Research Technical Completion Report

DEVELOPMENT AND DEMONSTRATION OF PUMP STATION AND SURFACE DIVERSION MONITOR SYSTEMS FOR WATER AND ENERGY EFFICIENCY IMPROVEMENTS

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WATER for IDAHO

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ABSTRACT

Microprocessor based monitoring units for pump station and open channel diversions were developed and installed at eight locations in southern Idaho. Commercial electronic units and sensors were utilized to provide operator accessible data as well as storage of measured and calculated parameters. Pump station monitors measure and record input energy, lift and pumping pressures, discharge, and calculated system efficiency as well as cost per unit volume of water pumped. Open channel diversion monitors utilize float-operated variable potentiometers to record water stage as input to discharge rating curves stored in the processor.

Some start-up and operational problems such as battery drain have been corrected and the units provide useful data both for operational evaluation as well as water rights administration.

INTRODUCTION

Water management of river and ground-water systems in the Western United States is dependent upon timely and accurate measurement of diverted water. In areas where high lift pumping is required, the determination of both discharge and energy use is mandatory for optimization of system hardware and operation. Recent adjudication procedures in some states require water users to install and maintain flow measuring devices accessible to watermasters for regulation and management of streams or aquifers according to water rights priorities.

Flow measurement in open channels and monitoring of pumping station flow and energy use has traditionally been performed using laborintensive current metering procedures on rated sections of channels and/or use of expensive commercial electronic devices for sensing the flow and pumping parameters. Low cost electronic monitoring systems providing real-time operator-accessible data are not available.

OBJECTIVES

The objectives of this research were to develop low-cost electronic devices for monitoring open channel irrigation diversion rates and pump station discharge, energy use and system efficiency, and to install and demonstrate such units in southern Idaho.

PROCEDURES

Automatic, electronic data acquisition systems were developed to monitor and record water stage levels on open channel irrigation diversion measurement devices and to monitor pump lift, pressure head, discharge, and energy input on pumping plants. The systems utilized programmable hand held calculators as the microprocessor unit with commercial pressure transducers and discharge sensors along with commercial watt-hour meters for energy input. Essentially, two primary systems were developed: one for open channel measurement and one for closed conduit pumped systems. A third configuration which logged only time of operation and volume pumped for fixed flow wells was also developed.

