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Utah Water Research Laboratory

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Telemetry System Modifications and 1968-69 Operation

Duane G. Chadwick

TELEMETRY SYSTEM MODIFICATIONS
AND
1968-69 OPERATION

by

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Wasatch Weather Modification Project
Under Contract No. 14-06-D-6003
U. S. Department of the Interior
U. S. Bureau of Reclamation

Utah Water Research Laboratory
College of Engineering
Utah State University
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ABSTRACT

A discussion of telemetering system modifications is given, and discussion is presented of system operations for the 1968-69 snow season. A telemetering error analysis has been made for an operational period in February. A log is presented giving station operation periods, and a general summary of operational costs for the 1968-69 operational year is summarized.

SYSTEM DESCRIPTION

The system is comprised of a non-standard FM-FM interrogate-respond telemetering network for obtaining data from remotely located precipitation catchment devices. Use of a non-standard FM-FM system accomplishes several important things:

(1) The wide-band FM system permits deviations between 1100 Hz and 2500 Hz or 1400 cycles total. The standard FM channel, i.e. channel 6 operating at a center frequency of 1700 Hz has a usable deviation of only 256 Hz. A resolution advantage greater than a factor of five is thus obtained in the modified system.

(2) Any non-linearities, characteristic to some extent in any transducer scheme, are stored in the data reduction computer. When data from a station are processed by the computer, these non-linearities are taken into account giving no loss of accuracy due to departures from a "best-fit" straight-line calibration that would arise in the typical FM-FM system.

(3) By use of a unique wide-band narrow-window tracking filter, the readout system can read out data in the presence of extremely high noise without error. Noise levels sufficiently high to almost completely mask the signal cause little difficulty in detection and readout.

(4) Data are read out to five significant figures by taking a time period average of the incoming frequency. Thus a 2000.00 Hz

signal would be read out as a time period of 500.00 microseconds. Theoretical resolution obtainable in the system described is the difference in numerical digits between 1/1100.00 and 1/2500.00 or 50,909 (with the decimal point omitted). This is because fractions of a cycle can be measured by period measurements whereas only whole cycles are counted on a frequency basis. There are practical reasons why the theoretical limit of resolution cannot be achieved at present; the most significant being aperiodic winds which produce slight loading and unloading effects on the catchment can.[(4)]

The remote telemetering units, powered by batteries, can operate unattended for periods of time up to one year. The precipitation can capacity is also sufficiently large for one full year's precipitation accumulation without requiring emptying. Evaporation from within the can is prevented by floating a quart of oil on top of the liquid surface. Freezing is abated by putting a gallon of glycol in the precipitation can to serve as a snow melting agent.

Radio transmission is quasi line-of-sight as the radio signals are about 2 meters in wavelength. The radio transmitters operate in the hydrologic telemetering band at 170-174 MHz. Signals, transmitted from the remote site, are beamed to the Mt. Logan translator which lies about 4 air miles from the Utah Water Research Laboratory. Signals are thence transmitted via land line to the base station located at the laboratory.

