A COMPARISON OF TECHNIQUES OF SAMPLING THE ARCTIC-SUBARCTIC SNOWPACK IN ALASKA 1/

By

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The Soil Conservation Service and the U. S. Army Cold Regions Research and Engineering Laboratory have cooperated in the operation of a snow course network in the interior basin and remote northern areas of Alaska since 1964. Snow sampling procedures using the CRREL equipment and the Bowman version of the Federal sampler have been compared at several of the snow courses each year since that time. In 1967 the sampling procedure was revised to include a Bowman sample from each CRREL site. This paper is based on data collected since that year. The snow samplers were tested to compare the relative accuracy, ease of handling, and general utility value of each.

The Federal sampler and the CRREL instruments are used extensively throughout Alaska for snow water equivalent and snow density measurements. CRREL maintains a separate network of stations in northern and western Alaska using its equipment exclusively for snow property measurements. SCS operates a network of 120 snow courses in the state using the Federal sampler at all sites. This paper compares the two types of measurements.

Snow courses where both samplers were used are at rather remote sites including Bettles Field, Chandalar Lake, Circle City, Fort Yukon, Eagle Village, Koness Lake, and Chicken Airstrip.These courses are located along the southern edge of the Brooks Range of mountains, the Yukon Flats, and the hills of east central Alaska. The transects range in elevation from 425 to 2,300 feet, which is typical of the watersheds in much of this region. Comparative measurements were made consistently at nine snow course sites that are part of a 24 snow course - aerial marker network in this region.

An experienced snow survey crew of two men has always been assigned to the project, and nearly all of the samples have been taken by the same individual. Transportation is by fixed-wing bush aircraft. To complete the circuit requires 4 days.

Measurements were made each year about March 1 and April 1. Weather conditions during these trips have often been very severe. Temperatures down to -45° Celsius have been experienced on several occasions. At other times, temperatures slightly above freezing also made for very difficult sampling.

Snow depths and densities have varied from year to year and from station to station. Snow in the region studied, however, is usually shallow in depth with relatively light densities. A typical snowpack on March 1 is approximately 20 inches deep. The lower half of the total profile consists of very well developed depth hoar crystals. Above that is a layer of fine grained moderately bonded snow. A layer of very light loose snow is observed at the surface.

The depth hoar is usually strongly bonded near the ground surface but elsewhere in the pack has very little structure and is difficult to sample because it tends to collapse as soon as it is touched by the snow tube.

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Samplers

The Bowman snow tube is a Federal type sampler. The 30 inch sections are constructed of Ryertex 4/ plastic and are graduated in inches and half inches. This material does not conduct heat or cold as readily as metal, which is a distinct advantage when the snow and air temperature differ greatly. The cutter point is 1.485 inches inside diameter, sharp, and is made of hardened steel (Fig. 3). The sampler is weighed using the standard Federal tubular scale. The Bowman sampler has proven to be superior to the aluminum tubes when used in the light cold subarctic snowpacks. This sampler is not commercially available, but a few sets were made for SCS by Professor Charles Bowman of Montana State University.

The CRREL snow sampler consists of a kit containing several 500cc stainless steel cylinders sharpened on one edge. The cylinders are equipped with rubber caps for each end so the sample can be preserved and weighed at a later time. Gross and tare weights are measured using a gram scale. Total snow depth and thickness of strata observations are used to determine the weighted density and/or the total water equivalent of the snowpack.

Procedure

Each snow course at which comparative measurements were taken was visited in the previous fall to take care of necessary maintenance. Special care was taken to remove all vegetative growth from the areas to be sampled.

Snow depth and water equivalent were measured at each of the sample points using the Bowman sampler. Measurements were then averaged to arrive at depth and water content figures for the snow course as is standard practive in snow surveys throughout the West. Particular care was taken to insure an accurate measurement at the sample point nearest the CRREL plot. Snow water equivalent and density at this point were compared to the results using the CRREL method.

