MT. HOOD PRESSURE PILLOW SNOW GAGE1/

By

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Introduction

On the slopes of Mt. Hood, Oregon, at an elevation of 5500 feet, the past three years the Soil Conservation Service, U. S. Department of Agriculture, has improved and evaluated the pressure pillow as an approach to measuring the equivalent water content of the snow and snowfall rates.

The sensor reported upon and developed has been named the Mt. Hood pressure pillow snow gage. The pressure pillow approach to measuring the equivalent water content of the snow was first suggested by the writer in 1957. C. C. Warnick and V. E. Penton (1) made the first pressure pillow field installation at Moscow, Idaho under an Agricultural Research Service contract for the Soil Conservation Service. Unfortunately, during the life of the contract snowfall at their test site was insufficient to give an evaluation of this device. Warnick has continued to study this approach to measure snow water equivalent at Moscow.

Pressure pillows were first installed in cooperation with the University of Idaho and Pacific Power & Light Company by the Soil Conservation Service at Mt. Hood, Oregon the winter of 1961-62, and evaluation has continued by the Soil Conservation Service. Information reported upon in this paper is a result of the work performed by the Soil Conservation Service at Mt. Hood and other locations in the west.

Principle of Operation

The pressure pillow snow gage is a device on which the snow falls with a minimum of natural physical changes in the snow. As the snow falls on the pillow, the internal pressure is increased within the pillow. The pressure is directly related to the mass of the snow resting on the pillow. A manometer or pressure transducer can be used to measure this pressure.

Installation

The pressure pillow is manufactured from thin sheets of butyl rubber approximately .0625 inch thick. Two sheets are welded together and fitted with two outlets, one for filling and subsequent readout and one for exhausting the air while filling with fluid. The original configuration of the pillow was round but later models have six to twelve straight sides for easier manufacturing. (See Figure 1.) The top surface of the pressure pillow is painted with a white plastic base paint to reduce absorption by radiation.

Installation of the pressure pillow is made on a pre-levelled area of sawdust or sand. The pillow is filled with a mixture of water and antifreeze. Methyl alcohol has been used to mix with water to prevent freezing in pillows installed by the Soil Conservation Service. A 1/2 inch inside diameter rubber hose is used to connect the pressure pillow to a stand pipe on which a float-actuated recorder is installed.

Several different size pillows have been installed for testing purposes. The smallest is 5 feet and the largest is about 12 feet in diameter.

1/ Paper prepared for presentation at Western Snow Conference, Colorado Springs, Colorado, April 20-22, 1965.