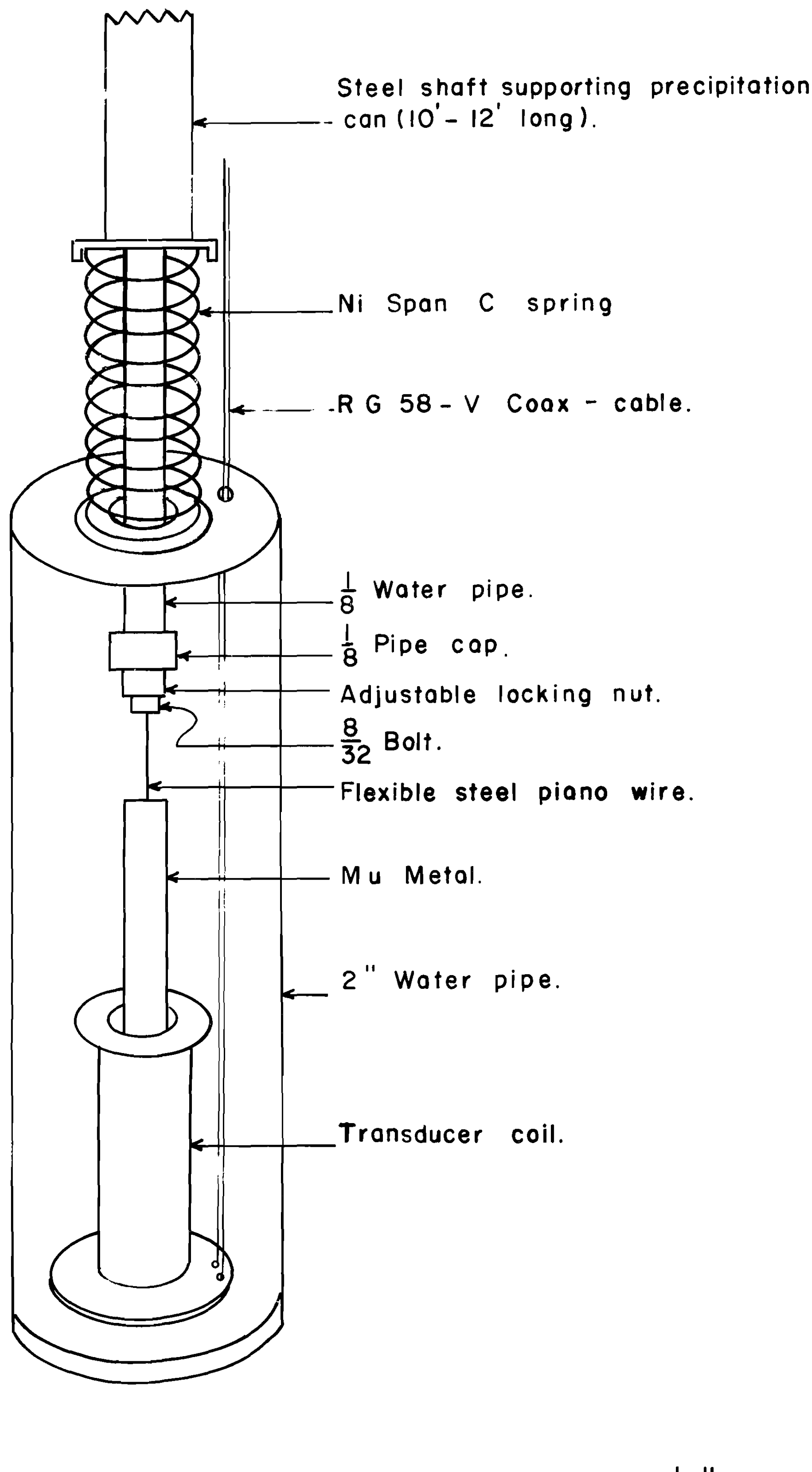

Fig 4. Sketch Of Transducer Assembly Which Fits Inside The $2\frac{1}{2}$" Pipe Column Used To Support The Precipitation Can Assembly.

guides which were used to stabilize the precipitation can in the vertical position. The substitution of nylon rollers for the sliding metal guides used to stabilize the can reduced the static friction by a factor of about 4, (Figure 5). Details of the old and new guides are illustrated in Fig. 6, 6A. Still a third improvement was possible, in the instance of the low elevation tower design, by installing three stabilizing pipes from the wind shield-header assembly into the ground. This tended to stabilize the guide support assembly and improve tower stability in the presence of wind, Fig. 7.

Operating stations

The number of operating stations at the end of each month during the winter season is presented below. A detailed account of stations responding each day is shown in the Appendix, Table 3. Early heavy snows and delays in making modifications in equipment as described above are reasons that equipment installation was carried into the winter months. Normally, installations at such a time would be avoided if possible.

Month Ending	Number of Stations Installed and Operating
November 30	11
December 31	16
January 31	24
February 28	28
March 31	40
April	39

limits on these two measurements differ considerably. In determining the annual catch, the accuracy of the system can be no better than the most inaccurate feature of the system. Assuming inaccuracies of 10 percent due to the can catch itself, a 1 percent long-term telemetry accuracy would be adequate. This assumes an accuracy of measurement 10 times greater than inherent system errors.