CRREL tube measurements were made by first digging a pit on the plot previously marked for this use (Fig. 1). The stratigraphy of the profile was carefully examined and a 500cc tube inserted horizontally into the wall of the pit in the center of each recognizable horizon (Fig. 2). The total depth and extent of each stratum was measured and recorded. Snow was carefully shaved from the ends of the sampling tubes and capped. Gross, tare, and net weights for each sample were determined using a gram scale. Density was calculated in grams per cubic centimeter and multiplied by the depth of the horizon represented by the sample to find the water content. Water contents for each horizon were then added to obtain the total water content. The snow profile was described and snow temperatures taken within each strata. A summary of a typical set of observations and computations using the data obtained from samplers at one site follows:

Arctic Village - March 2, 1972

Federal sampler measurements, averaged from the ten sample snow courses were: depth, 17.6 inches; water content, 2.7 inches; density, 15.3%. CRREL measurements were as follows:

Total depth 17.0 inches; air temperatures, minus 19° C

Sample No.	Snow depth from Ground (inches)	Tare	Gross	Net	Density	degrees Celsius
1	2.0	292	378	86	.172	-14.0
2	6.0	280	360	80	.160	-18.5
3	11.0	277	364	87	.174	-25.0
4	15.3	308	379	71	.142	-24.5

4/ Trade names are used solely to provide specific information. Mention of a trade name does not constitute a guarantee of the product by the U. S. Department of Agriculture nor does it imply an endorsement by the Department over comparable products that are not named.

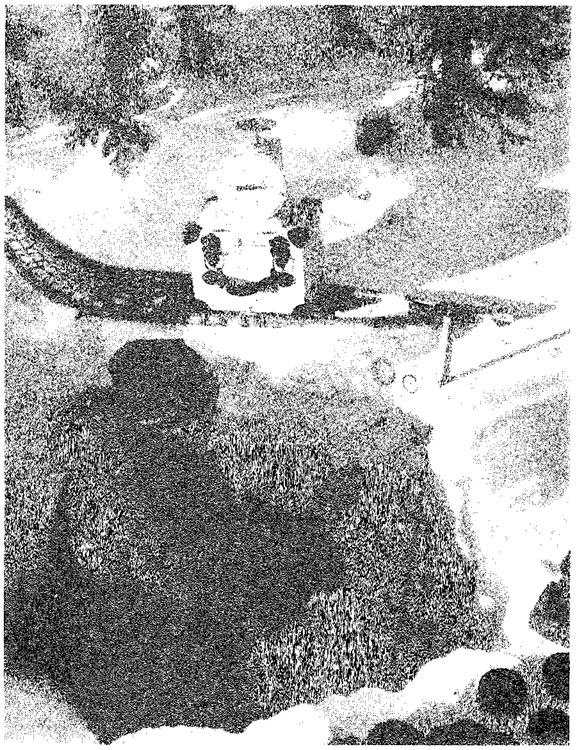

Figure 1 - Typical CRREL sampling pit with equipment. SCS PHOTO 1-273

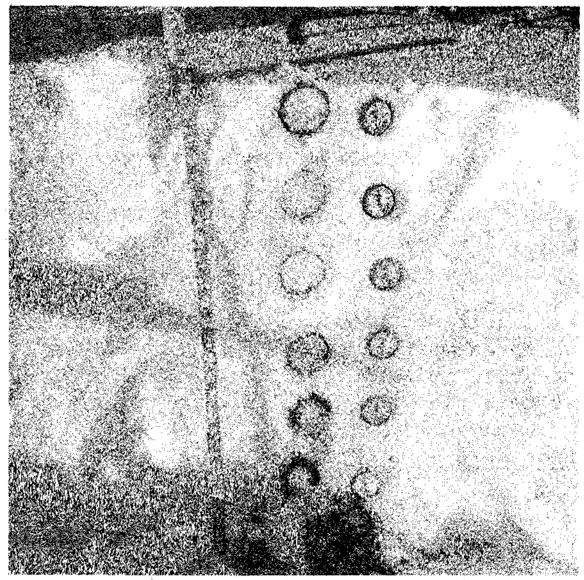

Figure 2 - Typical snow pit with CRREL tubes and thermometers inserted in each horizon. Note depth hoar near ground surface. SCS PHOTO 1-250-10

