RADIOACTIVE SNOW GAGE
WITH TELEMETERING SYSTEM

by

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Dr. Gerdel has described the basic principles upon which the radioactive snow gage is founded. We like to describe our role in this project as that of the engineering group who has taken the basic idea conceived by Dr. Gerdel and his scientists and out of it built practical tools that can be used whenever and wherever required to give dependable and accurate data for the forecasters.

TELEMETERING SYSTEM

To form a useful system, the information from many gaging stations must be transmitted to a central collecting station, which might be far removed from the data transmitting sites. Further, these sites, by their nature, are at locations inaccessible to pole line facilities. Radio is the only practical medium for transmitting the data to the recording station.

To provide simplicity, a one-way radio system is used, in which data stations are actuated according to a definite program, controlled by a time clock at each station.

Referring to the calibration curve (Fig. 1) obtained from a typical station, it is apparent that a count rate as high as 20,000 per minute, or as low as 120 per minute (background rate), must be transmitted. Since the lower count rates represent the maximum depth of snow cover, and since minimum count is limited by background count, it is important to study the probable error due to the random nature of the background count. This follows the well-known distribution of random events where the maximum deviation, $D = \sqrt{N}$. Thus a maximum deviation of 11 counts might be expected with a background count of 120 cpm. It is further obvious that a longer counting period would improve the accuracy of reading. Using 5 minutes as a counting period, $D = \sqrt{600/5}$ or 4.9 counts per minute. A 5-minute counting period has been chosen as a practical compromise between the number of stations to be handled in a given period of time, and the probable error incurred due to the random nature of the quantity.

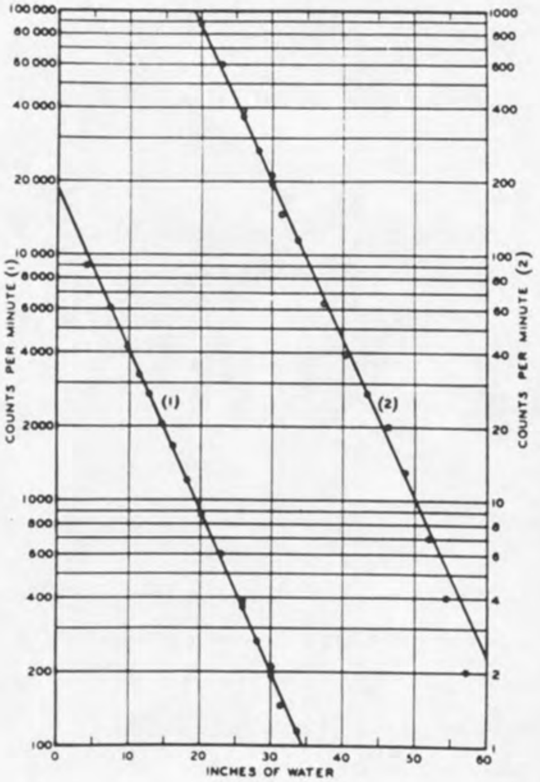


Fig. 1

Calibration of radio-active Snow Gage.

The bandwidth required of the transmission system is directly proportional to the rate of data transmission. However, the noise power affecting the system is also proportional to the system bandwidth. It is highly desirable, therefore, to reduce the bandwidth of the system to a minimum, provided that this reduction does not incur an intolerable error in the reading.

In the data transmission system chosen, an audio sub-carrier is used to frequency-modulate an r-f carrier in the 169-173 mc range. The frequency of the audio sub-carrier is shifted from its nominal value to a second value by the first count signal from the G-M tube. The next count shifts it back to its original value. Each count is identified as a point in time when received at the recording station. However, the average frequency of "modulation" of the audio sub-carrier is only half the count rate.

If a further division by 2 is incorporated, using a conventional divider circuit, an error of +0 to -1 count is incurred. Additional dividers can be used, with the following errors being incurred.

Division by	Maximum errors in count	Maximum error in count rate (5-min. period)
2	— 1	— .2 cpm
4	— 3	— .6 cpm
8	— 7	—1.4 cpm
16	—15	—3.0 cpm
32	—31	—6.2 cpm

It should be noted that the error incurred by the use of dividers is an error in basic count. When taken over a 5-minute period, the maximum error in counts per minute is only one-fifth of the basic count error as shown above.