On short-term measurements an error equivalent of 1 percent of the season's catch would be excessive. Greater short-term accuracies must be obtained if small storm effects are to be detected. Fortunately, it is practical to achieve greater short-term accuracies than can be achieved on a season basis.

Short-term accuracies vary from station to station:

(1) Site selection--Some sites are inherently less windy than others. At times, winds can cause considerable "noise" in the data. The magnitude of this noise level is approximately .02 inch to .04 inch level for the 36-inch cans and .03 inch to .05 inch for the 70-inch cans. Through multiple interrogations the data can be smoothed to lessen the effect of this type of error.

(2) Can size--For a given can size the accuracy can be expressed as a percent of its full scale value. For a given percent accuracy of the full scale value, a large can has less absolute accuracy than a small can. More graphically, the weight of a single raindrop can be measured more accurately in a thimble than it can in a barrel. This,

coupled with the fact that wind loading is much greater on a large can than on a small can, compounds the problem of obtaining high accuracy using large containers. In the USU T/M system, the can size adequate for a winter's catch was the determining factor in the design rather than the proper can size to achieve the desired accuracy. Higher accuracies can be achieved with smaller cans, but smaller cans would require periodic emptying during the winter instead of once a year as is the case now.

Regarding the short-term accuracy, an estimation of accuracy can be made by looking at data collected during precipitationless periods. Data in Fig. 3 represent the short-term stability of the station. Negative numbers in the "Change in Precipitation" column would probably indicate system noise as opposed to an actual loss of precipitation. Assuming as many positive as negative perturbations, gives one an idea of the noise in the data. A few negative excursions will be masked during periods of precipitation when the precipitation increment is greater than the negative noise increment. Neglecting this fact, the mean square deviation in the incremental values for the data of Fig. 3 is 0.005 inch. These data have less noise than does the average station, but it does indicate the approximate maximum capability of the system at the present time over a 10-day period for a low capacity, 36 inch, station. Standard errors have been calculated for a five-day period for 33 stations operated between February 14-19 of 1969. This information appears in Table 4 of the Appendix.

The comparison between the annual measured catch and the T/M information is only partially available. All of the large can stations are as yet unaccessible. Only two of the low elevation stations were accessible at the time of writing the report. Comparisons of the telemetered values and the manually weighed values for these two stations are as follows:

	Telemetered Value	Measured Value
Petersboro	12.86 inches	12.4 inches
Hyrum	12.0 inches	11.9 inches

There are, of course, many ways in which errors in either of the above measurements may creep in. The following items are worth noting.

The T/M system was calibrated using volumetric measurements. The final value was determined by using a spring scale weight measurement. Errors in water volume versus weight are 0.4 percent for a temperature fluctuation of 44° F. There was approximately this amount of difference in the temperature between the October and May calibrations.

As there was no snow on the ground at Hyrum and Petersboro in May, the ground temperature and hence the transducer was at a different temperature than they were last October 22 when calibrations were made. This fact may account for the May T/M reading being slightly higher. Still another factor is that a dry can was used for initial calibrations in the autumn. This spring the can was wet inside and had an oil film on the walls. Upon post analysis, this residual can liquid has been shown to account for up to 0.1 inch when the oil is at room temperature and a somewhat higher residual tare at colder temperatures or with higher viscosity oils. Also the scales used to weigh the precipitation accumulation in May were uncompensated for temperature. Taking these facts into consideration, the correlation between T/M and measured values for the two stations tested above appears within expected tolerance. Hopefully as the higher elevation stations are visited much more data will be available to better determine long-term accuracies.

COST OF TELEMETERING OPERATIONS - 1968-69

The cost of the telemetering operations for the 1968-69 year is divided into several categories which include personnel, capital, current expense, travel, and indirect costs.