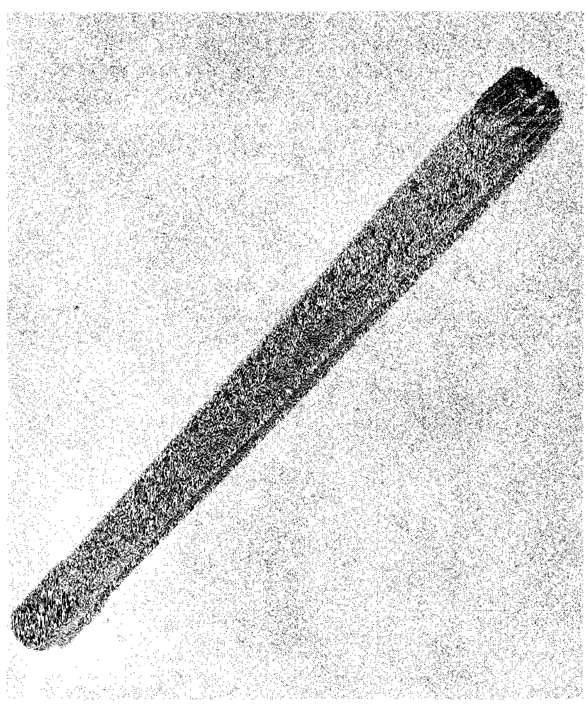

Figure 3 - Bowman version of the Federal sampler-cutter section. SCS PHOTO RO-785-6

Snow Profile Description

0 - 4"	Very large, mature, strongly bonded depth hoar crystals	4 X .172 = 0.688
4 - 9"	Large, mature, very weakly bonded depth hoar crystals	5 X .160 = 0.800
9 - 13"	Immature, very weakly bonded depth hoar crystals	4 X .174 = 0.696
13 - 17"	Very fine, loose crystalline snow	4 X .142 = 0.568
	Total water content	2.752

CRREL measurements, in summary, were: depth, 17.0 inches; water content, 2.75 inches; density, 16.2%. Federal sampler results at station one, adjacent to the CRREL plot were: depth, 18 inches; water content, 2.7 inches; density, 15.0%.

Results

Statistical tests (Snedecor, 1956) on the two sets of data indicate that densities as determined by the CRREL method differ slightly from those determined by the Bowman procedure. The "t" test of all data yielded a value of 7.68 which indicates the difference is significant at the 99 percent confidence level.

Figure 4 is a scatter diagram of the CRREL sample density (on the Y axis) versus the Bowman sampler (on the X axis) at the same site. The correlation is highly significant; r = 0.940, with n = 97. The regression coefficient is 0.906, near the optimum ratio of 1:1. The arithmetic mean of all CRREL densities is .1844 gm/cc while the mean Bowman sampler density is .1770 gm/cc.

The data were analyzed on a station by station basis. The Bettles snow course has the highest mean densities - CRREL = .2056 gm/cc and Bowman = .2011 gm/cc; the best r value (0.970), and a regression coefficient of 1.059 with n = 12. (See Figure 6.)

The station with the poorest coefficient of correlation also had low mean densities. At Koness Lake (Fig. 5) the CRREL densities averaged .1684 gm/cc while the Bowman sampler densities averaged .1620 gm/cc.

Table 1 - Summary of Density Statistics by Snow Course

	MEAN DENSITY (gm/cc)				
Snow Course	CRREL sampler (y)	Bowman sampler (x)	Correlation coefficient (r)	Samples (n)	Regression coefficient
Bettles Field	.2056	.2011	0.970	12	1.059
Eagle Village	.1976	.1907	0.935	11	0.747
Chicken Airstrip	.1923	.1840	0.848	11	0.937
Ft. Yukon	.1849	.1728	0.940	10	0.977
Circle City	.1818	.1725	0.965	12	0.876
Venetie	.1808	.1736	0.859	9	1.240
Arctic Village	.1741	.1647	0.892	12	0.892
Koness Lake	.1684	.1620	0.763	8	0.524
Chandalar Lake	.1644	.1621	0.951	10	0.887
ALL DATA	.1844	.1770	0.940	97	0.906

Discussion

There appears to be a relationship between mean density and the coefficient of correlation. Those stations with higher densities usually have higher r values and regression coefficient values more nearly equal to 1.0- the optimum value for which unit change by one method equals unit change by the other.

