500	568	569	565	40
MT 32	137	555	629	622	613	41
MT 33	214	892	987	958	942	42
MT 34	204	850	928	903	901	42
MT 35	99	390	456	440	425	39
MT 36	89	356	398	403	382	40

Table III - Basic Data 1978-79 (cont.)

Location	Snow Depth Glacier Sampler cm	Glacier Sampler SWE mm	Standard Federal SWE mm	Sharpened Federal SWE mm	1979 Metric SWE mm	Density Glacier Sampler Percent
ONT 1	45	157	146	144	162	35
ONT 2	27	57	68	67	68	21
ONT 3	28	61	64	60	70	22
ONT 4	95	278	310	302	303	29
ONT 5	37	124	121	122	124	34
ONT 6	26	93	97	93	92	36
ONT 7	29	124	138	128	126	43
ONT 8	36	175	169	164	158	49

AR - Science and Education Administration, Agricultural Research, Idaho
BC - British Columbia
CA - California
MT - Montana
ONT - Ontario

METRIC SNOW SAMPLING TEST PROCEDURES

I EQUIPMENT NEEDED

- Metal clipboard with:
  - Snow Profile Chart
  - Millimeter Grid
  - Glacier Sampling Sheet
  - Water Equivalent Adjustment Chart
- Single beam balance and weights
- 2 °C thermometers (1 digital)
- 2 Plastic buckets
- Centimeter tape measures
- Snow saw
- Metric snow sample set:
  - Standard Federal cutter
  - Sharpened Federal cutter
  - Metric cutter
  - Glacier Sampler and plate
  - Other cutters to be tested
- Aluminum scoop shovel
- Tarp
- 10x hand lense

II NOTES ON PROCEDURE

A Samples are taken along the wall of a trench dug down through the entire snow profile to the ground surface.

B Temperature profile and glacier sampling must be done along a wall shaded from the sun.

C If profile will be deeper than 150 cm, sampling should be carried out in 150 cm steps to prevent external interference with exposed snowpack.

D Always wear gloves when handling the equipment.

E Depths are recorded in cm in Column H.

F Temperatures are recorded in °C, Graph T. Temperatures are taken at intervals ranging from 10-15 cm depending on snow conditions and depth. Note air temperature.

III ADDITIONAL NOTATIONS

A Surface condition - note depth you sink-in while standing. Also note crystal surface roughness (i.e., smooth, rippled, pitted or gullied).

B Crystal shape is identified in Column F for each layer using the millimeter grid and recorded in Column D.

Feature	Units	Symbol	Subclassification a	b	c	d	e
Grain Shape	—	F	+ + + New snow, Close to F1-F7[1]	/ \ / Often felt-like. Partly settled[2]	● ○ Granular, Rounded without/ with melting[3]	□ □ □ Granular, With facets, full crystals[4]	∧ ∧ ∧ Depth hoar. Cup shaped[5]
Grain Size	mm	D	0.5 very fine	0.5-1 Fine	1-2 Medium	2-4 Coarse	4 Very Coarse

1. Unchanged new snow crystals according to F1 to F7 of table 'Type of Particles' above or slightly transformed crystals. Original shape will recognizable.
2. Crystals in advanced transformation (destructive and/or constructive metamorphism), but elements of original new snow crystals are still recognizable. Symbol for b may be mixed with type a, c or d to characterize intermediate states. Snow of type b often has a felt-like structure.

3. Rounded, often elongated grains formed in prevailing destructive metamorphism without melting are marked with full dots. They are usually in the size range below medium. Melting and refreezing produces characteristic rounded grains with strong bonds. They are symbolized with open circles. Grain size usually ranges from medium upward.
4. Usually only parts of the surface of a crystal of this type are developed as even glittering facets. Often rounded grains or cup-shaped elememts are intermixed. Combined symbols of a with b, c and e are possible.
5. Depth hoar does not necessarily imply fully developed cup-shaped crystals. Usually only fragments of cups characterized by re-entrant angles and peculiar ledges are found (for combination of symbols see note 4).

C. Snow hardness - determined for each layer and recorded in Column K.

Feature	Units	Symbol	Subclassification				
			a	b	c	d	e
Strength hardness[6]	kp cm^{-2} kp	K R	Very soft	Soft	Medium	Hard	Very Hard

6. The subdivision of strength and hardness is based on the Ram hardness (4 cm diameter cone-penetrometer with 60° apex) and the following rough correlation:

	Ramsonde 4 cm diam. R (kp)	Hand Test	Shear Strength (Cohesion) K_1 (g cm^{-1})
a Very soft	0-2	Fist	0-10
b Soft	2-15	4 fingers	10-75
c Medium	15-20	1 finger	75-250
d Hard	50-100	Pencil	250-500
e Very hard	> 100	Knife	> 500

The hand test indicates the object which can be pushed in the snow with a pressure of about 5 kp up to the upper limit of the given hardness class. (Unit kp stands for kg weight.)

D. Free water content is determined by gently squeezing a sample of snow in a gloved hand and observing the reaction. Free water content is recorded in Column W.

Feature	Units	Symbol	Subclassification				
			a	b	c	d	e
Free water	%	W					
Note			Dry*	Moist	Wet	Very Wet	Slush

*Note - snow with a temperature below 0°C can only be dry.