MICROPROCESSOR CONFIGURATION

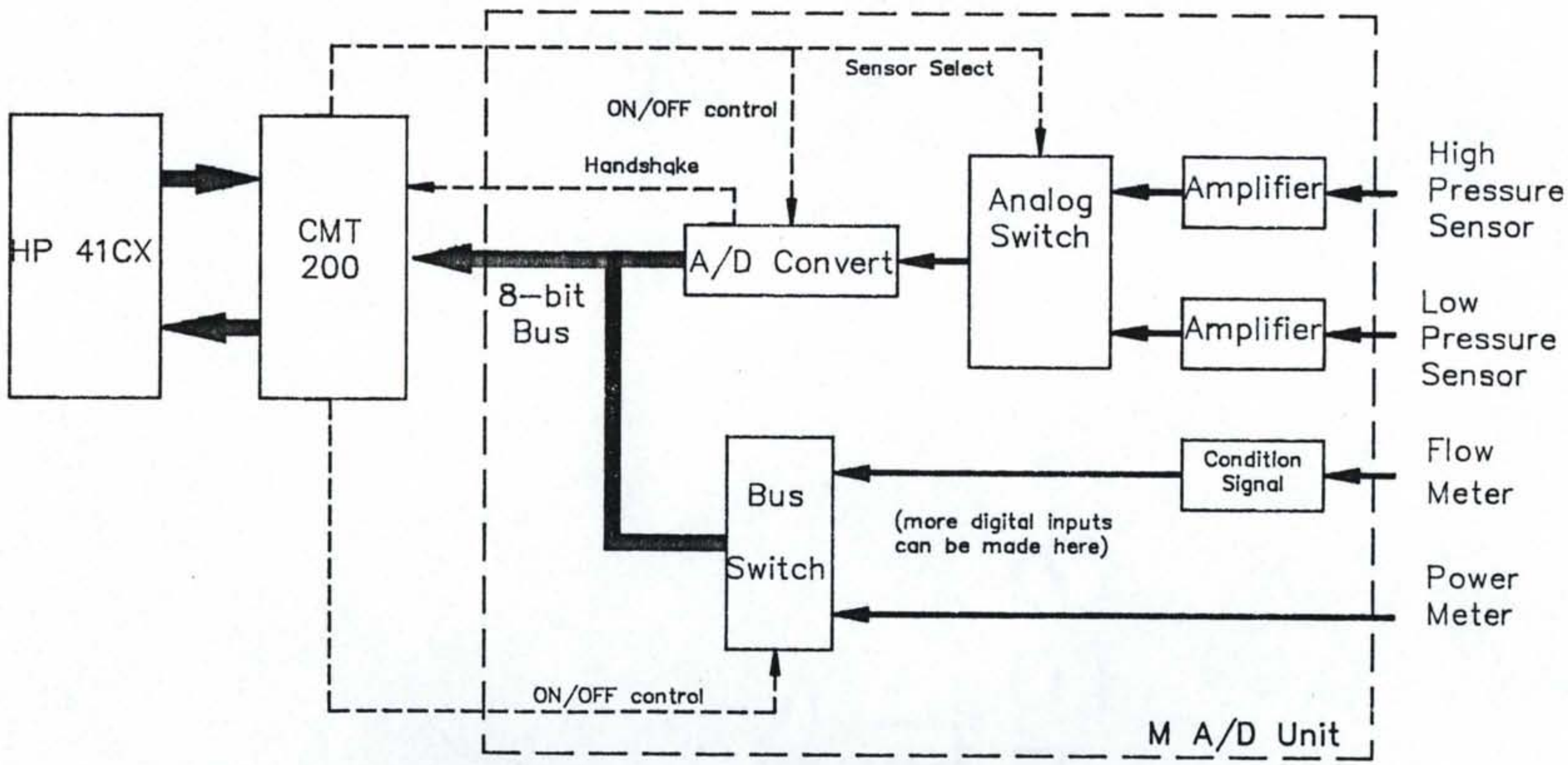
Both the pumping station monitor and the diversion monitor utilized an HP-41/CX programmable calculator as the control and computation processor. This processor was interfaced to a Corvallis Microtechnology CMT 200 data acquisition unit or a CMT 300 VOM unit as shown in Figure 1. The data acquisition unit was interfaced to the measuring sensors through an analog to digital (A to D) multiplexer unit, developed at the Kimberly laboratory. Various sensors were utilized depending on the parameter being measured. Stage discharge sensors for the diversion or open-channel monitoring units utilized modified Stevens water stage recorders equipped with variable resistors; however, low-head pressure transducers with bubbler tubes could be used.

The calculator includes a real time clock which schedules the acquisition of water level data. Upwards of 16 daily observation sets of water level and calculated discharge data or calculated discharge and pump efficiency parameters can be stored in the calculator depending on the configuration of the internal memory. The calculator is battery powered and an optional printer can be interfaced for producing a hard copy of the discharge data or data can be dumped to a RAM disk unit for later interrogation by a personal computer.

The Corvallis Microtechnology CMT-200 data acquisition unit converts digital data from a specific channel into the format expected by the HP-41/CX calculator and also performs timing functions for pulse signals. The unit is interfaced to the transducer with a multiplexer unit built by the USDA ARS at Kimberly for this project, Figure 1.

The A to D converter and multiplexer unit, which was developed specifically for the monitoring units, performs four functions. The unit first allows the CMT-200 data acquisition unit to select the

Figure 1. Electronic pump station monitor block diagram.



correct parameter channel for scanning. A second function is amplification of the low level analog voltage signals from analog transducers to appropriate levels for A to D conversion. The unit then converts the amplified analog signal to a digital format, which the CMT-200 can interpret and send to the HP-41/CX. Excitation power for the various sensors and protection from stray voltages which may be induced on the transducer leads is also provided by the A to D multiplexer unit. Figure 2 shows a typical field installation of a pump station monitor.

