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Snow surveyors at work measuring the potential water supply. (Elevation 10,500 feet)

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Utah Snow Sampler and Scales for Measuring Water Content of Snow

By George D. Clyde

Snow surveys are usually conducted in uninhabited and mountainous areas. The surveyors must travel on snowshoes or skis; therefore, the necessary equipment must be light, strong, and compact.

Development of Snow-Surveying Equipment

Many types of snow samplers have been used in the past 30 years, all apparently based on the principle of determining the water content of the snow by weighing a snow core of known volume. In 1900 Mixer (8) cut snow cores and determined their density by melting the snow and measuring the water. Horton (4) was apparently the first to use the weight method of determining the density of snow. Frankenfield in 1905 introduced the Horton tube into the U. S. Weather Bureau. In 1908, Marvin (7) designed the "density of the snow gage", consisting of a measuring stick and a spring balance with a bucket for determining the density of a measured volume of snow. In 1910, Marvin, now chief of the U. S. Weather Bureau, devised a sheet metal sampler 2.75 inches in diameter and approximately 4 feet long, having a coarsely serrated cutter. This sampler, however, proved to be too large in diameter and was structurally too weak for use in deep and compact snows. An early snow sampler, was designed by Kadel, Chief of the Instrument Division of the Weather Bureau (5), especially for weighing dry granular snow. This sampler consisted of a sheet-iron tube, 5.94 inches in diameter and 5 feet long, within which was operated a simple form of a soil auger to get beneath the core of snow. The core could be weighed in the sampler or, if necessary, could be removed to a special weighing can. This sampler was well adapted to light and shallow snows where a limited number of measurements are desired and a high degree of accuracy is essential. It was not practical for deep, compact snows. Later (6) the U. S. Weather Bureau developed a snow sampler (now called the Kadel tube) for general use. This tube is about 3 inches in diameter with a cutter 2.65 inches in diameter. It may be made in any lengths up to 10 feet. The tube is coated thinly with zinc to prevent rusting. This tube is now the standard used by the Weather Bureau. It is heavy to carry and difficult to drive through compact frozen snow. Due to its large size it is almost impossible to push it though ice layers in the snow. In 1908 Church (1), of the University of Nevada, designed the Mt. Rose Snow Sampler. The tube in this sampler is much smaller than that in any of the other samplers in use. Numerous experiments by Church (2) and Weather Bureau and Forest Service officials indicate that the small diameter tube is just as accurate as the larger tubes for sampling both compact and loose snow. The Mt. Rose tube consists of a seamless steel tube with an outside diameter of 1.75 inches and of any desired length up to 10 feet. (For greater depths of snow the tube is built in sections.) The tube is usually made of 20-gauge metal. It is slotted throughout its full length with alternate slots 1-16

\(^{1}\) Contribution from Irrigation and Drainage Department, Utah Agricultural Experiment Station

\(^{2}\) Irrigation and Drainage Engineer.

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An inch wide and 4 inches long. The outside of the tube is calibrated in inches. A milled steel cutter is soldered to the bottom of the tube. The inside diameter of the throat of this cutter is 1.5 inches. The inside diameter of the tube is larger than the diameter of the cutter, and the shoulder between them prevents the snow core from falling out when the tube is withdrawn from the snow. The cutter is made of high carbon steel and tempered to a degree of hardness that will just permit filing. It has a serrated edge to facilitate drilling through hard crusts or ice layers. The entire tube and cutter must be covered with a thin coat of shellac to prevent rusting and to keep the core from sticking in the tube. With a cutter 1.5 inches in diameter, 1 inch of water in the snow will weigh slightly more than 1 ounce. Therefore, a specially calibrated scale is necessary for use with this tube.