Since the quantity being measured was previously to have a possible error of 4.9 counts per minute (at minimum counting rate), it is practical to divide the basic count rate by 8, and incur a maximum error that is small compared with the uncertainty already existing.

Let us now examine the bandwidth required of the transmitting system. The maximum expected average count rate of 20,000 cpm is equivalent to 333 counts per second. However, with currently available Geiger-Mueller tubes having a dead time of 150 microseconds, the maximum frequency of pulses could be as high as 6667 per second. Since two pulses are required to provide a full cycle of frequency shift modulation, this is equivalent to 3,333 cycles per second. A further division by 8 reduces the requirement to 416 cycles per second.

The bandwidth required to transmit this modulation width is generally taken as 2.3 times the highest modulating frequency. Thus a 1,000 cycle wide system would provide practical operation.

The system used is equivalent to a double frequency-modulation system. The signal-to-noise improvement factor in this system is represented by the relation:

$$F = \sqrt{3/2} \quad (D_1/fm) \quad (D_2/f_{sc})$$

In the data transmission system just described, this signal-to-noise ratio improvement is set at 12 db over an equivalent amplitude-modulated system.

The use of audio-frequency sub-carriers has two more important attributes. In a practical-snow-gaging system, many stations are spread over a wide area. Repeater stations are required to collect and transmit the signals on to the recording station. Simultaneous reception at a repeater station of two or more data transmitting stations is possible through the use of multiple receivers on separate r-f carrier frequencies. If the audio sub-carriers of these several stations are at different selected points in the audio spectrum, then the audio signals may be combined and sent to the recording station simultaneously on a single r-f circuit. At the recording station, separate decoding equipments, one operating at each of the audio sub-carrier frequencies, will provide simultaneous records of the data. This greatly simplifies the radio network needed to handle large volumes of data in a given period.

The second very important need for the audio-frequency sub-carrier is that it can be transmitted through one or more repeater stations without demodulation and, therefore, without materially affecting its signal-to-noise ratio, and without affecting in any way the accuracy of the reading which it is carrying.

In a typical Data Station (Fig. 2) pulses from the Geiger-Mueller tube are amplified in a pre-amplifier contained in the G-M tube housing. In the main housing, the pulse rate is divided by 8 and the resulting pulses used are to frequency-modulate the audio oscillator which generates the sub-carrier frequency. This modulated sub-carrier is used to frequency-modulate the radio transmitter shown as the top unit in this main housing.

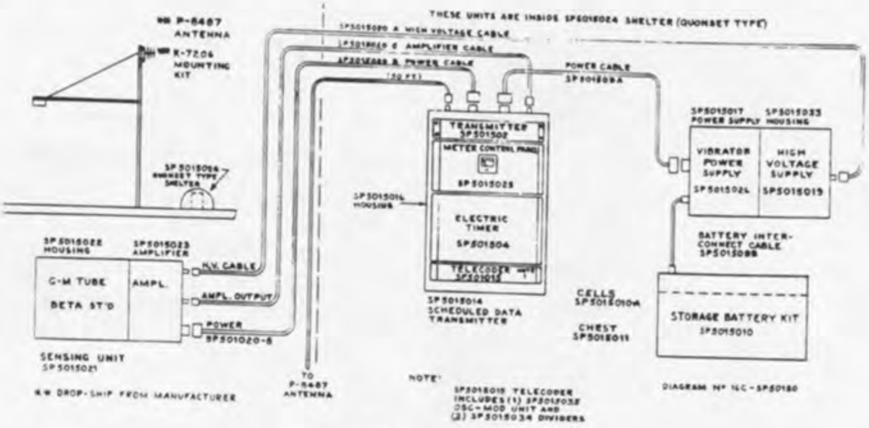


Fig. 2

Block diagram of scheduled data transmitting station for radio-active snow gage.

The station is turned on for 5 minutes each day by a specially-designed electric time switch. This is really a jewelled, highly accurate, spring-driven movement wherein the spring is wound by a small electric motor about once each day. Temperature compensation has been included in this clock for operation as low as -50 degrees C.