The professional and indirect costs are itemized as follows:

<u>Personnel</u>

Engineering	1 1/4 man years	
Electronic technician	1 1/2 man years	
Miscellaneous student help	1/2 man year	
Other help	1/2 man year	
Secretarial assistance	1/4 man year (est.)	
Indirect cost on above salaries		$53,913

<u>Current Expenses</u>

The current expenses excluding dry cell batteries	$ 4,572
Dry cell batteries	$ 400
Shop assistance--Transducer fabrication, snow machine, truck, trailer, and miscellaneous repairs	$ 3,693

<u>Travel</u>

Travel which included vehicular rental of a jeep, wagoneer, 2 pickup trucks, snow machine, helicopter, per diem, meals, etc.	$17,098

Total expenditures chargeable to telemetering data network, excluding data handling, card punching, or computer time	$79,676

Some of the above expenses were considerably higher than would be the case in a normal operating year. These additional expenses resulted from (1) the installation of several new stations, (2) the modification to the transducer and to the centering guides, (3) relative high transportation and helicopter charges arising from the installation of much of the equipment during winter months, and (4) corresponding manpower requirements connected with the first three items above.

SUMMARY

During the 1968-69 snow season, the telemetering system used on the Wasatch Weather Modification Project operated for about 600 hours total elapsed time. Twenty-five thousand interrogation responses were recorded from a total of 39 stations. The standard error of the precipitation telemetering system was calculated using data collected for the period February 14-19, 1969. The mean value of standard error is 0.016 inch for the 36-inch can. The mean value of standard error is 0.03 inch precipitation for the 70-inch capacity can.

Two stations were checked for their ability to hold calibrations over a 6-month period. The differences noted in telemetered and measured catches of the two cans were 0.1 inch and 0.4 inch, respectively.

The units worked reliably with only two or three electronic-type failures. There were five battery failures, but the cause has been determined and this problem can be remedied.

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APPENDIX

Table 1. Wasatch Weather Modification Project precipitation telemetering stations.

STATION Number	Name	LOCATION Latitude	Longitude	Altitude	Can Size
002	Dayton	42°08'51''	112°04'03''	7550'	36 inch
006	Tony Grove Ranger Station**	41°53'10''	111°36'10''	6800'	36 inch
008	Petersboro	41°46'45''	111°59'00''	4450'	36 inch
010	Gold Hill	40°50'03''	110°53'55''	9800'	70 inch
015	Clarkston	41°55'09''	112°05'45''	6300'	70 inch
016	Franklin Basin*	42°03'08''	111°35'55''	8100'	70 inch
017	Hell Canyon	41°40'22''	112°00'30''	6400'	70 inch
020	Curtis Creek	41°36'05''	111°24'30''	8500'	70 inch
021	Magpie Flat	41°13'57''	111°38'37''	7600'	70 inch
025	Herd Hollow	41°43'12''	111°35'42''	7350'	70 inch
026	Providence Traps*	41°42'08''	111°41'40''	8800'	70 inch
029	Hoodoo	41°09'30''	111°35'12''	8350'	70 inch
044	Hyrum Dam	41°37'17''	111°50'45''	4795'	36 inch
046	Tony Grove Lake*	41°53'00''	111°39'00''	8400'	70 inch
047	Lily Lake	40°51'17''	110°46'50''	9300'	70 inch
049	Ben Lomond	41°21'49''	111°55'05''	8800'	70 inch
050	Dry Bread Pond***	41°24'50''	111°32'46''	8250'	70 inch
057	George Peak	41°52'56''	113°27'31''	8800'	70 inch

Table 2. Record of the number of station interrogations and station failures.

No.	Station Name	Number of Interrogations	Operating Record
002	Dayton	498	transducer broken
006	Tony Grove R. S.	773	good
008	Petersboro	828	good
010	Gold Hill	657	good
015	Clarkston	273	batteries failed (moisture on terminals)
016	Franklin Basin	330	good
017	Hell Canyon	547	batteries failed
020	Curtis Creek	656	good (can appears to have a leak in it)
021	Magpie Flat	191	quit in Feb.--reason unknown
025	Herd Hollow	770	batteries failed (moisture)
026	Providence Traps	256	good
029	Hoodoo	284	good--but sometimes jams other stations
044	Hyrum Dam	603	good
046	Tony Grove Lake	340	batteries failed (moisture)
047	Lily Lake	210	good
049	Ben Lomond	752	good
050	Dry Bread Pond	365	good
057	George Peak		good

