AUTOMATIC MEASUREMENT OF HYDROLOGIC PARAMETERS AT REMOTE LOCATIONS

By

L. M. Maxwell, C. C. Warnick, L. A. Beattie, G. G. Hespelt 1/

INTRODUCTION

In this age of automation it is natural for those who have journeyed by skis to a distance snow course to turn attention to an automatic means of telemetering the needed data from a remote location.

Earliest attempts to transmit snow data appear to be the efforts of the Corps of Engineers[1] in the Cooperative Snow Investigations at the Central Sierra Snow Laboratory. This was the work of Gerdel and Hanson[2] in the 1948-49 snow season, using a radioisotope snow gage that transmitted information to a standard radio receiver at Sacramento from the Central Sierra Snow Laboratory near Soda Springs, California, a distance of 70 airline miles. The tests utilized a frequency of 2350 kc and used both an "on call" and a "program schedule" system. Since that time much developmental work has been done on this system by the Corps of Engineers. The Bureau of Reclamation[3] have developed a radio-reporting rain and snow gage in Northern California for use in operating the releases from Shasta Dam. This used a mechanical weighing system to indicate the precipitation collected in a gage. This weight measurement was keyed to give an electronic signal and operated on an "on call" basis. The Japanese[4] likewise have developed a radioisotope snow gage for indicating water content of a snow pack. It is similar in design to the Corps of Engineers' gage except the counter is buried beneath the snow pack and the isotope is suspended above the snow pack. The Russians[5] are also known to have been experimenting with telemetering such data.

PURPOSE AND JUSTIFICATION

The purpose of a hydrologic telemetering system as discussed in this paper is to provide data on snow-melt runoff parameters from remote mountain locations at frequent intervals and at sites where such information is pertinent to operating reservoirs for controlling floods, irrigation releases and power production scheduling. This purpose should be governed by three items: (1) reliability (2) coverage (3) cost.

Justification for this program comes from the fact that in fifty years of snow surveying there has come about a very active use of the data and yet coverage has been limited in many cases due to the remoteness of the desired stations. Costs for manually making snow surveys have steadily increased. Need for more frequent measurements has been demonstrated and the use of other parameters such as soil moisture contents have been initiated to bring about better and better accuracies of the forecasts. This coupled with the fact that each year as more dams are built and use of the water resource becomes more intensive there is greater demand for an up-to-the-minute record of the parameters that control the flow characteristics of the stream.

The Engineering Experiment Station at the University of Idaho became interested in this problem through its cooperative work on studies of shielding of storage type precipitation gages and also investigations dealing with capping of precipitation gages. Active interest in the automatic measurement started with informal meetings at Bozeman at the time of the Western Snow Conference in 1958. Since then the encouragement and discussions with representatives of various federal agencies and private utility personnel has led to the present program referred to as Special Research Project 61.

MEASUREMENT PARAMETERS

Study and discussion with various groups led to the initial selection of the following parameters to be measured and reported:

1. Total accumulated precipitation
2. Water content of the snow pack
3. Air temperature
4. Snow quality (wetness)
5. Soil moisture condition
6. Snow depth

1/ Engineering Experiment Station, University of Idaho, Moscow, Idaho.

The accumulated precipitation was chosen because it represents the overall source component that will influence runoff and flood magnitude. This is used in most hydrologic forecasts as the base or beginning parameter. Water content of the snow has long been recognized as the key factor in volume runoff forecasts because it represents the potential water in surface storage available for runoff at a given time. In recent years many studies have correlated runoff with air temperature degree-day values as a parameter indicating snowmelt runoff relationships. Up to the present most of the correlations have been made on the available air temperature data at valley stations. It is therefore reasonable to hope that air temperature from the remote locations where actual snow melting is occurring will be a valuable parameter in snowmelt-runoff forecasting techniques. The snow quality measurement is a parameter indicating the free water content of the snow and is directly related to the ripeness of the snow pack. Technically it is percent by weight of the snow which is ice. This should give a good indication of the progress of the accumulating and melting processes in the snow pack as time elapses during any snow season.

