AN ECONOMICAL TOTAL-PRECIPITATION TELEMETERING SYSTEM

Progress Report *

By

Duane G. Chadwick[1] and Gregory L. Pearson[2]

Introduction

During the winter of 1960-61, the authors discussed the possibility of using radio signals for weighing the accumulated total precipitation at the various remote mountain raingage sites of the Soil Conservation Service in Utah. In the interest of economy, the system was to be devised so the gages could be read from an airplane.

Since that time, a total precipitation telemetering system has been designed. Successful tests on this system have been conducted for the past two years, and they are now ready for use on a larger scale.

Two main requirements for a reliable total precipitation telemetering system are: First, the mechanical catchment device must be durable and reliable in making a representative precipitation catch; and second, the electro-mechanical transducer and composite telemetering system must be reliable and perform its duties unattended under the severest of environmental conditions. The requirement concerning the catchment device has largely been met for areas where snowfall conditions are similar to those encountered in Utah. Results of the work done in Utah have been reported elsewhere.[3] The electro-mechanical transducer telemetering system used on the catchment device has a shorter history of operational success than the catchment device, since the units of the type described in this paper were first installed in the fall of 1962. Since that time they have operated successfully without electronic malfunction.

The system, shown in Figure 1, incorporates the use of a shielded precipitation can, electro-mechanical transducer, electronics hardware, batteries, and antenna. Since essentially line-of-sight high-frequency signals will be used in mountainous regions, and as the transmitting power of the system is low, an airplane seems to be the logical "over-snow-machine" to use. Signals transmitted from the ground site can be decoded easily while flying in the airplane. There appear to be no technical reasons why a high fast-flying airplane cannot obtain hydrologic information from an entire state in a few hours. Flights in Utah would normally be made at elevations around 13,000 to 14,000 feet in order to comfortably clear or circumvent higher peaks.

Transducer

The transducer is comprised of a mechanical spring arrangement which deflects under load. This deflection actuates a resistance potentiometer. The frequency of the modulated transmitted signal is in turn proportional to the potentiometer resistance. Two types of transducers that have worked successfully are shown in Figures 2 and 3. The "buggy spring" type is essentially free of static friction. The only static friction present is that of the potentiometer. The buggy spring mechanism has the objectionable feature of bulk and a tendency to build up snow on top of the protective metal cover.

* The work reported herein was conducted by the authors under a cooperative agreement between the Utah State University and the Soil Conservation Service.

1/ Assistant Professor, Utah State University, Logan, Utah.

2/ Snow Survey Supervisor, Soil Conservation Service, Salt Lake City, Utah

3/ Mountain Totalizing Precipitation Gages. Unpublished paper presented by Gregory L. Pearson at Snow Survey Supervisors Planning Conference, Fort Collins, Colorado, July 22, 1963.

In heavy-snow country, the buildup could be high enough to affect the rain can. Worthy of note, however, is the fact that no problem of snow buildup has occurred over the last two winters on three such mechanisms.

The arrangement in Figure 3 has a slight amount of friction at the bearing point near the top of the shaft. Careful alignment upon installation and use of teflon bearings reduces the friction in this configuration. A further reduction in friction is obtained by a coating of silicon resin baked onto the cylindrical shaft.

Still a third mechanical transducer configuration, which eliminates all bearing surfaces, is similar to that of Figure 3. A prototype of this frictionless type has been built and is presently being evaluated.

Transmitter

The telemetering transmitter is a low-power transistor type, operating crystal-controlled in the 170 mc region. The transmitting range can be altered considerably, but present models can be received with usable signal strength for a 6-mile radius when flying about 5,000 to 7,000 feet above the transmitter.

Transmitters presently used are operated continuously. This was done to achieve the ultimate in simplicity. Temporary authorization was granted by the Interdepartment Radio Advisory Committee (IRAC) to operate at ten locations in Utah on an experimental basis during the present year. Upon completion of this year's tests, a more permanent type of authorization will be sought.