Table 2. Continued

Station No.	Name	Number of Interrogations	Operating Record
061	Monte Cristo	267	good
063	Francis Canyon	290	good
065	Guilder's Peak	248	good
066	Hardware Ranch	778	good
068	Paradise Canyon	480	good (radio path is poor sometimes)
070	Bug Lake	810	good
071	Deer Springs	567	good--but sometimes jams other stations
078	Sargent Lakes	546	good
095	Chalk Creek #2	542	good
097	McCoy Park	89	weak signals
104	Shingle Mill Flat	525	good
109	Chalk Creek #1	365	signals are weak
111	Kelley Ranger Station	42	good--but answers on one tone instead of two
113	South Canyon Lower	665	good
124	Little Bear Upper	194	receiver failed
125	Porcupine	531	good
132	Middle Fork Ogden	290	good
146	Woodruff	722	good
147	Klondike Narrows	698	batteries failed

Table 2. Continued

No.	Station Name	Number of Interrogations	Operating Record
152	Trigara Springs	56	good
162	Steel Creek Park	260	good
164	Sinks	687	good
170	Deseret Peak	646	good

Table 3. Continued

Number of Operating Stations

First Day	13
Last Day	24
Day of Least No.	13
Day of Greatest No.	24

January — Station Number

Day	002	006	008	010	012	015	017	020	021	023	[illegible]	026	029	044	046	047	049	[illegible]	[illegible]	063	065	[illegible]	066	070	071	[illegible]	080	[illegible]	097	[illegible]	[illegible]	[illegible]	[illegible]	121	[illegible]	132	[illegible]	147	[illegible]	162	164	170
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Table 3. Continued

Number of Operating Stations

First Day	39
Last Day	35
Day of Least No.	15
Day of Greatest No.	39

April — Station Number

Day	002	004	008	010	012	015	017	020	021	023	025	[illegible]	029	044	046	047	049	050	057	063	[illegible]	[illegible]	[illegible]	071	[illegible]	078	[illegible]	[illegible]	097	[illegible]	109	111	[illegible]	[illegible]	125	132	[illegible]	147	[illegible]	[illegible]	[illegible]	[illegible]
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18			✓	✓		✓		✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
19	✓		✓	✓		✓	✓	✓	✓		✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
20	✓		✓	✓		✓	✓	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
21	✓		✓	✓		✓	✓	✓			✓	✓	✓	✓		✓	✓			✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓
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Table 4. Estimates of standard error for instrumentation variability by station and parameter, for the period Feb. 14-19, 1969, during a precipitation period.

Station		Equivalent Precipitation Error	
No.	Name	Variance	S. E.
002-1	Dayton	.0000	.0034
006-2	Tony Grove R. S.	.0003	.0175
006-3	Tony Grove R. S.	.0000	.0094
008-1	Petersboro	.0005	.0220
015-1	Clarkston	.0003	.0178
017-1	Hell Canyon	.0002	.0136
020-1	Curtis Creek	.018	.0429
021-1	Magpie Flat	.0013	.0358
025-1	Herd Hollow	.0008	.0277
029-1	Hoodoo	.0040	.0630
044-1	Hyrum Dam	.0002	.0145
046-3	Tony Grove Lake	.0000	.0023
049-1	Ben Lomond	.0027	.0524
057-2	George Peak	.0009	.0301
057-3	George Peak	.0028	.0525
063-1	Francis Cyn.	.0162	.1271
066-1	Hardware R.	.0001	.0105
068-1	Paradise Cyn.	.0024	.0492
070-1	Bug Lake	.0006	.0236
071-1	Deer Springs	.0002	.0151
078-1	Sargent Lakes	.0002	.0139
080-1	Monte Cristo	.0007	.0273
095-1	Chalk Creek #2	.0005	.0232
104-1	Shingle Mill Flat	.0027	.0515
109-2	Chalk Creek #1	.0010	.0318
109-3	Chalk Creek #1	.0005	.0223
113-1	South Cyn. Lower	.0016	.0396
125-1	Porcupine	.0010	.0318
132-1	Middle Fork Ogden	.0008	.0283
146-1	Woodruff	.0424	.2059
152-1	Trigara Springs	.0023	.0475
164-1	Sinks	.0217	.1474
170-1	Deseret Peak	.0250	.1583