The water content of the snow sample is determined by weighing the snow core, cut out by the tube, on a spring scale. The tube containing the core is laid horizontally in a sling attached to the scale (Fig. 1). The difference between the
weight of the empty tube and the tube and core is a measure of the water content of the snow core. For convenience, the scales are calibrated to fit the particular tubes with which they are to be used so that they will indicate the water content directly in inches of water. The Mt. Rose snow scale designed by Fergusson is a modified form of the well-known Forschner spring balance. It is a dial scale made of aluminum and weighs complete about 2.5 pounds. Its smallest division is 1 inch of water and it can be interpolated to 0.1 to 0.2 inch of water. The scale for the Kadel tube is also a dial scale made of aluminum weighing about 1.5 pounds. It is calibrated to indicate the water content in inches. The Mt. Rose scale has an adjustable zero which permits the weight of the empty tube to be set off and the water content determined with one reading. The Kadel scale must be read twice—once to get the weight of the empty tube and once with the tube and core. The difference is equal to the water content of the snow. The drawbar in both the Kadel and the Mt. Rose scales is rectangular in cross-section. The tube when in a weighing position is horizontal and when even a light breeze is blowing the tube has a tendency to swing. Swinging the tube through a small arc will cause the drawbar to bind. This is a distinct disadvantage as measurements often must be made under adverse weather conditions.

The Kadel and the Mt. Rose scales, although fairly light, are both large and cumbersome. Experience in making snow surveys during the past 10 years has emphasized the need for a lighter and more compact spring balance and a lighter non-corrosive tube for taking snow samples.

**Utah Snow Sampler**

The Utah snow sampler is a Church sampler modified in two important respects:

1. The Church cutter has a throat diameter of 1.5 inches. The equivalent of 1 inch depth of water in a snow core 1.5 inches in diameter weighs 1.02229 ounces, thus requiring a specially calibrated scale. By changing the diameter of the throat of the cutter from 1.5 to 1.4872 inches, the unit weight is made to equal just 1 ounce. This permits an easy conversion to inches depth of water when ordinary commercial scales reading to ounces and half ounces are used. It also facilitates the calibration of special scales.

2. The Church tube of seamless drawn-steel tubing weighs approximately 0.7 pound per linear foot and it must be kept coated to prevent rusting and to keep the snow for sticking in the tube. The Utah sampler tube (Fig. 2) is made of seamless drawn-aluminum alloy, No. 17ST, has an outside diameter of 1.75 inches, and is 18 stubs gauge. This alloy is rust-resistant. It has an extremely smooth bore and has been used in lengths up to 12 feet. The strength of this alloy is about equal to that of structural steel and it weighs only one-third as much as structural steel. The polished inside surface of this metal largely prevents the snow from sticking in the tube and thus overcomes one of the greatest difficulties encountered by the snow surveyors.

The success of the snow sampling is largely determined by the cutter and the smoothness of the inside of the tube. The Church cutter, modified only in diameter of throat, has proved entirely satisfactory for cutting through hard snow and ice. If the cutter is kept clean and sharp it will cut a true core and not clog up with snow. The shoulder in the cutter will prevent the snow core from dropping out as the tube is withdrawn from the snow. The cutter must be properly tempered.
and ground to a true diameter. The hardness should be such that it will just permit filing to keep the points sharp. It is difficult, when sampling the snow cover, to distinguish between rock and ice, with the result that the cutters are sometimes broken. The cutters may be removed by heating the end of a tube with a torch and pulling out the cutter. To replace a cutter, the end of the tube is expanded by heating; a new cutter is then inserted and the tube allowed to shrink up on it in cooling. The zero of the tube is at the shoulder in the cutter. Figure 3 shows the detail of the tube and cutter. It will be noted that the lower seven-eighth inch of the cutter is tapered so that the diameter of the hole in the snow is slightly larger than the outside diameter of the tube. This section is also milled to provide cutting action when it is being rotated through ice and hard snow. The Utah snow sampler made of aluminum alloy No. 17ST with a high carbon steel cutter weighs approximately 0.3 pound per foot, which is about one-third the weight of a steel tube of the same diameter and gauge.

Any competent machinist can make the Utah sampler, using only the details of design given in Figure 3 as a guide. Single tubes up to 12 feet in length are practical for use in the field. Where longer tubes are required they should be built in sections and threaded for couplings.

