SNOW PLATES: PRELIMINARY RESULTS

by

J.A. Moffitt[1]

ABSTRACT

This paper presents the design, construction and calibration of a field instrument to measure snow water equivalence (SWE). This instrument, referred to as a 'snow plate', consists of a 1 m^2 circular, perforated aluminum plate assembly mounted on three loadcells. When coupled with a ultrasonic snow depth sensor, measurements of snow density can be made. This plate was designed to make high-frequency, high-resolution SWE measurements on the Front Range of Colorado. Snow events typically are temporally isolated and produce a SWE of 2 cm or less. The tested plate can measure a maximum SWE of 34.5 cm. The maximum SWE capacity can be increased by using higher capacity loadcells. A preliminary 0-4.5 SWE (0-45 kg) loading/unloading calibration test shows that the plate has an average error of 0.0284 cm SWE (0.284 kg), with a maximum error of 0.0817 cm SWE (0.817 kg) at 3 cm SWE (30 kg). Ninety-five percent of the 1210 test measurements had errors of less than 0.05 cm SWE (0.5 kg). This test indicates that the snow plate may be a useful alternative to the traditional snow pillow for measuring SWE. This instrumentation is portable, requires minimal maintenance, and may be used in dense forests and rocky and sloped terrain. The snow plate may help provide important information on the effects of topography and vegetation on snow accumulation.

INTRODUCTION

Snow water equivalence (SWE) and snow density are important and fundamental input and verification parameters for snowmelt modelling. The SWE at the time of maximum snow accumulation establishes the amount of potential snowmelt available for soil infiltration and run-off. Differences between the potential and locally measured snowmelt amounts can be attributed to the evaporative and sublimation processes. In addition, measurements of snow density with improved resolution may provide valuable information on snow dynamics and metamorphism.

The role of snowmelt in the fate and transport of contaminants in soils surrounding the Department of Energy's Rocky Flats Plant, near Golden, Colorado, is being investigated. The dynamic nature of snowmelt at this research site makes reliance on manual snow measurements difficult. Since a snowmelt monitoring system was installed in late 1993, fifteen snowfall events of more that 10 cm have occurred. Each event produced a SWE of less than 2 cm, was temporally isolated, and required an average of 3.3 days to completely melt. Automated instrumentation was developed to obtain improved resolution of SWE measurements. This instrumentation, referred to as a 'snow plate', was designed to weigh a 1 m^2 sample of snowpack. Since automated snow depth measurements are already available by using a snow depth sensor, snow density measurements will be possible. For a given area of a snowpack, average bulk snow density can be calculated if the SWE and depth of the snow is known. The snow plate will be fully integrated into an existing snow monitoring system. Measurements of snow mass will be made with the same ten minute interval of the snow depth measurements.

Paper presented at the Western Snow Conference 1995, Sparks, Nevada.

[1] Graduate student, Department of Civil, Architectural and Environmental Engineering, University of Colorado, Boulder, CO 80309; and Environmental Engineer, EG&G Soil Study Team, P.O. 464, Golden, CO 80402.

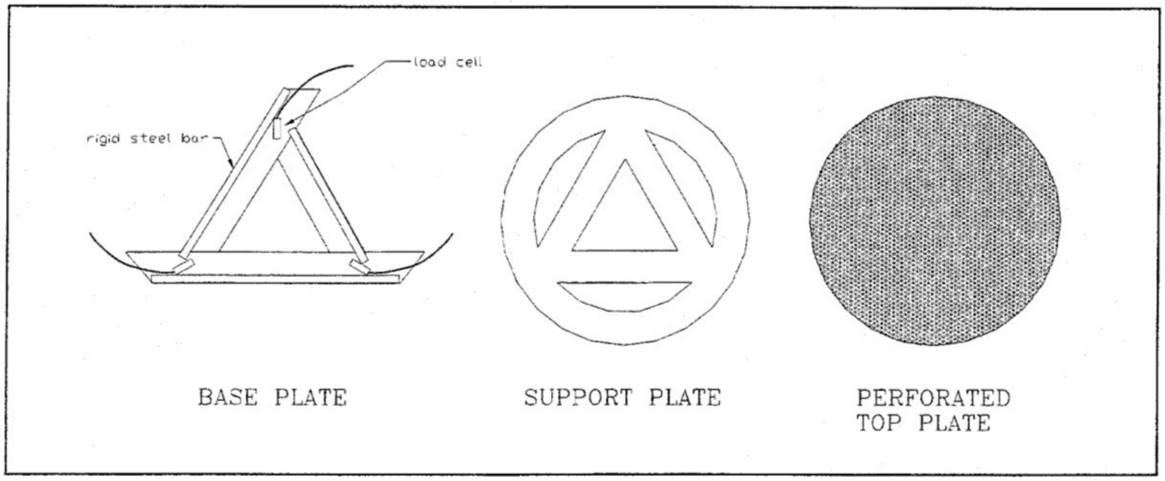

Figure 1 - Snow plate parts

SNOW DENSITY PLATE DESIGN

The snow plate is a scale for measuring the mass of 1 m^2 of snowpack. It consists of four parts: base plate, support plate, perforated plate, and loadcells as shown in Figure 1. Figure 2 displays how the plate is installed in the field. The base plate is mounted onto a level surface, and anchored with rebar. The perforated plate and support plate assembly is mounted with the support plate resting on the loadcells. Ideally this top plate is installed flush with the ground surface. The perforated plate allows snowmelt to drain from the snowpack collected on the snow plate.