Long-life batteries are used to supply the high potential for the G-M tube. It is expected that these will be changed once each year. All other elements of the station obtain their primary power from a nickel-cadmium storage battery which will be described later.

The elements of a sensing unit are the G-M tube, the pre-amplifier, and the Beta-standard, which, with its movable shutter, is located just above the G-M Tube.

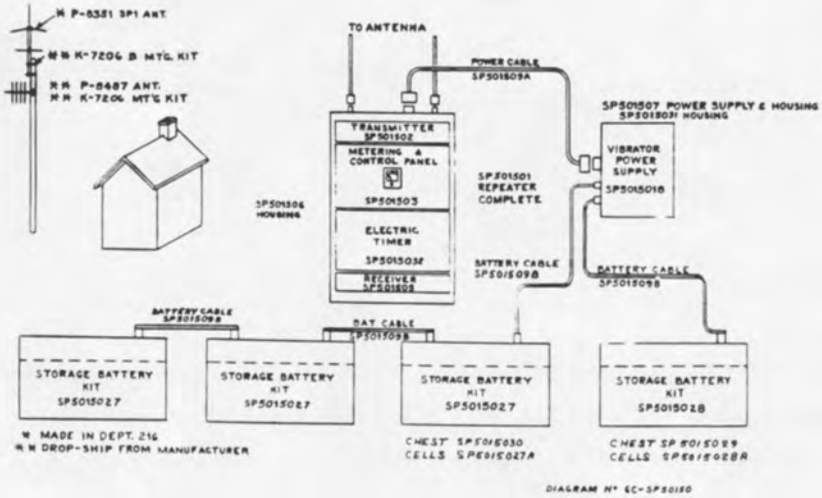


Fig. 3

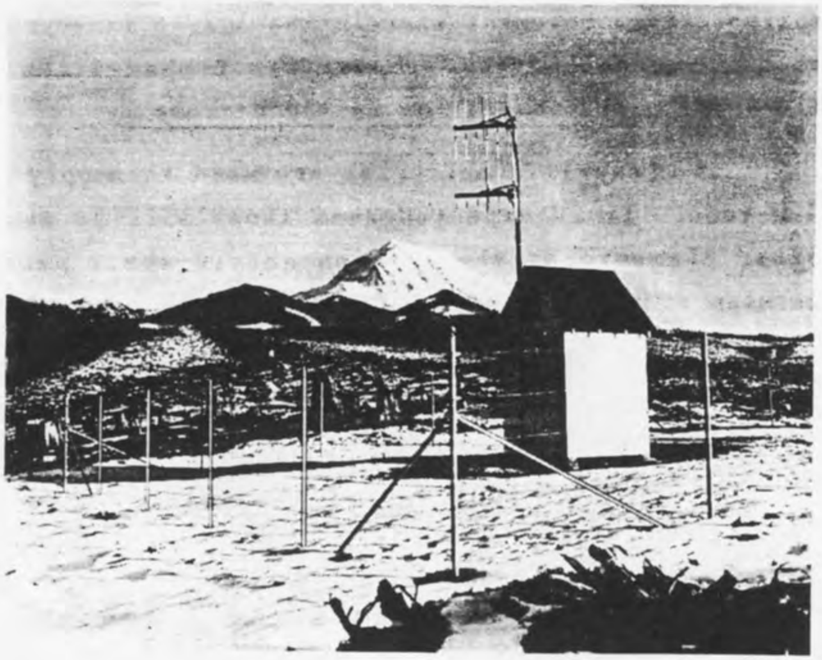
Block diagram of automatic repeater station for radio-active snow gage.

The main housing of the repeater station (Fig. 3) contains the transmitter, receiver and electric time switch. The time switch is set to turn a station on for the entire length of time that any of the Data Stations may be reporting. If the duty cycle of a station is high, several storage batteries are needed to provide an adequate power source.

At a typical repeater station (Fig. 4) two antennas are required, one for transmitting and one for receiving.

Fig. 4

Typical repeater station located on mountain for receiving signals from several radio-active snow-gage stations and sending them on to recording station.



STATION EQUIPMENT

When designing equipment for transmission of meteorological data, the system and components must be designed with the aim of providing the most dependable system possible, within the limitations imposed by the physical location of the station. Of major importance is the primary power source, since it will materially affect the circuit designs, transmitter power outputs and operating programs.