Figure 2. Field installation of Pump Station Monitor

PARAMETER SENSORS

Pumping Station Monitors

The pumping station monitors currently calculate flow rate from meters equipped with pulse output signals; however, they can be modified to accept analog output signals from other types of flow meters. Commercial flow transducers of the paddle-wheel or impeller type provide pulse type output signals with appropriate calibration formulas for incorporation in the software of the microprocessor. Discharge pressure from the pumping units was measured with standard piezo-resistive pressure transducers with ranges corresponding to the operating pressures at each site.

Measurement of pumping lift from the stream or pump forbay was also accomplished with commercial pressure transducers. The low-pressure transducers were coupled to bubbler type systems constructed by project personnel. These bubbler systems consisted of an air supply, pressure regulator and flow control valve, air flow indicator, and plastic tubing with associated fittings. Both bottled compressed air and portable rechargeable air tanks were evaluated for the bubbler air supply. The commercial bottled compressed air provided a full season supply, whereas the portable air tank required weekly filling. Air pressure on the bubbler tube was regulated with a standard compressed air regulator and a small needle valve was used to control air flow to allow a small bubble to be emitted from the end of the tube every one or two minutes.

Six pump station monitors were installed in eastern Idaho and one of four planned installations in southern Idaho was completed. Figure 2 shows a typical field installation. Late equipment arrival and scheduling problems prevented installation of the additional three units.

Diversion Monitors

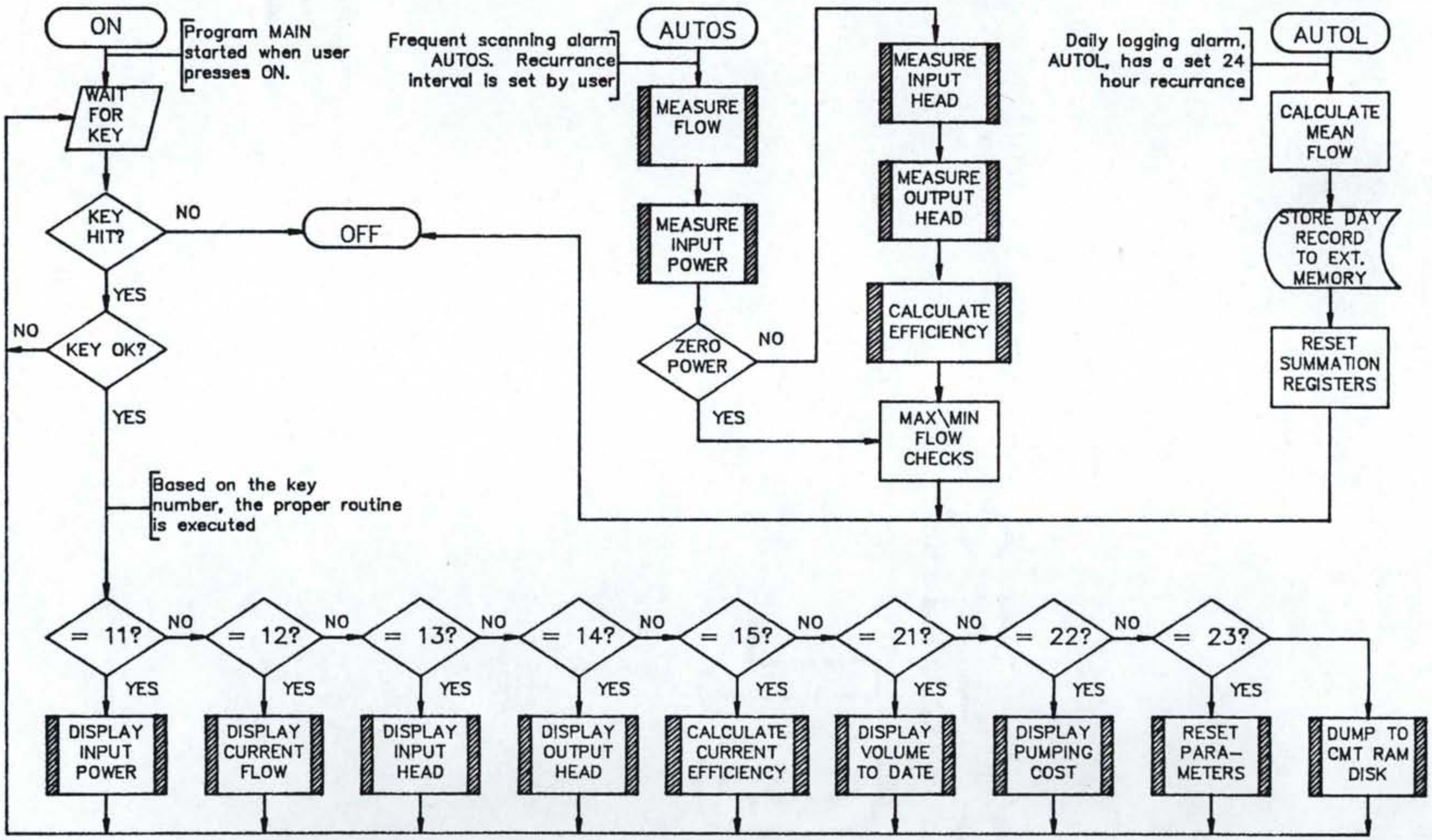
Diversion monitors for open channels utilized the same HP-41/CX microprocessor and a CMT 300 VOM measurement unit. Two monitors were installed during the 1987 irrigation season. For these installations, only the water stage elevation was monitored. On one installation, a single monitor was used to record the water stage at two adjacent open channel diversions using Stevens Type F water stage recorders modified by the installation of a variable resistor operating off the float pulley. The variable resistor and gears were selected to provide resolution of .01 feet per revolution. A strip chart record was produced at the same time as the electronic record to provide a means for error checking.