Also under consideration is a system modification which will facilitate turning on the transmitters from an airplane. The transmitters will transmit on an on-call basis. This mode of operation has the desirable feature of conserving some battery power and eliminating transmission when they are not actually needed. This will do so, however, at some increase in overall system costs.

Antenna

A Yagi-type directional antenna was used initially to insure sufficient transmission range. Subsequent tests indicate the antenna gain is unnecessary and a simple dipole or vertical whip antenna is satisfactory. The chief advantage of these is that they are rugged and there is less opportunity for snow to build up on the antenna. The antenna can be mounted on the tower that holds the precipitation can, or on a separate pole, as shown in Figure 1 and 4.

System Stability

A question, answered partially in the results to date, concerns the stability and lifetime of the electronics hardware. After a long period of operation, will battery sag, temperature variations, and component aging cause objectionable errors? While it is too early to make a complete long-term stability analysis, results are satisfactory, as judged from data collected to the present time.

In an analog-type system, errors are ever present, at least to some extent, such is the intrinsic nature of an analog. However, two years of results show that the error in the electronic apparatus is not appreciable. The output of the transmitters installed last November is believed to be within 0.1 or 0.2 percent of what they were when installed. The error cannot be determined completely until more elaborate tests are made in the laboratory, after the snow season has ended. This is not to say that the overall system has a 0.1 percent accuracy. With the present units, error is mainly due to the static friction of the transducer and read-out resolution.

As there is essentially no physical wearing-out process, as such, in the electronic system, the lifetime of the electronics hardware is difficult to predict. It is expected that in general a number of years of continuous operation will not cause noticeable degradation of performance. The potentiometer wiper is the wearing element in the transducer which can become noisy or worn. Potentiometers having lifetimes