In this system, the nickel-cadmium storage battery was chosen, because of its freedom from self-discharge, and its effectiveness (Fig. 5) at low temperatures. This battery shows 70% of nominal capacity at -20°F, while a charge-retaining type of lead battery shows 50%, and a vehicular type lead battery less than 20%. The latter type would also be useless because of its self-discharge characteristic.

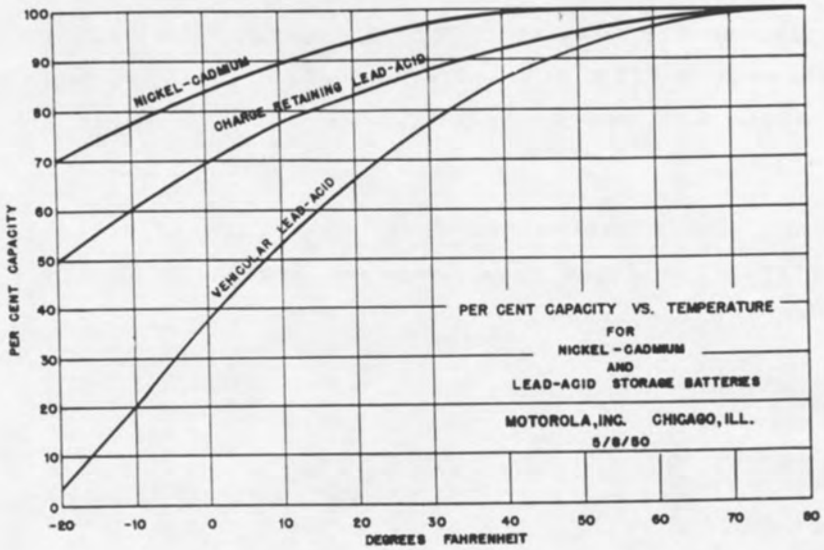


Fig. 5

Effective capacity versus temperature of several types of storage batteries.

Miniature Quonset-type shelters are provided for each of the stations. These are rugged enough to stand the elements, and attacks by brown bears and other animals. The G-M tube and Beta standard are mounted at the end of a Hubbard truss arm. The arm is mounted on a standard telephone pole (Fig. 6) which also mounts the antenna.

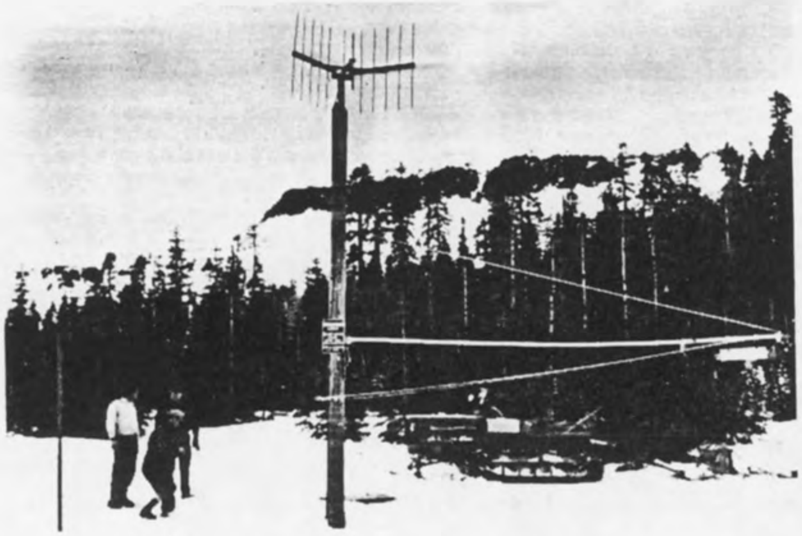


Fig. 6

A Field Station showing the Pole and Hubbard Truss Arm for supporting the Geiger Tube.

Antennas of both directional and non-directional types are used. All are ruggedized to stand the severe torture of the elements. The battery-operated transmitters and repeaters (Fig. 7) are mounted in small stainless steel cases, which themselves are weather proof. Power is brought in through gasketed glands.

In the units, individual sections as oscillators, dividers, transmitter and receiver stages and the time switches are individually removable for easy servicing in the field.