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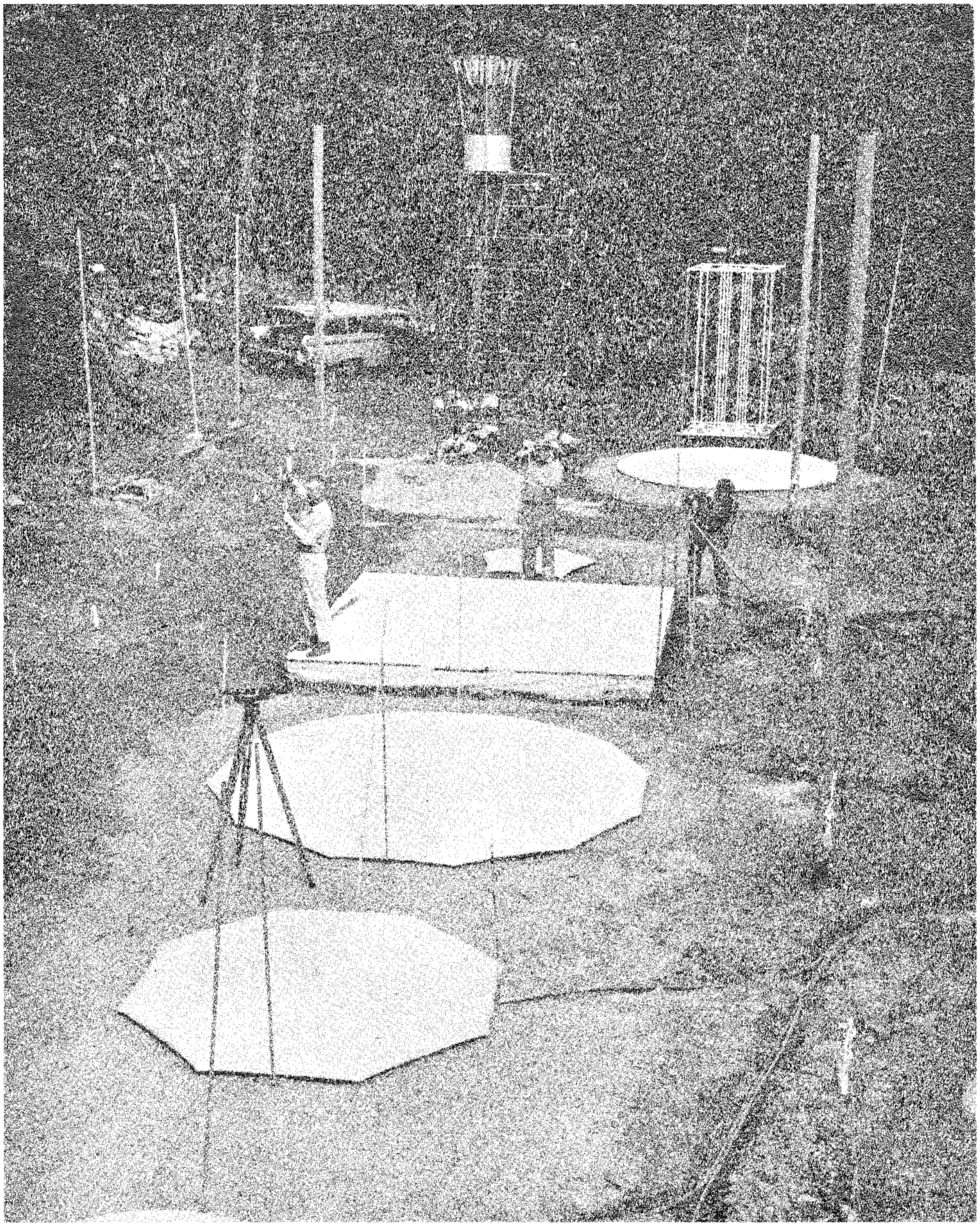


Figure 1. Pressure Pillow Installation at Mt. Hood Test Site. Photo Shows Various Size Pressure Pillows and Platform Tested. 100-Inch Recording Storage Gage Mounted on 15-Foot Tower in Background.

Evaluation

These pressure pillows have been evaluated during the past three years at Mt. Hood and a 12-foot-diameter pillow for two years at Lick Creek, Montana. Evaluation techniques have included making snow tube measurements on and near the pressure pillows and comparing these observations to the manometer readings of the stand pipe corrected for density difference. Snow tube measurements were corrected for error common to snow tubes.(2) Figures 2 and 3 show the comparisons for the 1962-63 and 1963-64 seasons on the 12-foot pillow. In addition to these observations incremental observations were made of short period snowfall and compared with manometer increases. These observations were made by exposing small flat boards of plywood approximately 10 in. x 15 in. in size on top of the snow and weighting the accumulation after exposure. Results of these observations are given in Table 1.