The perforated and support plates are constructed of 5052 aluminum to conserve weight, retain strength and rigidity, and resist corrosion. This assembly weighs approximately 16 kilograms (35 lb.). To create an area of 1 m^2, both circular plates have a diameter of 112.84 cm (44.42"). The perforated plate is 0.32 mm (1/8") thick and consists of 0.32 mm (1/8") holes drilled at a staggered interval of 0.48 mm (3/16"), for a porosity of 0.40.

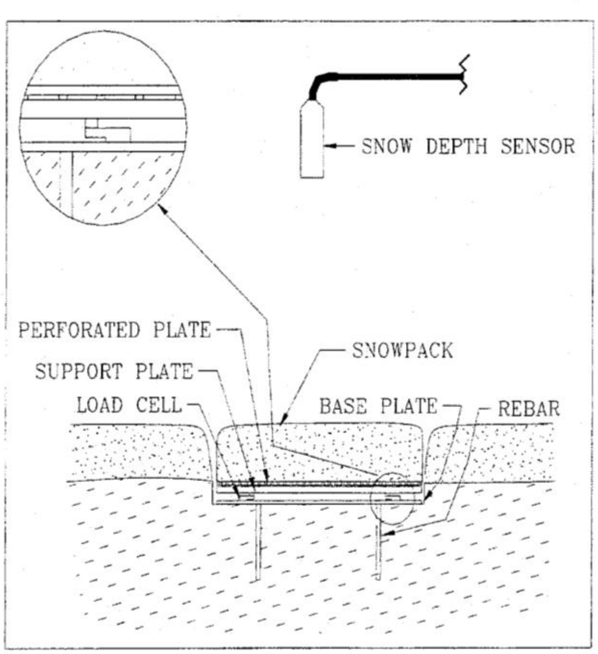

Figure 2 - Diagram of installed snow plate

To increase the rigidity and reduce the loading deformation of the perforated plate, the support plate is mounted directly underneath. This plate has a thickness of 0.64 mm (1/4"). To allow snowmelt drainage, there is a 0.48 mm (3/16") space between the plates. This space is created by an array of stainless steel nuts and bolts.

The most important design consideration for the steel base plate was resistance to deformation. This rigidity prevents the base plate from absorbing the loading force. Rectangular steel bars (1.25 cm x 5 cm) were welded onto the top surface of each plate edge for additional strength.

Parts were painted white to reduce thermal conductivity and increase reflectivity. These modifications should help prevent the plates from heating up and accelerating the snowmelt rate. Two coats of zinc chromate primer were applied, followed by a layer of acrylic latex enamel paint.

The important loadcell specification parameters were the loadcell mass measurement range, compatibility with the current monitoring system, and weatherproofing. Interface[2] SSB-MA-250 loadcells met these requirements. This model is specifically designed for outside applications, can measure a maximum of 115 kg (250 lb.), and is compatible with Campbell Scientific Inc. dataloggers, multiplexers and programming language. This loadcell type is available with a loading capacity of up to 460 kg (1000 lb.). Loadcells with larger capacities are available from a variety of manufacturers, although they will require additional waterproofing.

SNOW PLATE CALIBRATION

Calibration of the snow plates was performed by applying known masses to the plates and recording the output of the plate's three loadcells. The loadcell electrical outputs were recorded using a Campbell Scientific Inc. CR10 datalogger and AM416 multiplexer. A millivolt (mV) to kilogram (kg) conversion factor was then determined by dividing the electrical output by the applied mass. The calibration weights consisted of 1-liter plastic bottles filled with water. The reference masses were confirmed with a Sartorius F150S scale.

A series of three calibration tests were performed for the plates. These tests included mass ranges of 0-25, 0-45 and 0-100 kg. For the 1 m^2 plate, one kilogram corresponds to 1 mm SWE. Hysteresis effects were assessed by recording loadcell output for repeated loading/unloading cycles. The calibration tests ranged from one to three cycles. These tests were designed to assess the loadcell output linearity, the mV-to-kg conversion as a function of applied mass, and the mass resolution of the snow plates. For the 0-25 kg range, increments of 1 kg were used. Above 25 kg, increments of 5 kg were used. A higher mass resolution was used for the 0-25 kg range because this range represents the expected mass of 1 m^2 surface area of typical snow events on the Front Range of Colorado. The 25-100 kg range provided calibration information for more extreme snowfall events or for use of the snow plates in areas of deeper seasonal snow packs.