**Utah Snow Scale**

The range and accuracy of the snow sampler is limited only by the accuracy of the scale used to weigh the snow core. All spring scales are subject to inaccuracies due to temperature changes or defects in the springs. For well-built springs these inaccuracies are small and well within the probable error of sampling. The sensitiveness of a spring balance decreases with an increase in range. A spring balance sensitive to 0.5 ounce is satisfactory for weighing the ordinary deep snow samples found on the mountain watersheds of the west. The accuracy of such a balance would be within 2 per cent for a 10-inch water content and less than 1 per cent for a 50-inch water content.
To overcome some of the disadvantages of the scales now in use for measuring the water content of snow a tubular spring balance was developed by the author (3) in 1930. The Utah balance is believed to be an improvement over the original, to be more sensitive, and just as accurate as any snow scale now in use; it also has the further advantages of being lighter and more compact. The over-all length of the tubular balance is 12 inches, its diameter 1½ inches; and its weight less than 0.5 pound as compared to the Mt. Rose (2.5 pounds) and the Kadel (1.5 pounds).

The Utah snow scale (Fig. 4) is constructed of 18-gauge alcoa aluminum alloy tubing No. 17ST and a spiral spring No. .062 x .045. The diameter of the spring is 0.795 inch.

The inner tube telescopes inside the outer tube with sufficient clearance to prevent friction. The spring works inside the inner tube and is attached to the outer tube on one end and the inner tube on the other. An aluminum alloy plug fits into the end of the outside tube. The hanger ring for suspending scale is tapped into this plug. The plug is fastened to the outside tube with a bronze No. 4-40 set screw. A slot ½ inch wide and 9.25 inches long is cut in the outside tube parallel to the longitudinal axis. The scale is calibrated along the edge of this slot. An aluminium alloy plug is fitted into the opposite end of the inside tube, and into this plug is formed a hook swivel (Fig. 4). The inner ends of both plugs are slotted and pinned for fastening the spiral spring. The construction details for all parts of the scale are shown in Figure 4.

Scales of different capacities are required for snow covers of different depths. To keep the scale compact and as light as possible and still retain its sensitiveness, scales of the larger capacities are constructed with the spring under an initial tension. The scale shown in Figure 4 is for use with an 11-foot tube. It has a

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*This alloy has the following physical properties: Tensile strength—55,000 pounds per square inch; minimum yield strength—40,000 pounds per square inch; minimum elongation, percentage in 2 inches =14. It machines well.*
Fig. 4.—Design details of Utah snow scales
capacity equivalent to 80 inches of water. The spring with the scale fully telescoped is under an initial tension of about 3.5 pounds. The 11-foot tube and sling weighs about 4 pounds; consequently, the scale reading with the empty tube in the sling would be 8. To illustrate, if the scale reads 57 with the tube and core in the sling the water content of that sample would be 49 inches. A scale can be made to fit a tube of any length by changing the initial tension of the spring so long as the maximum load on the spring does not stress it beyond its elastic limit.

The scale indicator is fastened to the inner tube and it travels in the slot in the outer tube. The point of the indicator overhangs the outer tube so that a close reading on the scale may be obtained. The indicator will not permit the spring to be stretched beyond its elastic limit because the lower end of the slot is its limit of travel. The divisions on the scale are 3/4 inch apart and the spring is sensitive enough to permit interpolation to at least 0.1 of a division. Each division on the scale represents 1 inch depth of water.

To calibrate a scale for the Utah sampler tube the scale is first assembled and the zero marked for the initial load. For this tube each inch depth of water weighs 1 ounce; the scale, therefore, is marked off by loading it with known weights, or by computing the stretch for a given load and then subdividing the distance. The calibrations are marked on the tube in a milling machine.

Light-weight aluminum alloy snow samplers make possible the use of compact, light, rugged, tubular spring balances that are sensitive and accurate for weighing the snow core and determining the water content of a snow cover. Figures 1 and 2 show the scales, a section of a snow sampler, and the snow cutter. The total weight of an 11-foot snow tube and scales of the type described weighs less than 4.5 pounds as against 12 to 18 pounds for the equipment now in common use. The material from which this equipment is made is highly resistant to corrosion and yet has the strength of structural steel.

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