TABLE 1

Comparison Between Volume Snow Samples
and Measured Amount from "F" Recorders for Short Periods

	Test Site Snow Course					
Date and Time	Snow Depth (in.)	Water Content (in.)	Pillow Size (ft.)	Chart Increase "F" (in.)	Vol. Sample (in.)	Difference (in.)
9 Jan. 1140-1520	83.5	24.7	8	0.48	0.41	+0.07
1140-1520	83.5	24.7	12	0.50	0.41	+0.09
16 Jan. 0935-1405	90.6	27.4*	6	0.30	0.27	+0.03
0935-1405	90.6	27.4*	8	0.29	0.22	+0.07
25 Mar. 1120-1445	198.2	65.5**	12	0.16	0.18	-0.02
26 Mar. 1040-1444	198.2	65.5**	12	0.22	0.15	+0.07
15 Apr. 1315-1535	204.9	80.6	12	0.08	0.09	-0.01

* 14 January measurement
** 11 March measurement.

On June 3, 1963 a trench was excavated around the 12-foot-diameter pillow, and manometer levels were observed. Listed below in Table 2 are the results of this work.

TABLE 2

June 3, 1963 Observation of 12-Foot Pressure Pillow

Time	Amount Perimeter Exposed (feet)	Manometer Level (inches)
0920	0	64.25
1000	1	64.06
1015	6	63.94
1030	12	63.62
1045	15	63.50
1105	--	63.62
1130	--	63.44
1140	30	63.25
1150	31	63.25
1230	--	63.44
1250	Entire perimeter exposed	63.50

Snow depth at this time was 48.7 inches, water content of 22.0 inches with the resultant density of 45 percent.

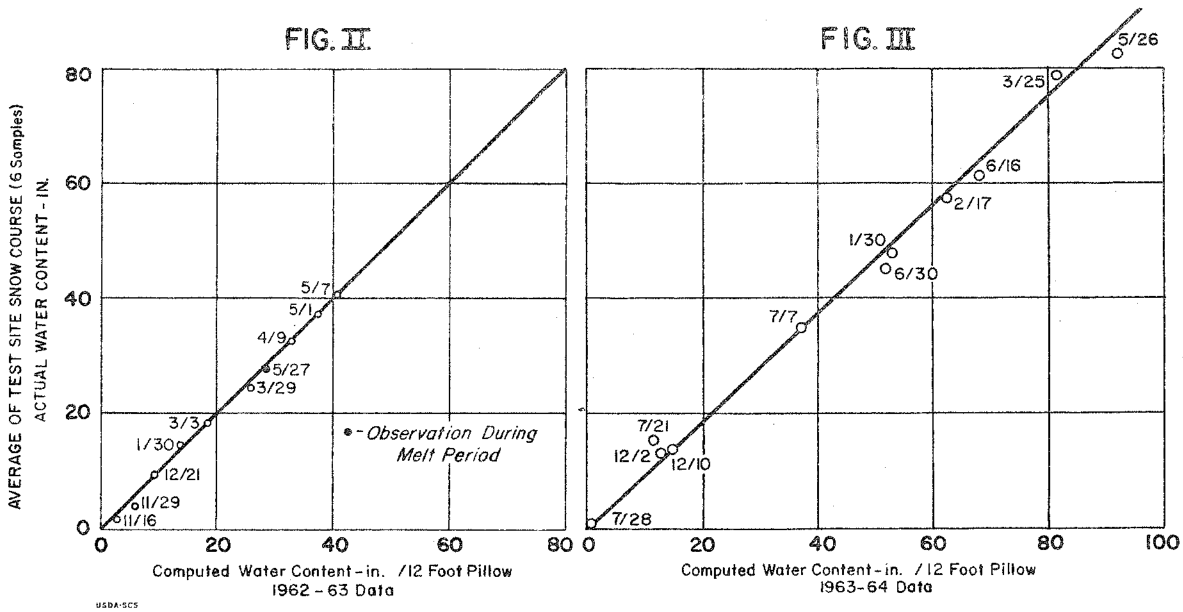
The slight drop in the manometer level was due to the small reduction of pressure on the exposed perimeter. This simple test indicated the lack of "bridging" of the snow on the pillow.

Records were also collected from a 100-inch-capacity Leupold Stevens precipitation

MT. HOOD TEST SITE

FIG. II.