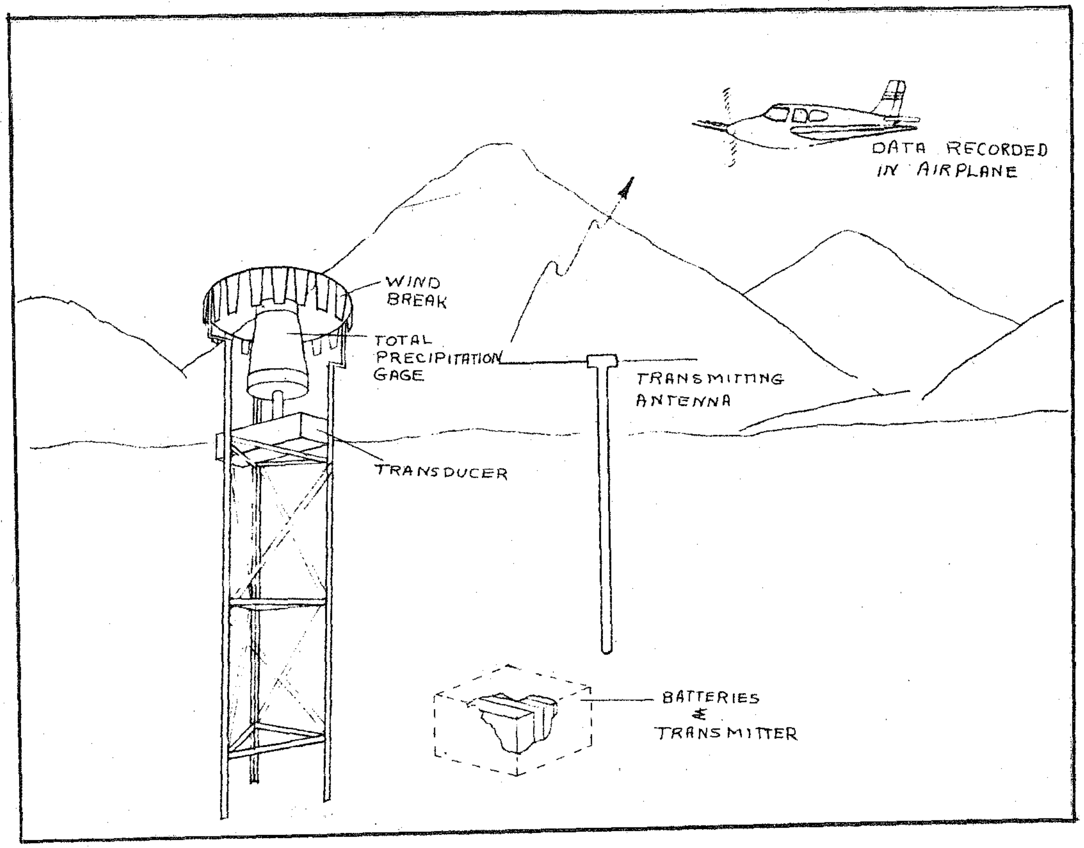

FIGURE 1. SKETCH SHOWING TOTAL PRECIPITATION TELEMETERING SYSTEM

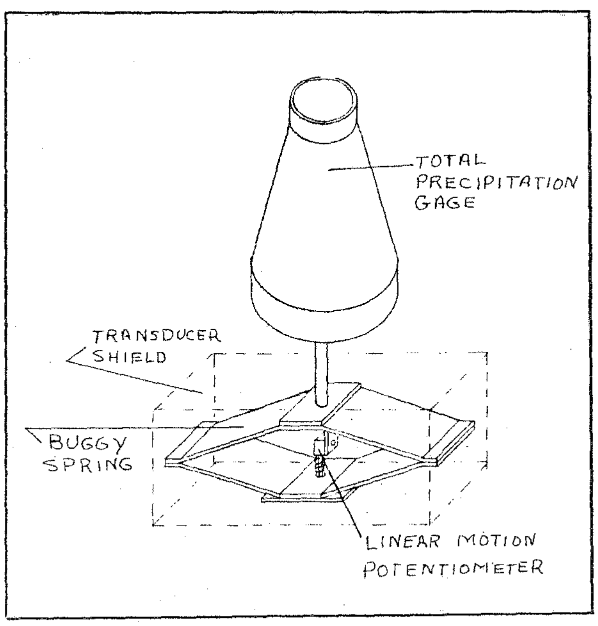

FIG. 2 TYPE OF TRANSDUCER USED AT TONY GROVE RANGER STATION

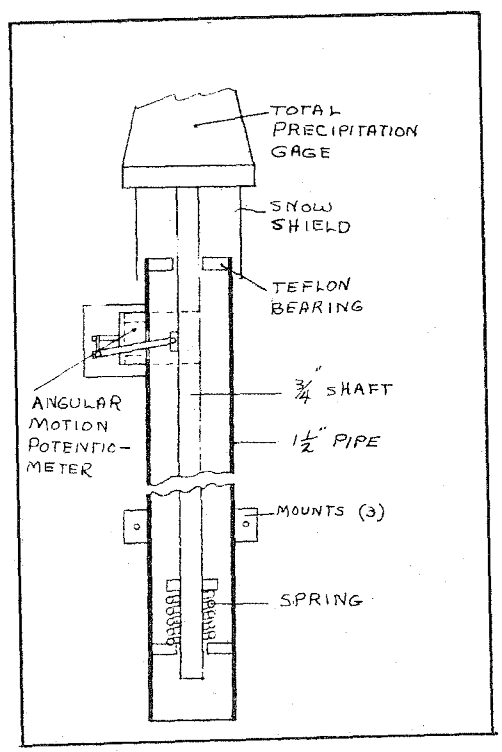

FIG. 3 TYPE OF TRANSDUCER USED AT GARDEN CITY SUMMIT

in excess of 10 million revolutions are available, however, and replacement does not pose a serious problem.