E. Density is obtained from the glacier sampler and recorded in Column G.

Sheet 1 of 1

WESTERN SNOW CONFERENCE
CONTROL WATER EQUIVALENT MEASUREMENT
(Glacier Method)

SAMPLING LOCATION New World Lower SE DATE 2-26-79

ELEV 1980 m

SAMPLER: NUMBER Montana DIAMETER 102 mm AREA 81.87 cm^2

CORE NUMBER	LENGTH (cm)	GROSS WEIGHT (g)	TARE WEIGHT (g)	NET WEIGHT (g)	W.E. = WEIGHT / AREA (cm)	DENSITY (%) = W.E. / LENGTH
1	37.6	838.9	167.5	671.4	8.2	22
2	32.9	985.3		817.8	10.0	30
3	32.4	1070.9		903.4	11.0	34
4	36.1	1049.4	167.5	881.9	10.8	30
	Cum. Length = 139.0 Total Meas. = 139.4				Total W.E. = 40.0	Mean Density Total W.E. / Total depth = 29

REMARKS:

WESTERN SNOW CONFERENCE
WATER EQUIVALENT ADJUSTMENT

Sampling Location New World Lower SE Date 2-26-79 Sampler Type 1979 Metric

1[1] Glacier Sampler Results:	Sample Number	2 Test Sample Depth (cm)	3 Test Sample W.E. (cm)	4 Depth Adjustment Factor (1A)+(2)	5 W.E. Corrected for depth (cm) (4)x(3)	6[2] W.E. Corrected for cutter area	7[1] Test Sample W.E. Error (cm) (6)-(1B)	8 Percent W.E. Error (7)÷(1B)	9 Density (6)+(1)
1A Total Measured	1	140	42	.99	41.6	46.6			34
= 139	2	138	41	1.01	41.4	46.4			33
1B W.E. (cm)	3	137	41	1.01	41.4	46.4			33
= 40.0	4	135	38	1.03	39.1	43.8			32
1C Density (%)	5	135	38	1.03	39.1	43.8			32
= 29						227.0			
						Mean = 45.4	Mean[3] = +5.4	Mean[4] = +13.5	Mean[5] = 33

[1] Glacier sampler results assumed to be true water equivalent

[2] Correction factor = $\frac{\text{Standard Cutter Area}}{\text{Test Cutter Area}}$ = 1.12

[3] Mean of (6) - Glacier W.E. (1B)

[4] Mean of (7) ÷ Glacier W.E. (1B)

[5] Mean of (6) ÷ Glacier depth (1A)

SNOW PROFILE

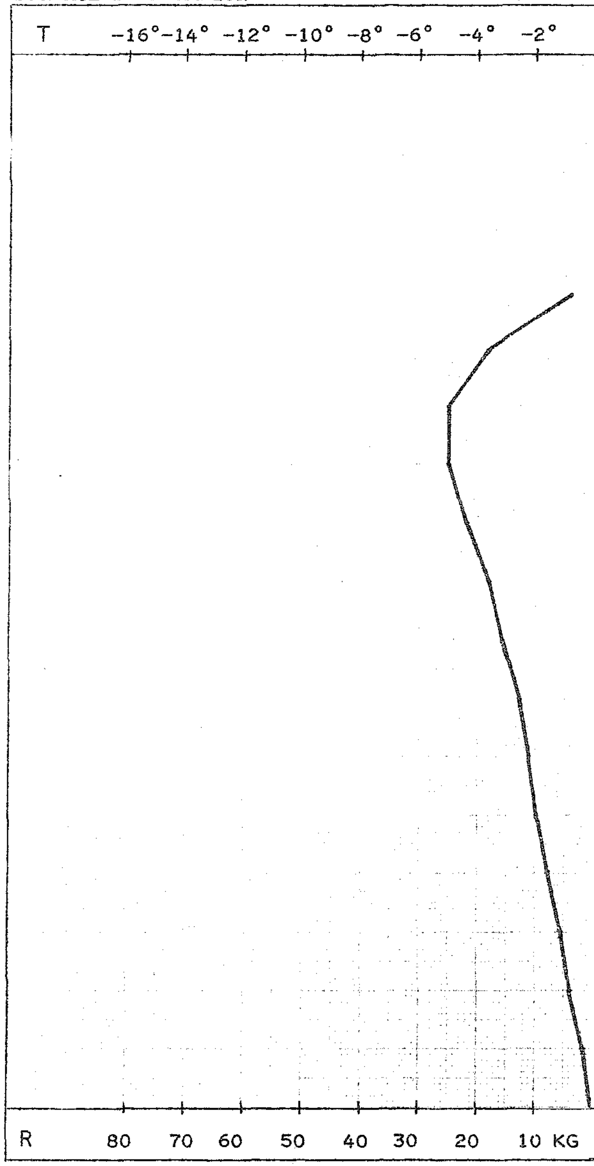
DATE *2-26-79* OBSERVER *Huffman - Herdina*

LOCATION *New World Lower*

ASPECT *Open Slope NNW* SLOPE INCLINE *1-2°*

WEATHER *Partly Cloudy, Light Breeze* *Ambient Temp: +0.3°C*

SURFACE PENETRATION *Ending* AMBIENT AIR TEMPERATURE *+3.1°C*



H	K	F	D	W	G	
139	Snow surface 0°C					−.8°C
130		+ + +	2		22	−3.6°C
120		° ° °	1½-2			−5.0°C
110						−5.0°C
100		□ □ □	2-2½		30	−4.4°C
90						−3.6°C
80						−3.1°C
70						−2.5°C
60					34	−2.2°C
50						−1.9°C
40		Λ Λ Λ	2-2½			−1.6°C
30					30	−1.1°C
20						−0.8°C
10						−0.3°C
0						0°C