FIG. III



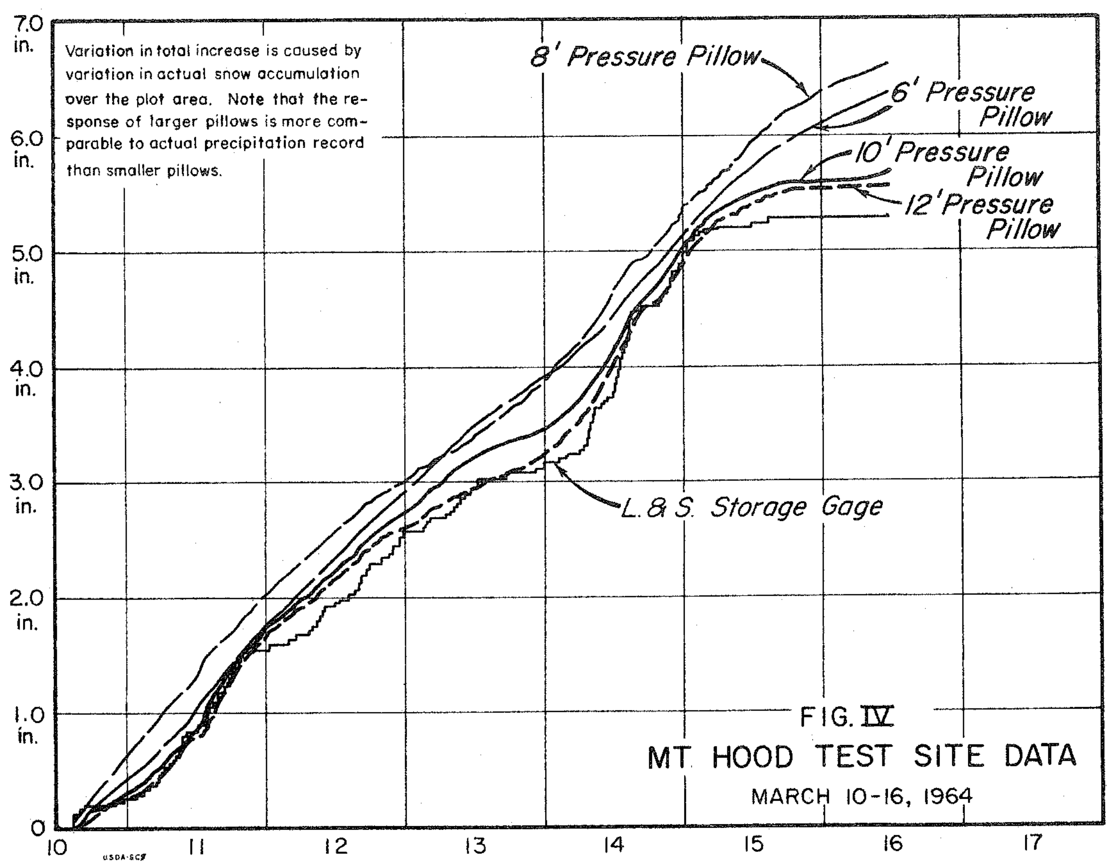


FIG. IV

MT. HOOD TEST SITE DATA

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storage gage. This gage also had an on-site recorder. A hydrothermograph provided temperature and humidity records and enabled comparison between the precipitation and increase in snow water equivalent when the temperature was below 32°F.

In order to compare the performance between individual pillows, the pen trace of each pillow was copied on a single chart for each week. Inspection of these charts indicated that the smaller size pillow over-weighs each snowfall. Other observations suggested this may be caused by the fact that the small pressure pillows recorded a lower rate of accumulation but continued to record increases many hours after the snowfall had actually ended, thus giving a greater total accumulation reading. Examples of these comments are shown in Figure 4. This was verified on several occasions by observers during the ending of a snowfall at Mt. Hood. These observations were again verified by the author studying a 5-foot-diameter pressure pillow installed at Old Faithful, Yellowstone National Park, in January 1965. For several days after a snowfall had ended, the 5-foot pillow continued to record a rise in pressure. It was also observed that the rise in the pillow pressure ceased after the settling of the new snow had become less than one inch per day. This, of course, suggests some change in physical properties of the snow either related to the settling of snow or dependent upon it which caused the over-weighing of the snow by the smaller pressure pillows. Snow depth at that time was 59 inches and the density was 37.5 percent.