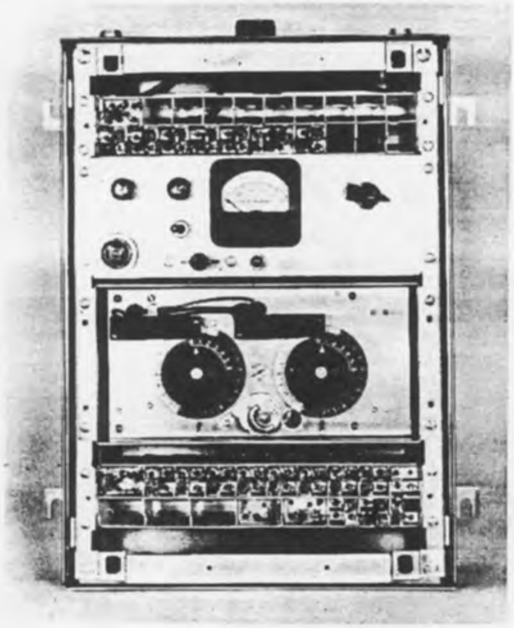


Fig. 7

Complete Repeater Station. Units from top to bottom: (1) Transmitter, (2) Control and Meter Panel, (3) Time-switch, (4) F-M receiver.

Storage batteries and power supplies are mounted in wooden chests, allowing easy handling for recharging. It is expected, however, that recharging will be done "on location" during summer months by gasoline driven charging equipment mounted on a Jeep. Battery capacity is sufficient for 9 months of operation of the stations at the program schedules described earlier.

At the Recording Station (Fig. 8), data are taken in terms of counts over a 5-minute period using a conventional scaler-divider and an accurate time clock. These data need only be multiplied by the division factor of the system and referred to the calibration data for the station to obtain water equivalent of the snow pack.

The Recording Station equipment includes the receiver and the tele-decoder which selects and receives the audio sub-carrier and detects the modulation put on it by Data Station. Both units have a separate power supply.

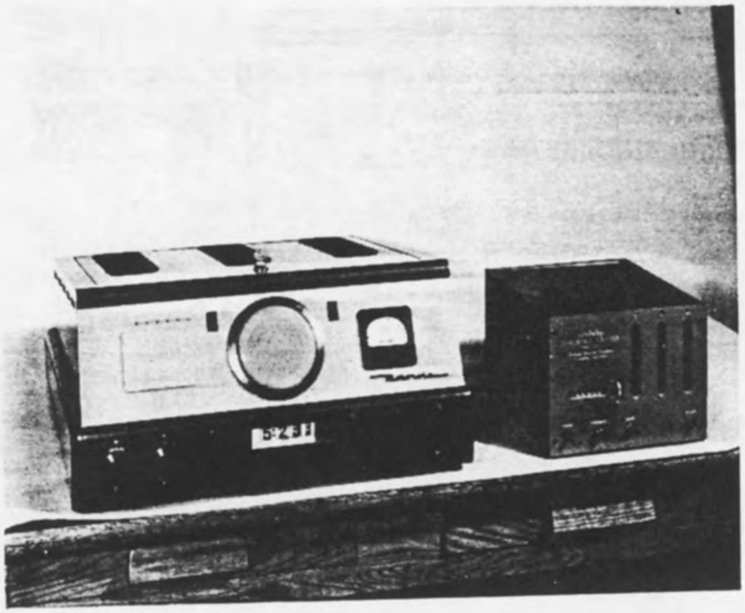


Fig. 8

Complete Recording Station.

FUTURE DEVELOPMENT

Future aims of this project are in the direction of providing more accurate data at a faster rate.

First, the use of scintillation detectors will provide a great improvement in efficiency and resolution of the sensing device. Counting efficiencies of 50% and a dead time of less than a microsecond can be obtained, as compared to the currently used in self-quenching Geiger-Mueller tube with an efficiency of 1/2% and a dead time of 150 microseconds.

Evaluation of the data at the field station will allow transmission of a quantity representing only the count rate, rather than the actual count. This will greatly shorten the time required to obtain data from a given station. In addition, it will make automatic recording possible, precluding the need for an operator to be constantly monitoring the system.