Results

The results obtained using both types of transducer units are presented in Figures 5 through 7. A large number of data points were desired for expediting determinations of hysteresis errors. Consequently, an attempt was made to crowd what might be considered years of accumulated precipitation data into the space of an hour by simply using numerous values of calibrated weights. These random valued weights were placed on the weighing platform in lieu of the precipitation can.

This type of test is perhaps unduly severe in one regard. Normally the precipitation can is centered, and a balanced load is presented to the mechanism. In this instance the weights are generally not centered and off-axis loading is present. Hence, in this type of test static friction error may be larger than that encountered under actual operating conditions. Also, since measurements were made using both increasing and decreasing values of weights, the error caused by static friction would be twice as large as normally encountered when only an increasing load is encountered, as in the actual case.

Figure 5 shows accumulated data taken at Tony Grove Ranger Station (T.G.R.S.). These data were taken over a three-month period. It has been determined that the noted change in slope was caused by battery sag in the portable read-out device. This difficulty can be readily overcome by using a battery voltage regulator. When effects of battery sag are eliminated, the data appear as shown in Figure 6.

A mechanical problem was encountered in the Garden City Summit System; consequently, it has operated undisturbed over a much shorter period of time than has the unit at Tony Grove Ranger Station (Figure 7).

The hysteresis in this unit is somewhat less than that of the Tony Grove Unit, owing to the somewhat inferior frictional properties of the linear motion potentiometer used at T.G.R.S. as opposed to a rotary motion transducer used at Garden City Summit. Preliminary results of new lab-tested equipment indicate that a modification to the Garden City Summit model will have a still lower static error band.

System Costs

One of the main objectives of this system was that it should be an "economical" system.

Within the present state of the art, this objective has been largely achieved. While actual costs to the user cannot be given in detail, estimates can be given.

The cost estimate for an "on-call" type of operation is outlined below. If permanent authorization for continuous transmission is secured, the actuating receiver at the ground, along with the airborne transmitter, would be eliminated.

Ground Equipment

Shielded tower, 100" capacity precipitation can	$115	
Transducer, transmitter, antenna	205	
Actuating receiver	45	
Batteries	7	
		$372