Soil moisture measurements are already being made at various sites to provide information on the antecedent moisture conditions and a term for considering the magnitude of water in groundwater storage. This then, is a direct measure of the groundwater recharge conditions. The snow depth parameter has been measured for many years and when combined with the water content of the snow gives a snow density value. Because of the difficulties of measuring this, present plans call for dropping this as a measured parameter and replacing it with an additional temperature measurement. Such a temperature measurement could be made in the snow pack, at the soil-snow interface, or within the soil itself.

Regarding the sensitivity of the above measurements a few preliminary remarks would seem appropriate. Hypothetically, a system which measures only one or two runoff parameters will require a fairly high degree of accuracy. In contrast if six measurements of various influencing parameters are measured it would be expected that there would be some correlation between some of the measurements, and therefore, lack of accuracy in one measurement would tend to be compensated for by knowledge of related conditions. For example, if it is known that snow depth and water content in the snow pack are decreasing at a rate exceeding expected evaporation rates and that air temperatures were considerably above freezing, then one can be reasonably well assured that he knows much about the snow wetness without measuring it. For this case a snow quality (wetness) measurement would probably not be justified. However in the case of a relatively slow decrease in snow depth and a decrease in accumulated snow moisture, the condition of the snow wetness would be uncertain without a measurement since evaporation might account for the decreases noted. Snow wetness, on the other hand, does not necessarily indicate anything about run-off since it does not show whether the snow is simply holding the moisture or whether there is a flow of moisture through the pack. Similar considerations hold in relation to other combinations of the six measurements listed above.

Because of the inherent correlation between many of the measurements, it has been decided to use past experience in establishing the sensitivities of the various measurements. Some of the measurements are relatively basic and independent of the other quantities. In these areas measurements are proposed with appreciable accuracy. However, some of the measurements, for the most part, give what might be termed supporting data; here the choice has been made to realize a good indication of a condition without incurring the high cost which is associated with accuracy. Moreover, for all the measurements there is some question whether a high degree of accuracy is really pertinent since the measuring device is located at only a discrete point in the snow pack and may not represent an average condition to better than 10 or 20 percent error. Finally, wherever accuracy can be realized at moderate cost it has been decided to do so, but where accuracy implies high cost and the quantity measured is of lesser importance, then only rough indications are proposed.

GENERAL TECHNICAL DESCRIPTION

In essence a complete pictorial description is made of the system in Figure 1. When the entire system is completed there will be several remote stations and one master station. The remote stations will operate on an "on-call" basis, each remote station being capable of being placed into operation by a transmitted code sent from the master station. Upon being placed into operation the remote station will transmit to the master station information concerning the parameters being measured at that station. The operator at the master station will then read out and record the information which is displayed by means of time delayed pulses as presented on an oscilloscope.

In order to implement a trouble free equipment, all of the electronic circuitry at the remote station is transistorized and a minimum of moving mechanical components are employed in the measuring apparatus. The transistorization also makes it more feasible to supply all of the power necessary for the station operation by means of storage batteries. Since the transistor uses considerably less power than its counterpart, the vacuum tube, it makes it very much more possible to have the remote stations completely battery operated over the full nine-month period, while they are unattended.