MONITOR OPERATION

The control and computation instructions, or software, consist of several subroutines to utilize the capabilities of the HP-41/CX and the CMT-200. Initial subroutines request station physical characteristics and coefficients for rating or calibration of the various transducers and meters connected to the monitor and the sampling frequency.

Operation of the monitor unit after initial setup for a pump station installation is shown in the flow chart of Figure 3. A similar flow chart without measurement of input power and pumping parameters is applicable for the open channel flow monitor. In the automatic mode,

Figure 3. Pump station monitor flow chart



the monitor turns itself on at the pre-selected time and determines the electrical input power usage level. If this level is above some threshold level, the monitor proceeds to scan the flow meter sensor and pressure transducers. If the input power level is below the threshold, the monitor sets flow to zero and foregos any efficiency calculations. If the input power level indicates the pump is operating, the monitor samples all inputs, calculates efficiency parameters, and stores the set of values. Every 24 hours, another routine calculates the mean of flow rate and stores both observed minimum and maximum measured or calculated parameters and the average daily values to ring memory. In the manual mode, the pumping station operator activates the unit by turning on the calculator and pressing a specific key associated with information desired. The information available to the user includes current electrical horsepower demand, flow rate, water level, discharge pressure, energy efficiency, pumping cost ($/acre foot), and total pumped volume to date. If the user fails to turn the unit off after manual sampling, the monitor will turn off automatically in 90 seconds.

Daily minimum, mean, and maximum data such as flow volume and efficiency are stored in the HP-41/CX extended memory as a separate data area. This area is a standard HP-41/CX extended memory data file with a beginning and an ending location; however, the monitor program operates as if it was a ring memory area without a beginning and ending location, as shown in Figure 4. Ring memory is a memory area in which new data is written over the oldest data in memory. Associated with the ring memory area are two pointers, a write pointer, and a read pointer. Data records are written to the area starting at the write pointer, and read from the area starting at the read pointer and ending at the write