Results of data analysis have demonstrated that a pressure pillow 12 feet in diameter can provide an accurate measurement of the equivalent water content of the snow. Response time of the readout related to the beginning of snowfall is a matter of minutes. This is the same for all pillow sizes. There appears to be a relation between snow depth, pillow size, and error. The smaller the pillow and the deeper the snow, the greater the error. These errors, in most instances, were positive; i.e., the smaller pillow gave a pressure reading indicating more equivalent snow water than was actually on the pillow. A possible explanation of this over-weighing may be the configuration of the pressure pillows. Each pressure pillow has a sloping surface at the edge. In case of the smaller pillows, the ratio of the height of the pillow as measured at the center to the radius was greater than that for the larger pressure pillows. Inasmuch as the resulting forces of the fluid inside the pillows react normally to the surface of the pillow, this could result in a larger amount than the actual volume of snow resting on the pillow. A simplified example of this is given in Figure 5. The hatched area indicates amount of extra snow that could contribute to the pressure on the pillow. With a snow depth of 172 inches, the dimension "x" for the 12-foot-diameter pillow is 12.3 inches. For the 5-foot-diameter pillow the same dimension is 26.9 inches. Thus, this could contribute a considerable amount of additional weight if only part of it acted on the pillow.

Application to Avalanche Forecasting and Studies

Accurate records of snowfall accumulation are important to avalanche prediction and control. The Mt. Hood pressure pillow snow gage presents a possible device to secure such information. The application of this device could, via radio, secure information from remote areas and during periods of heavy snowfall.

Such information has been sent from the Mt. Hood test site and received in Portland, a distance of some 59 miles. In Figure 6 a schematic diagram of the component and radio linkage is given. Information was sent every hour and was recorded on paper tape.

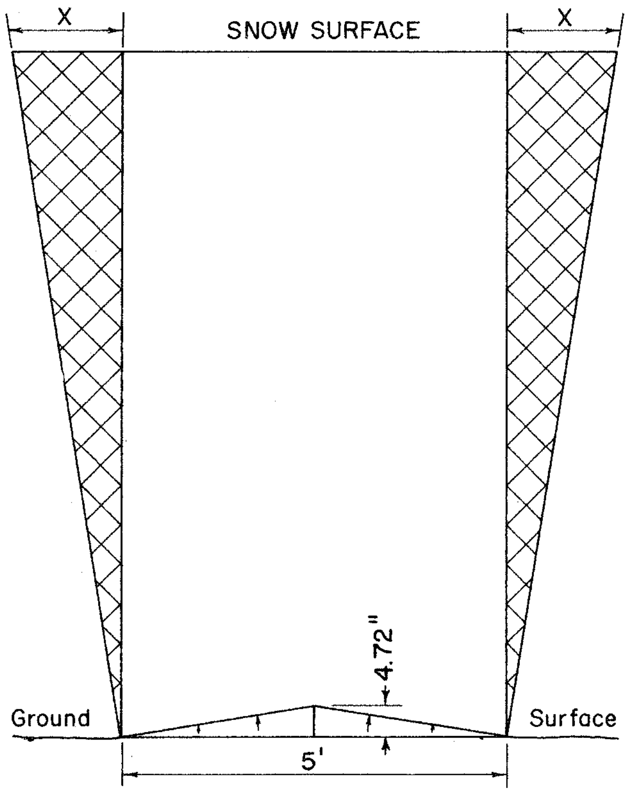
Inasmuch as the settling of snow is related to the initiation of snow slides, a smaller diameter pillow of 5 feet may provide this information if used in conjunction with a larger 12-foot pillow.