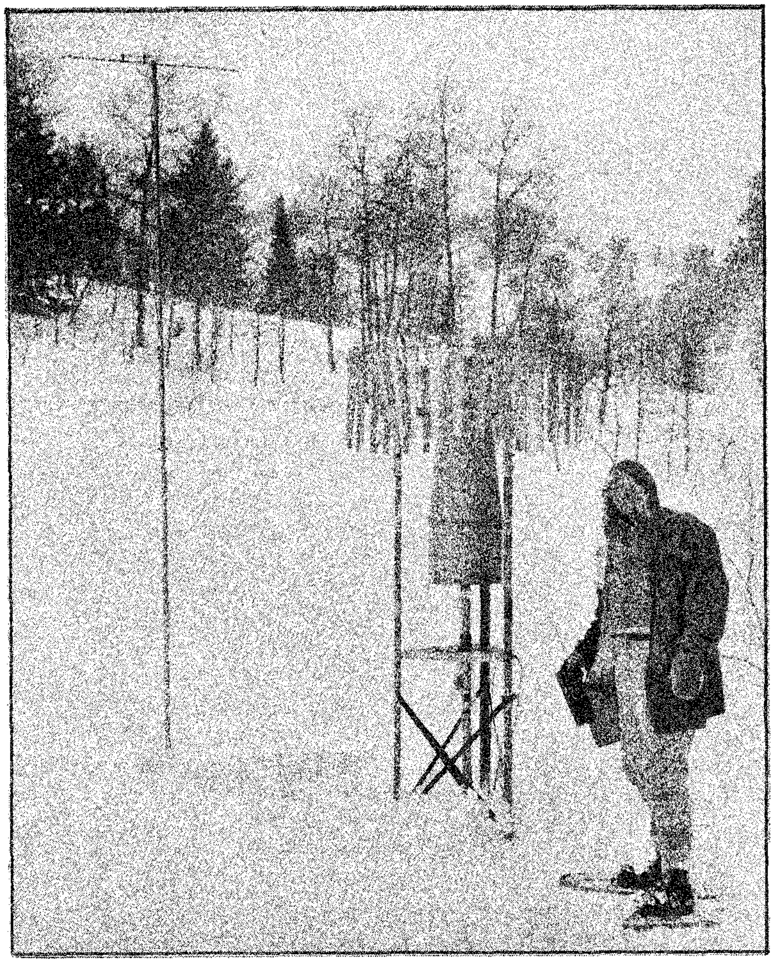

Figure 4. Telemetering rain gage located at Garden City Summit, Utah

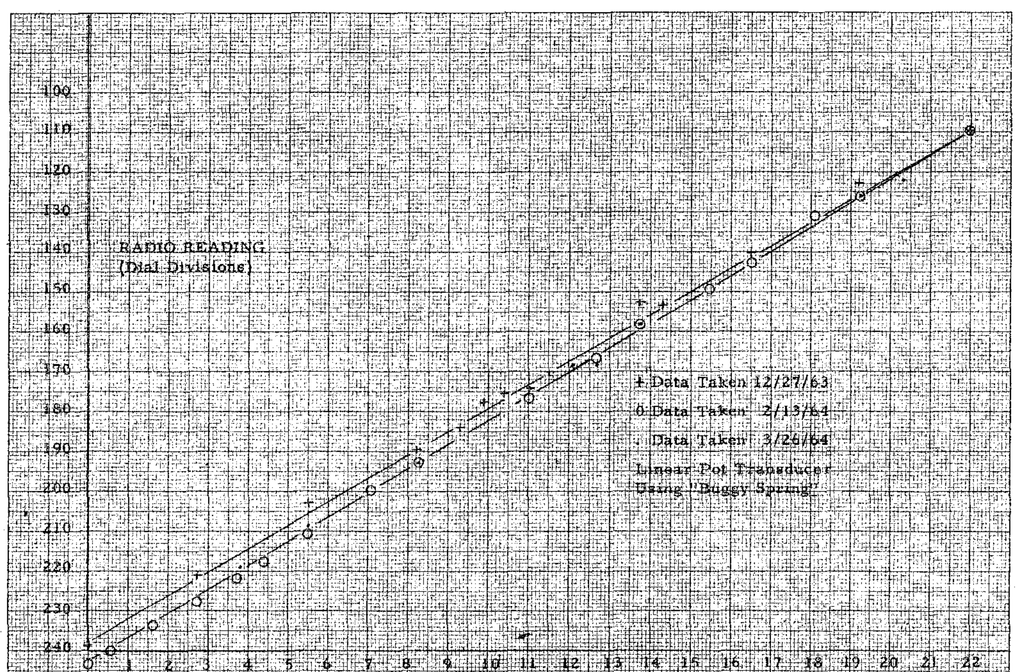

Figure 5. Radio rain gage data - uncompensated, Tony Grove Ranger Station.