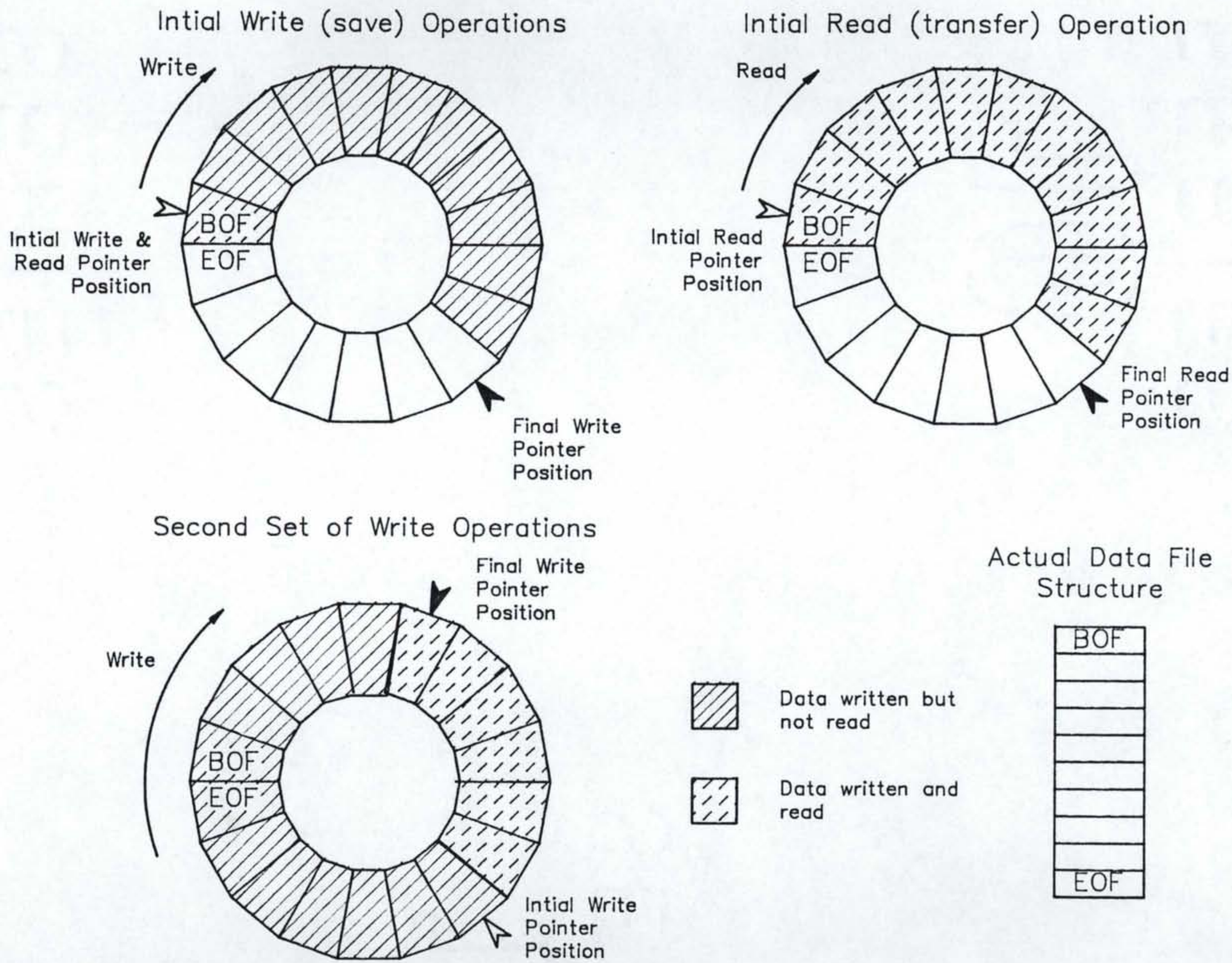


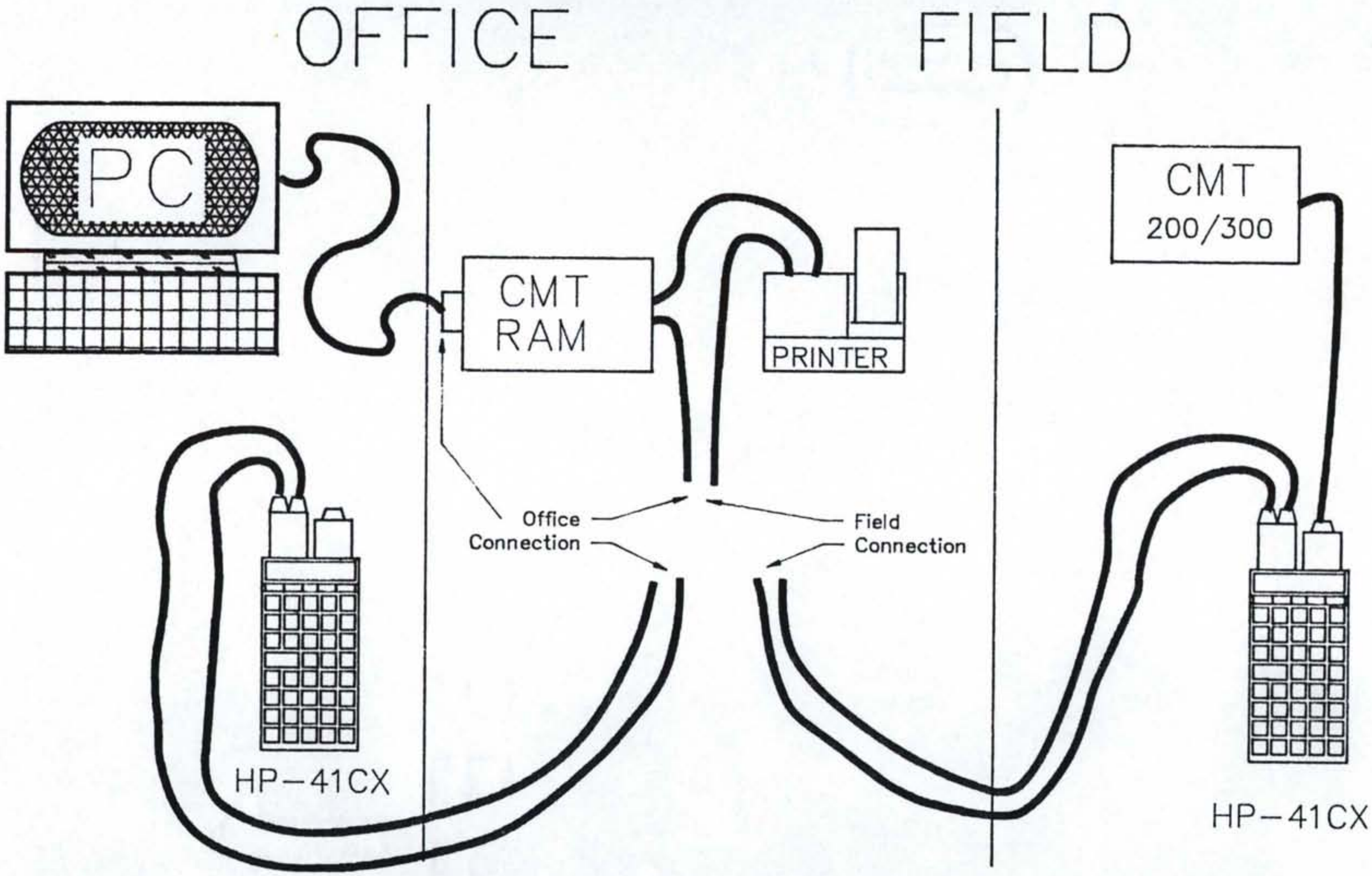
Figure 4. Electronic monitor ring memory operation.

pointer. The write pointer is allowed to advance around the ring without regard to the read pointer location; however, the read pointer is not allowed to advance past the write pointer. Depending on the hardware configuration of the monitor, the ring memory area will store 30 days of data prior to overwriting data.

Station performance data, including all measured input and calculated flow, TDH and efficiency, is retrieved from memory by pressing a key. The dump can be made to ram disk, tape drive, or printer, or displayed on the calculator for each sampling time. Future plans are to transmit via FM or utilize data collection platforms for transmission to satellite. Utilizing the ram disk, Figure 5, logged field data can be transferred to an office computer. The transfer requires an HP-41 calculator at the office location. Currently, a personal computer is being used and all the file manipulation routines are written in Basic language.

Six wells in eastern Idaho were instrumented with special 'time of operation' monitors to record the percent of time each day the wells were operated and calculate the daily volume pumped from each well. The wells were operated as exchange wells to provide ground-water in exchange for surface water during low stream flow periods. These monitors utilized the HP-41/CX microprocessor which interrogated the pumps every 15 to 30 minutes to determine if they were on and recorded the last time they were either turned on or off. The discharge of each well was measured either with an in-line flow meter or current meter and considered constant for the amount of time the well was operating. Total volume flow was then calculated by the microprocessor and stored in memory.