The 12-foot pillow does not continue to show pressure rises upon completion of snowfall, whereas the 5-foot size has been observed to show pressure rise until snow settling becomes a very small, less than one inch per day. These observations possibly could provide some information as to stabilization of the snow.

The pressure pillow has demonstrated its capability of indicating snow rates as low as about 0.03 inch per hour. As compared with conventional precipitation gages, the pillow gives a more accurate indication of the true rate because of its greater "catch efficiency." Installation of the pressure pillow must, of course, be in an area where the snow will collect and not be subject to strong winds.

FIG. V

MT. HOOD TEST DATA



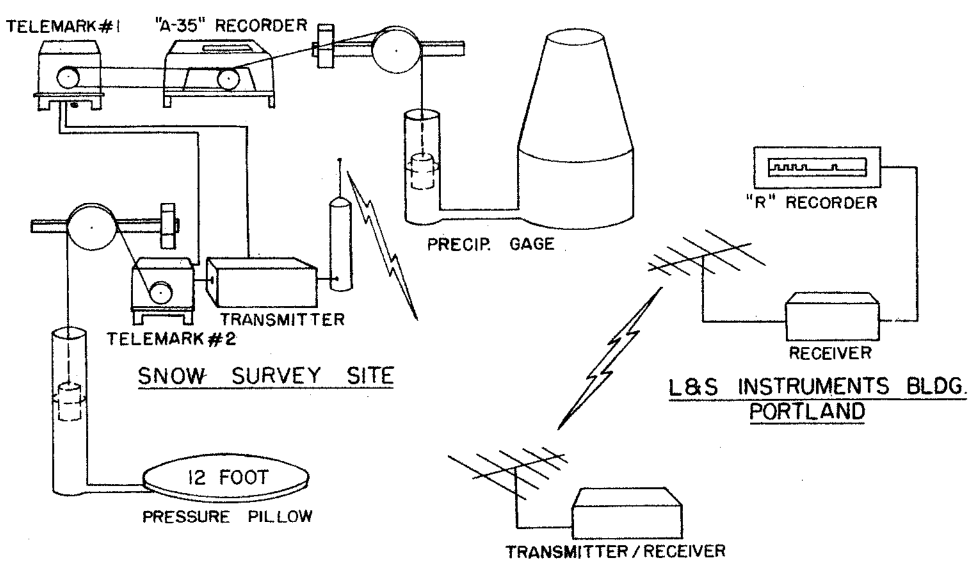


FIG. VI

DIAGRAM - MT. HOOD PRECIPITATION & PRESSURE PILLOW SNOW GAGES

1963-64

CONCLUSIONS

A pressure pillow of the 12-foot size has demonstrated in two winters at two locations in the western United States that it can provide an accurate measure of the equivalent water content of the snow.

With suitable equipment a signal can be produced which is easy to adapt to telemetry.

The response time of the pressure pillow to the initiation of new snow is a matter of minutes and appears to be independent of original depth of snow.

Rates as low as 0.03 inch per hour have been observed on the pressure pillow and confirmed by separate means.

Additional studies of the data and further tests of pillow designs and transmission equipment will be necessary before a standard automatic snow water equivalent sensing and transmitting device can be recommended. However, there is now every indication that this will be a practical device for collecting snow water equivalent data on an operational basis.

REFERENCES

(1) Warnick, C. C. and Penton, V. E.: Methods for Automatic Measurements of Snow Water Content to Predict Water Supply. Final Report, University of Idaho, Moscow, Idaho, 1963.

(2) Work, R. A., Stockwell, Homer J., Freeman, T. G. and Beaumont, R. T.: Accuracy of Field Snow Surveys in Western United States, Including Alaska. Report to U. S. Army Cold Regions Research and Engineering Laboratory at Hanover, N. H., 1964.

LIST OF FIGURES

LIST OF TABLES