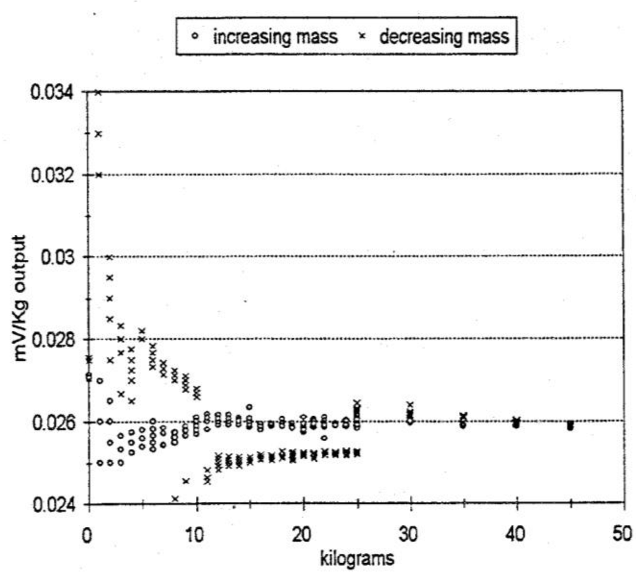

Figure 3- Snow density plate mV/kg conversion factor versus applied mass

Calibration Results

Preliminary results from one calibration test are presented below. This test consisted of one loading/unloading cycle of 45 kg. Linear regression of mV output versus mass applied resulted in a slope of 0.0257 mV/kg, with R^2 = 0.999, n = 1210. This value of 0.0257 represents the statistical average of the mV-to-

[2]Commercial names are for information purposes only and are not an endorsement by the author.

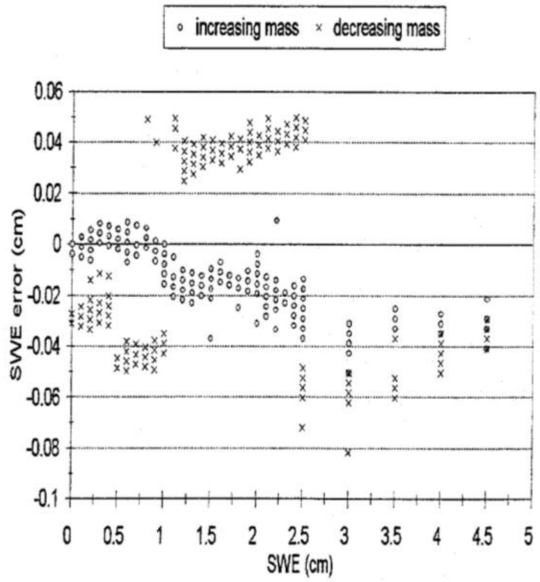

Figure 4 - SWE error versus applied SWE

kg conversion for this test. The mV/kg conversion factor versus applied mass is illustrated in Figure 3. Variation decreases with increasing mass. This is due to the use of loadcells rated for much greater loading capacities. The conversion factor for loading is more stable than for unloading. The average value for loading was 0.0256 mV/kg, with a coefficient of variation of 0.0142. For unloading, the average was 0.0260 mV/kg, with a coefficient of variation of 0.0678.

From this data, a mV-to-kg conversion factor of 0.0257 mV/kg was selected. The SWE resolution of using this constant conversion factor is presented in Figure 4. This plot was generated by converting the snow plate's mV output and comparing it to the SWE equivalent applied. Ninety-five percent of the 1210 mass measurements had errors of less than 0.5 kg. When this resolution is expressed in terms of SWE (or the height of water on the 1 m^2 plate), the resolution of the plate is less than 1 mm. The average error (using absolute values) was 0.0284 cm SWE. The maximum error was 0.0817 cm SWE (at 3 cm SWE). With design refinement and using a mass dependent mV/kg conversion factor, this resolution may improve.

DISCUSSION AND CONCLUSIONS

Initial tests demonstrate that the snow plate could be an effective instrument for high-frequency, high-resolution measurements of SWE. To confirm this, the snow plate's performance under field conditions must be studied. Comparisons with snow pillows and manual measurements need to be made.

Since the snow plate is a solid-state device, it offers important advantages over snow pillows. The snow plate does not require a hydraulic assembly or pressure measurement enclosure. Snow plate installation requires approximately one hour, and consists of wiring the three loadcells to a datalogger or multiplexer and a minimum of ground surface preparation. The snow plate should also require a minimum of maintenance. There are no fluids to leak or freeze and no bladder to be damaged. Summer maintenance consists of insuring that the perforated plate is free of debris and an annual calibration test.

The 1 m^2 surface area of the snow plate offers both challenges and opportunities. The main challenge is handling the 'bridging effects' of snowpacks. Due to the internal structure of snow, any device may be weighing more snow than the snowpack directly above it. Snow pillows typically have a surface area of 10 m^2. Weight of additional snow from outside that area is assumed to be proportionally minimal. This assumption can not be made with the snow plate. An option is to cut and isolate the snowpack directly above the plate. For comparison purposes, ideally two plates will be installed, with one being left undisturbed.

The smaller, rigid design offers several new opportunities for automated SWE measurements. The snow plate is portable and can be installed in dense forests, rocky terrain, and on hillsides. This may help provide important information on the effects of topography and vegetation on snow accumulation.