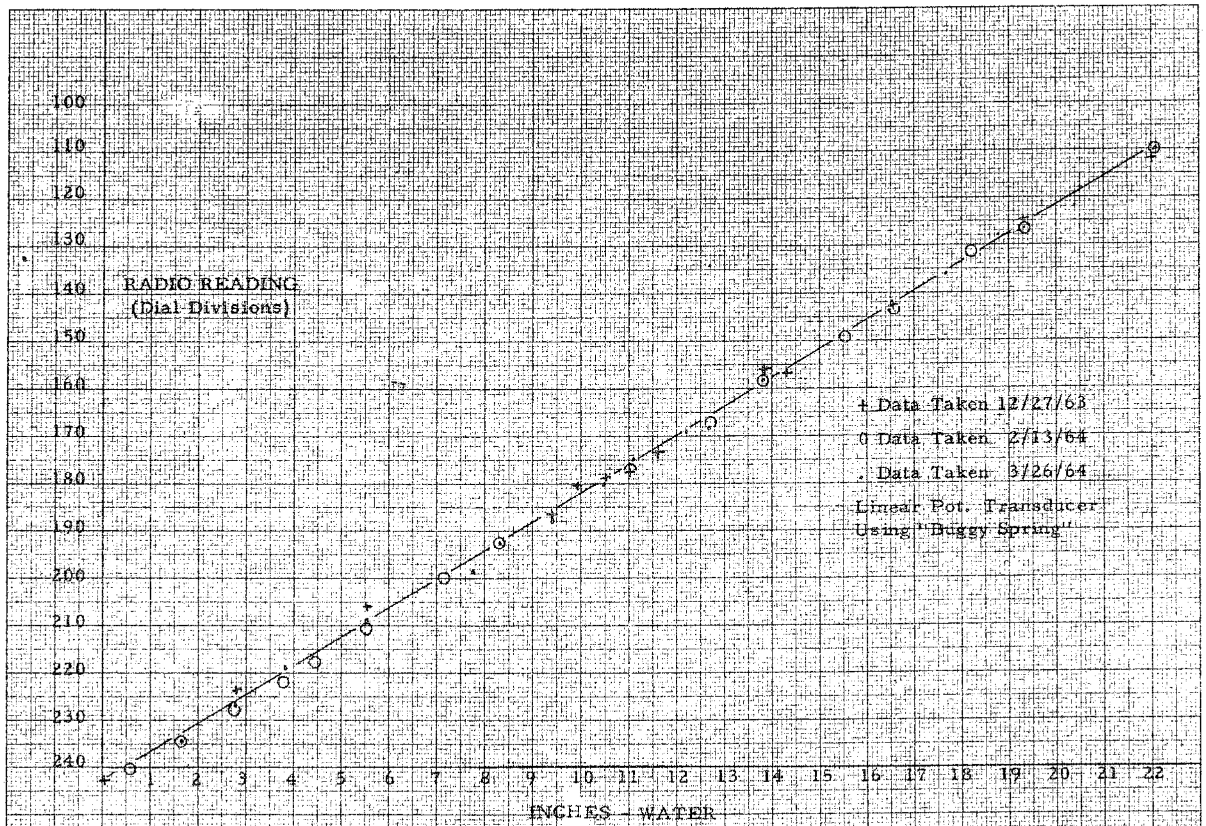

Figure 6. Radio rain gage data - compensated, Tony Grove Ranger Station.