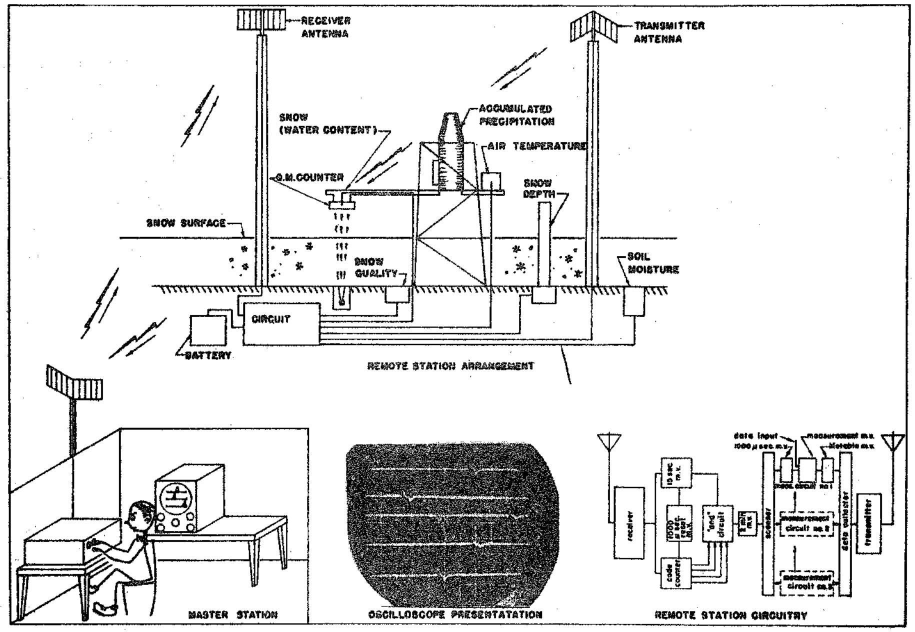

Figure 1. Schematic diagram of overall hydrologic telemetering system

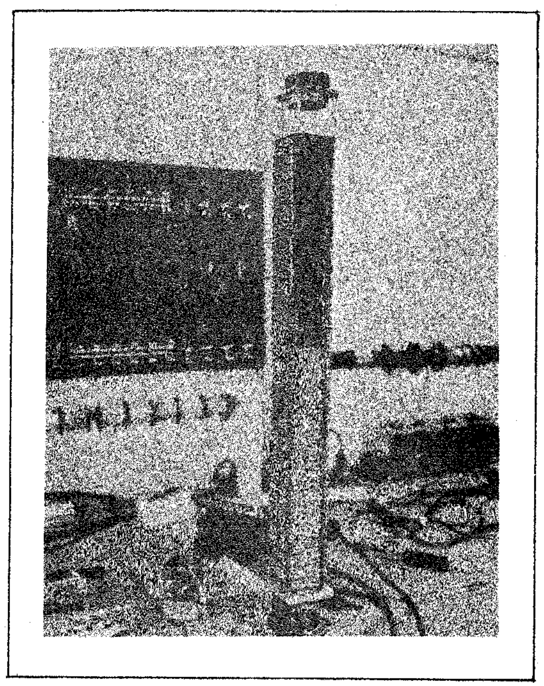

Figure 2. Construction detailed view of resistance rod for automatic precipitation gage

TRANSMISSION OF SIGNAL

The carrier frequency of the transmitters used in the system will be in the neighborhood of 172 megacycles. This is in one of the frequency ranges allocated by the Federal Communications Commission for this type of telemetry work. The carrier will be pulse modulated, each pulse length being determined by one of the measurement circuits. There are two main features of this type of system which serve greatly to enhance its reliability. First, since the transmitted information is contained only in the pulse position and not its amplitude there will be little chance that atmosphere disturbances will cause complete interference of its reception. Also, the entire set of measuring circuits is scanned at a rate of 15 times a second, for a total period of two minutes while the remote station is transmitting. This means that on the read-out oscilloscope at the master station every pulse is flashed on the screen 15 times a second, so if a few of these pulses were somehow interrupted or garbled for part of a second or even a few seconds, there would still be much time for the correct information to be received. Considering the above advantage it is felt that in this type of telemetering system that the above mentioned form of pulse modulation offers distinct advantages over amplitude or phase modulation.

MEASUREMENT TECHNIQUES

Four of the parameters (total accumulated precipitation, air temperature, snow quality, and soil moisture) are measured by electrical resistance methods.