Figure 5. Pump station monitor data transfer operations



RESULTS

OPEN CHANNEL MONITORS

During the 1987 irrigation season three open channel diversions in Water District Number 1 were instrumented with the HP-41CX/CMT-300 monitors. These stations were the Clark and Edwards canal, the Bramwell Ditch, and the Ellis Ditch. The Bramwell and Ellis Ditches were monitored with a single HP-41CX/CMT-300 system and the diversion measurement sections were standard rated sections. The Clark and Edwards diversion measurement section was a broad crested weir.

The monitor system at the Clark and Edward canal was operated from July 7 through October 20. The system was inoperable from the July 21 to August 4, from August 10 to 11, and from September 4 to 8 due to battery problems and calculator lock-up problems. For the period of record, the monitor recorded a minimum stage of 0.52 ft, or 12.3 cfs, and maximum stage of 1.95 ft, or 95 cfs. Table 1 shows some of the data collected at the Clark and Edwards site. The data shown is the output from the office personal computer using input from the field monitor. When the monitor was reinitialized on August 5, the operator did not load the rating equation into the monitor resulting in zero discharge indicated for the period August 5 through 9.

The monitor system at the Bramwell and Ellis ditches was operated from July 7 through October 14. The system experienced battery problems, calculator lock up problems, and operator initialization during at least 10 periods during the season. The extreme number of failures at this dual station monitor were due to the calculator locking

Table 1. Diversion Monitor, Clarke and Edwards Canal.
1987 typical data.

Date	--- Water Level (ft) --- min	mean	max	---- Discharge (cfs) ---- min	mean	max
07/07	1.65	1.71	1.73	72.7	77.1	78.7
07/08	1.67	1.70	1.72	74.4	76.2	77.6
07/09	1.70	1.71	1.72	76.2	76.9	77.8
07/10	1.68	1.71	1.76	74.9	77.2	80.7
07/11	1.74	1.75	1.76	78.9	79.8	80.8
07/12	-2.36	1.74	1.84	30.8	81.7	86.9
07/13	1.81	1.82	1.84	84.1	85.3	86.4
07/14	1.79	1.82	1.83	83.2	84.8	85.7
07/15	1.78	1.81	1.84	82.0	84.2	86.3
07/16	1.77	1.81	1.83	81.1	84.5	85.7
07/17	1.72	1.80	1.82	77.6	83.5	85.3
07/18	1.72	2.29	2.63	77.8	124.7	153.8
07/19	2.46	2.47	2.49	137.7	139.0	141.1
07/20	2.46	2.47	2.53	137.7	138.8	144.5
08/05	1.61	1.63	1.65	0.0	0.0	0.0
08/06	1.56	1.60	1.64	0.0	0.0	0.0
08/07	1.54	1.59	1.67	0.0	0.0	0.0
08/08	1.56	1.61	1.68	0.0	0.0	0.0
08/09	1.57	1.63	1.69	0.0	0.0	0.0
08/12	1.80	1.83	1.95	84.0	85.7	95.0
08/13	1.77	1.79	1.82	81.3	83.2	85.4
08/14	1.76	1.79	1.95	80.9	83.0	95.0

up after two days of operation. The calculator was removed from the site for a period of one week and operated in the office where it locked up after two days of operation. The equipment suppliers suggested that a different calculator be used due to reported problems with repeating alarms (wake up programs) on older model HP-41/CX calculators. Another calculator was used, which corrected the problem. Tables 2 and 3 show some of the data collected at these two stations.

Table 2. Diversion Monitor, Bramwell Ditch. 1987 typical data.

Date	--- Water Level (ft) --- min	mean	max	---- Discharge (cfs) ---- min	mean	max
07/07	1.50	1.54	1.57	13.2	13.7	14.0
07/08	1.33	1.45	1.50	11.2	12.6	13.2
07/09	1.32	1.53	1.61	11.1	13.6	14.4
07/10	1.58	1.61	1.67	14.1	14.4	15.0
07/11	1.64	1.66	1.70	14.8	15.0	15.4
07/12	1.70	1.72	1.79	15.4	15.6	16.2
07/13	1.12	1.72	1.83	8.7	15.4	16.6
08/04	1.25	1.27	1.29	10.2	10.4	10.7
08/05	1.24	1.26	1.30	10.1	10.4	10.8

Table 3. Diversion Monitor, Ellis Ditch. 1987 typical data.