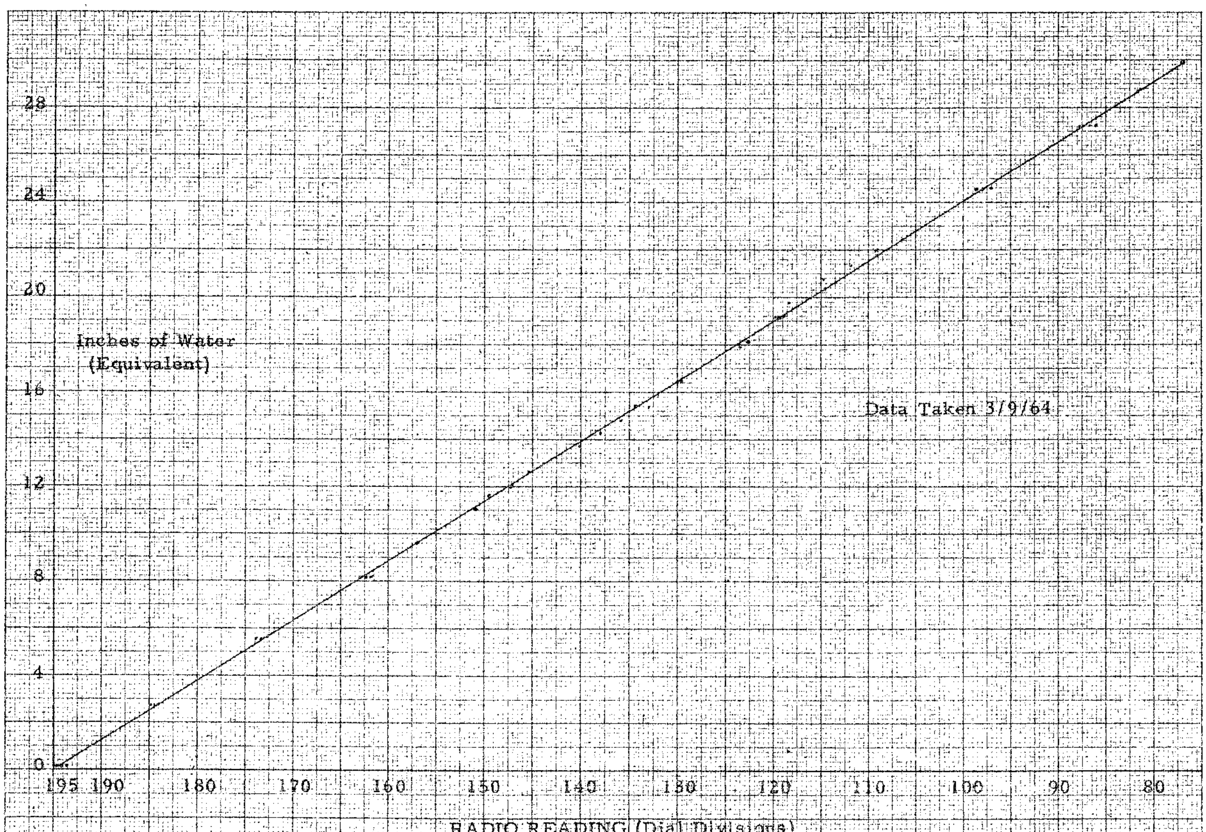

Figure 7. Radio rain gage data, Garden City Summit.

Airplane Equipment

Receiver, decoder, antenna	$295	
Power converter, transmitter	125	
		$420

Airplane rental time, including pilot - $20/hour

Conclusions

The telemetering system described above has operated successfully for a two-year period and, subject to permanent frequency approval authorized by IRAC, is operational.

The versatility of the telemetering system is such that parameters other than total precipitation can be readily telemetered, including pressure-pillow information, soil and air temperatures, etc.

System accuracy appears satisfactory. In future models a maximum error of 0.3 inches in a 30-inch-capacity system should be readily achieved. In the present form the system error is typically less than 0.5 inches. Average error over many readings should be much less than this.

The capacity of the system is not limited to any particular maximum or minimum. Generally speaking, the unit should not have excessively over-designed capacity as the general sensitivity of the system will be reduced.

Costs are such that multiple installations on a state-wide basis are possible. Most towers that are already in existence are readily adaptable, without modification, to the telemetering system. Some variation in tower configuration from that illustrated are possible, but probably not much saving could be made in tower design without sacrificing durability or capacity of the rain can.

The telemetering transmitters are simple to install. The entire system is readily calibrated in situ, which enhances its remote-area applications. Annual maintenance will consist chiefly of installing new batteries, and a routine calibration check.

The apparatus flown in the airplane is minimal and easy to use, even by the pilot if necessary. However, an observer would normally be expected to operate the airborne electronic equipment. The airplane data-gathering system does not meet every need. Use of an airplane is not practical where data are required on a daily or hourly basis. In this situation the transmitting portion of the system remains the same, but a mountaintop relay, "hard line," or possible meteor trail link could be used.

In summary, the present system as described is versatile and accurate, and we believe time will prove its reliability. The system is economical enough so that, over a period of time, it will pay for itself in savings created through reduction in manpower and equipment costs required to obtain the same data by men traveling on the ground or in helicopters. Also, it will be possible to obtain data in regions that are now inaccessible.