The amount of total accumulated precipitation is detected by having the water short out resistances which are mounted on a rod placed in the precipitation storage tank. Figure 2 shows the construction of this rod, which is merely a column of aluminum laminations that are the electrodes that become shorted by the water in the precipitation storage tank. As the precipitation increases, so does the height of water in the tank and more of the resistance rod becomes shorted. The resistors of the resistance rod are placed in a circuit such that when one of the resistors becomes shorted a change is produced in the pulse length of a multivibrator (electronic switch) associated with this particular measurement. This shift in pulse length produces a corresponding shift of location of the precipitation pip as observed by the master station operator. By means of this method it is believed that total precipitation can be measured to the nearest two-tenths of an inch.

The air temperature measurement is made by detecting the resistance of a thermistor, a device whose resistance is extremely sensitive to temperature changes. This change of resistance is likewise converted into a change of pulse length and is read out by the master station operator in the same way as the precipitation measurement. The accuracy of this measurement varies for different temperature ranges; however, preliminary tests indicate that temperature in the ranges of 20 to 40 degrees F can be read to the nearest degree.

The snow quality (wetness) measurement is made by merely detecting the resistance of a quantity of snow accumulated between a set of parallel plates made of materials which are noncorrosive and also good conductors. The resistance between the plates is a function of the snow quality or free water to ice ratio of the surrounding snow pack. Because of other factors involved, this measurement will yield more or less only qualitative results which will enable the operator to classify the snow quality condition as either wet, moist, or dry.

The soil moisture condition is determined in a way very much like the snow quality and likewise the same qualitative results produced. A Bouyoucos soil moisture resistance block is employed in the circuit so as to produce a change in pulse length produced by a change in the resistance of the block which in turn is a function of the wetness of the soil. Again, a wet, moist, or dry condition is to be observed by the operator.

The water content in the snow pack is to be measured by using the already existing method of a radioactive source and a G M counter. The amount of moisture between the source and the counter affects the counting rate of the counter tube. This counting rate of the G M counter is transferred into pulse length form and this measurement is displayed like all of the others. A new study separately supported by a contract from the Agricultural Research Service is considering new methods of measuring snow water content and it is hoped that this may provide a simpler and less expensive means of obtaining this key measurement.

The snow depth measurement is the only one to have incorporated a mechanical system. A photo cell mounted on a motor driven chain senses either the presence or absence of light and correspondingly dictates to the assembly so as to position itself at the top of the snow pack. A potentiometer mechanically fixed to the chain then indicates, again by the resistance method, the location of the photo cell, and

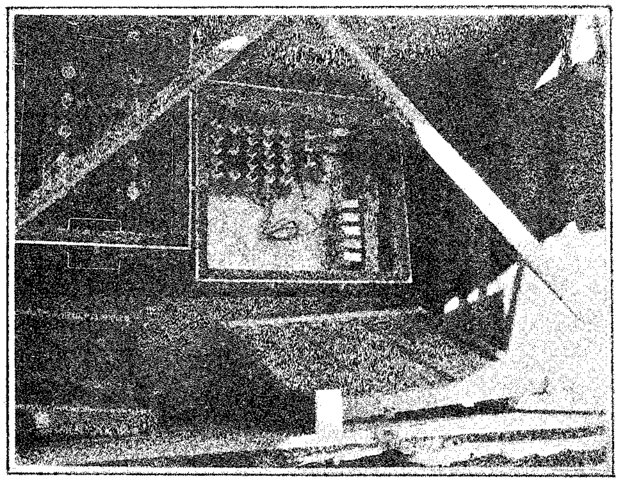

Figure 3. Battery box and remote station measurement circuitry prior to sealing beneath ground surface