Date	--- Water Level (ft) --- min	mean	max	---- Discharge (cfs) ---- min	mean	max
07/07	1.01	1.03	1.05	11.2	11.4	11.6
07/08	0.92	0.98	1.02	10.2	10.8	11.3
07/09	0.32	0.98	1.34	4.3	11.0	15.1
07/10	0.08	0.69	1.32	2.5	8.2	14.9
07/11	-0.04	0.74	1.39	1.7	8.7	15.7
07/12	-0.04	0.16	0.35	1.7	3.1	4.5
07/13	-0.04	0.36	1.20	1.7	5.2	13.4
07/21	1.28	1.40	1.48	14.4	15.9	16.8
07/30	0.02	1.37	1.46	2.1	15.5	16.6
08/04	0.01	0.02	0.03	2.0	2.1	2.1
08/05	0.01	0.02	0.03	2.0	2.1	2.1
08/12	1.19	1.20	1.20	13.3	13.4	13.4
08/13	1.19	1.19	1.20	13.3	13.3	13.4
08/14	1.18	1.19	1.19	13.2	13.2	13.3
08/15	1.18	1.19	1.20	13.2	13.3	13.4

EXCHANGE WELL MONITORS

During the 1987 irrigation season, six exchange wells were instrumented with four HP-41CX/CMT-200/MAD monitors in Water District Number 1 near Rexburg, Idaho. These wells were owned by a group of water users located on the upper Teton River. The monitors were installed in the middle of July and were removed September 15. Of the six wells monitored, four wells were not operated. Table 4 shows some of the resulting data collected from an exchange well station after down loading to a personal computer. Some of the problems experienced with the exchange monitors were correct identification of the steady state flow rate of the well, as well as battery problems and operator initialization of the monitoring program during the installation.

PUMP STATION MONITORS

Five river pump stations and one booster pump station were monitored in upper Teton River Basin of Water District Number 1. The monitors were installed during the later part of the 1987 irrigation season due to problems with equipment acquisition.

At the booster pump station only flow was monitored as requested by the operator. After installation of the monitor and electronics modifications for the flow sensor signal, the monitor recorded water usage from 0 to 15.7 cfs and mean daily usages from 0 to 10.01 cfs-days.

The river pump stations were instrumented to monitor flows and efficiency data. All of the monitors experienced the same signal conditioning problems as did the booster pump monitor. The signal conditioning circuitry was added to the monitors by the first of September. By this time the three pump stations on the Teton river system had basically shut down for the irrigation season. Some data was collected which is representative of the stations capabilities. Table 5 contains some of the data collected from one these stations.

Table 5. Clementsville Pump Station #13054043.

Date	Min Flow cfs	Mean Flow cfs	Max Flow cfs	Min/Max Eff %	Flow cfs	Input Head ft	Output Head ft
9/10/87	0.00	4.11	14.35	33.8	7.57	0.00	262.6
				74.8	3.91	0.00	324.8
9/11/87	6.19	6.52	6.85	39.9	6.19	0.00	343.8
				46.9	6.85	0.00	370.9
9/12/87	5.86	6.44	9.35	24.4	6.30	0.00	268.0
				74.1	6.59	0.00	365.5
9/13/87	3.63	5.43	6.51	22.8	3.63	0.00	186.8
				50.3	6.51	0.00	243.6

The two monitors on the river pump stations located on the Snake River were operational by the first of September. Again this only allowed for data during the last part of the irrigation season.

The five pump station monitors did have some problems in addition to the flow signal, such as operator error in initialization and battery problems. One interesting error occurred which involved the setting of a internal flag in the HP-41/CX calculator which cannot be cleared until the calculators memory is cleared completely, resulting in the loss of all data.

CONCLUSIONS AND RECOMMENDATIONS

The major problem with the monitor system operation was excessive battery drain under a frequent scan interval. This problem has been addressed and is currently being corrected by addition of solar panel battery charging systems. The other problems involving programing and incorrect initial assumptions on sensor interfaces have essentially been corrected. The systems, when operating, are very functional, allowing single button access to accumulated flow volumes and current operating characteristics of the system, as well as providing convenient long term data recording for system analysis.