This relationship might be partially explained by the existence of relatively more depth hoar crystal development in shallower, lighter snowpacks. The CRREL technique of inserting tubes horizontally into the profile is difficult where depth hoar crystals are encountered. In many cases large depth hoar crystals, strongly bonded, are encountered near the ground surface. Extracting an accurate sample from this horizon is quite difficult when

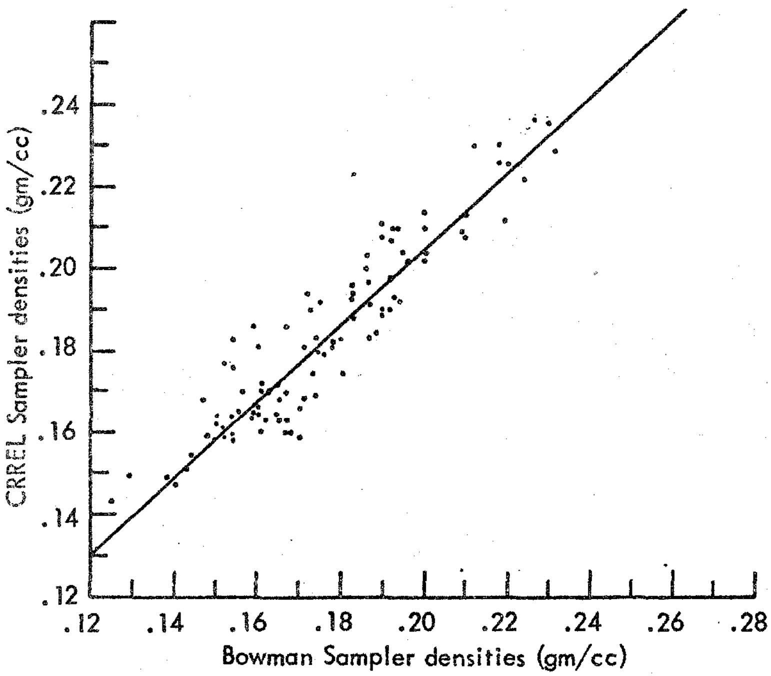

Figure 4 - Comparison of all CRREL and Bowman Samplers data.

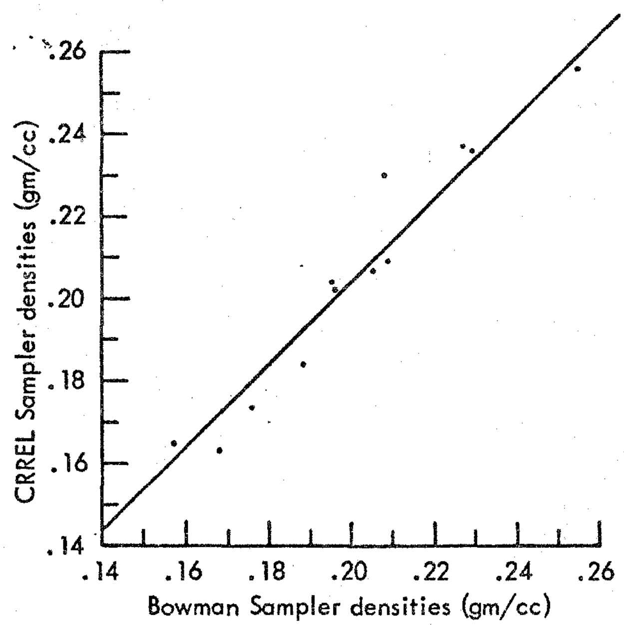

Figure 5 - Densities at the Bettles snow course.