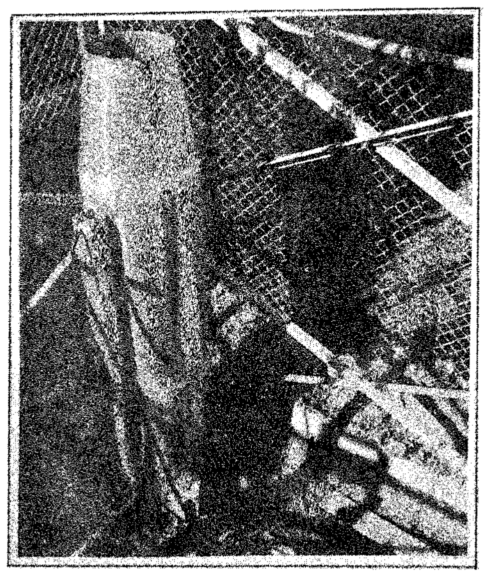

Figure 4. Prototype precipitation gage showing location of resistant component

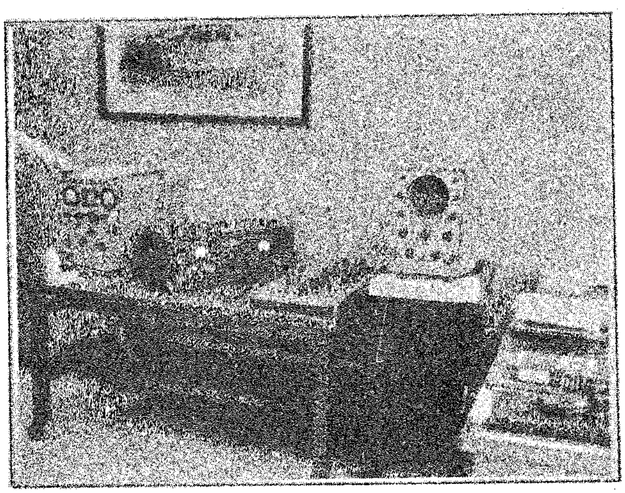

Figure 5. Picture of monitoring circuitry and oscilliscope showing time delay pulse train

thus the height of the snow pack is determined. A plus or minus two inch accuracy is expected of this measurement. Recent discussion concerning the snow depth measurement have indicated that this may not be an essential or desirable part of the system. At this time further work is not being conducted on this measurement and this will not be included as one of the measurements in the prototype system.

A far more detailed discussion of the above measuring circuits may be found in other published reports of the Engineering Experiment Station[6, 7 and 8]. At the present time the University has authorized patent searches to be made in regards to more than twenty of the designs involved with the above mentioned report.

The system design has been kept flexible enough so that a total of ten different measurements may be made and transmitted from the site of the remote station. New or different measurements may be added with relative ease after the system is placed in operation.

PRESENT STATUS OF THE PROJECT

At the present time the parts of the system which are in operation include; the total precipitation measuring circuit, the air temperature measuring circuit, the snow quality measuring circuit, the scanning circuit, and the oscilloscope sweeping circuit.

In order to simulate remote location operating conditions the remote station equipment has been placed outside the laboratory. The batteries and electronic circuitry have been buried in the ground. Figures 3 and 4 are pictures of this installation. Wires carry the measurement information inside to the simulated receiving station. See Figure 5. The installation has been in operation two months to date and while all calibrations have not been completed there has been no equipment failures.

Three project personnel have received first class radio operators licenses from the Federal Communication Commission and work has been started on design and construction of the transmitters and receivers. As soon as the transmitter design is completed an application will be made for station licenses.

Depending on the availability of funds it is hoped that necessary equipment soon can be ordered for the installation of the water content in the snow pack measurement. Further study is now in progress on possibilities of adapting new methods to measuring water content of the snow. Suggested approaches under consideration are:

1. Pressure pillow to weigh snow
2. Deformation of a diaphram to weigh snow
3. Precipitation gage and calibrated soil moisture to get residual
4. Capacitance or resistance of snow
5. Ultrasonic measurements
6. Attenuation of infra-red rays or some form of heat energy
7. Attenuation of a radioisotope emission

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All project work has been carried out under the direction of Dean A. S. Janssen as Director of the Engineering Experiment Station.

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