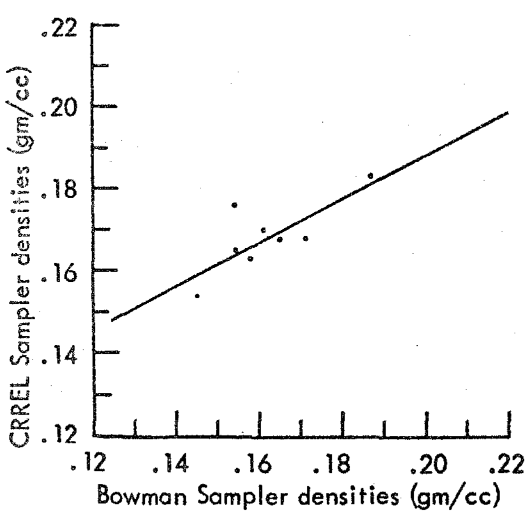

Figure 6 - Densities at the Koness Lake snow course.

the entire structure shatters. Just above this layer is a horizon of large very weakly bonded depth hoar crystals. This is the layer that collapses when touched by the snow tube.

Accuracy of individual samples was not felt to be a problem. Of the 102 total samples available only five were rejected as highly suspect. One was an obviously poor Bowman sample that was not detected in the field. Subsequent comparisons with other samples taken on the snow course revealed the error. The other four rejected samples, when plotted in Figure 4, fell well beyond the limits of the scatter, and as such were deemed unusable.

Accuracy of both the Bowman and CRREL sampling equipment was the subject of an earlier investigation (Work et al. 1965). These tests showed that measuring Alaska snowpacks with an average of about 3.0 inches snow water equivalent the Bowman sampler overweighed the snowpack by 4.1 percent while the CRREL procedure yielded an excess of 7.1 percent.

The Bowman sampler, or for that matter any Federal-type sampler, offers an onsite validity check procedure that is difficult to duplicate using the CRREL procedures. Since the density is computed at each point prior to moving to the next sampling station a comparison of results will indicate a possible error, and a repeat of the sample can be quickly made.

The CRREL procedure requires a more detailed arithmetic reduction of data and since only one sample in each horizon of the profile is taken there is no way to validate the results onsite. Replicate sampling destroys a significant portion of the plot. Frequent samplings would necessitate using a larger area.

The CRREL method is clearly superior for an analysis of the stratigraphy of a snowpack because the observer must sample each horizon independently. The core sample extracted by Federal-type samplers can be examined for crystal structure, but the density of any individual layer and cohesiveness of crystals are examples of observations that would not be accurate.

Conclusions

Snowpack data is being gathered in Alaska by several procedures including CRREL observations and snow course surveys using Federal samplers. The results of the study reported in this paper indicate that values by either method can be estimated if data from the other procedure is available.

CRREL observations yield slightly higher density values than Bowman observations in light density snowpacks. The difference tends to diminish as density increases. Previous studies have shown that the Bowman sampler overweighs the snowpack (Work et al.), hence CRREL procedures overweigh the snowpack by a higher percentage. It is presumed that the overmeasurement is a result, at least in part, of sampling strata of depth hoar crystals. Deeper snowpacks were characterized by higher densities and the fact that a smaller proportion of the profile had been metamorphosed to depth hoar crystals. The study indicates that the CRREL procedure overmeasure percentage may be inversely proportional to density.

Selecting a sampling technique in this environment is, of course, guided by the type of data desired. The Bowman method offers a convenient, accurate, and reliable alternative for collecting snow depth and snow water equivalent and has a note-reduction procedure that allows for convenient onsite validity checks.

The CRREL procedure gives a much more complete description of the stratigraphy of a snowpack. Onsite validity checks can be made most conveniently by routine replicate sampling within each horizon.

Each procedure originated because of a specific need: CRREL to describe the profile and Bowman to determine water equivalent. Each has proven to be a highly suited method of collecting these data. In addition now certain data collected by one method can be readily adjusted to conform to values observed by the other procedure.

ACKNOWLEDGEMENTS

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