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IMPLEMENTATION OF AUTOMATIC REMOTE
CONTROL FOR CANALS

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ABSTRACT

This paper was written for presentation at a joint symposium during May 1979 in Frunze, U.S.S.R., as a part of the Project III-2, "Methods and Means of Automation and Remote Control in Water Resource Systems." The paper describes the implementation of automatic remote control on three Bureau of Reclamation canals in the State of California. Implementation includes design and/or modification of canal structures; design and fabrication of the control equipment; installation, placing in operation, and testing; and operation and maintenance of the equipment. The facilities and control systems considered in the paper are: the supervisory control and digital control system on the Delta-Mendota, the EL-FLO control system on the Corning Canal, and a supervisory control system with programmable microprocessor-based remote units for the Tehama-Colusa Canal.

INTRODUCTION

The continuing development of agricultural irrigation and the possible shortage of water require more accurate control of water in the various distribution systems. This paper discusses three canal projects that have been automated in an effort to provide a desirable method of control. A demand system is desirable because it can quickly respond to the changing needs of the farmer. Such a system correct for changing water requirements resulting from weather, equipment failures, etc. Also, as development of agricultural applications increase, and canal utilization approaches design capacity, quick response is required because of the decrease in available storage capacity in the canal.

The Bureau of Reclamation has been involved with canal automation for many years starting with simple run-rest controllers such as the Littleman controller for upstream or downstream level control and progressing through various levels of remote and automatic control.

The application of automatic remote control equipment should be considered while planning a canal project. The type of control is a function of the terrain, the type of water users, the utilization of the capacity of the canal, and the design features of the canal. A canal with properly located check structures serving water users on demand is best suited to a downstream automatic control system with remote control a desirable option. A canal which flows at a constant level for a considerable length of time may be controlled manually, either locally or remotely. Remote control may be desirable where weather or other conditions prohibit easy access to control structures. If automatic control is anticipated, computer modeling should be used to assist in locating the check structures. For existing canals, computer modeling is required to verify automatic control methods using existing check structures or to identify necessary construction changes. The check structures must be designed using electric or hydraulic actuators with necessary raise-lower and local-automatic controllers, and a gate position encoder. The site must also be provided with stilling wells for upstream and downstream water level measurement. Communications are an important consideration for any control system other than a local onsite controller. Our experience has shown multiple conductor buried shielded cable to be the most reliable. Two more items to be considered for automation are a structure to house the equipment and electric power for the equipment and gate hoists. The requirements of the control equipment with respect to temperature, humidity, and dirt must be considered in the design of the adequate equipment structure. Adequate lightning protection must be provided for all communications and power circuits. Finally, maintenance of the equipment must be considered. As the control equipment becomes more complex, the skill level of maintenance personnel must also increase.

These are some of the important considerations in the implementation of automatic remote control and will be discussed as they relate to each of the following Bureau of Reclamation canal projects:

1. A supervisory control and digital telemetering system for the Delta-Mendota Canal
2. The EL-FLO controller for the Corning Canal
3. A supervisory control and telemetering system with programmable microprocessor-based remote terminals

General Comments

Five specific problem areas should be reviewed before any major planning is started:

1. If automatic or closed loop control is to be included, studies will be required to determine if the control algorithm is stable. This is best accomplished using a computer simulation model. The results of this study will reveal if closed loop control or automatic control is feasible or if changes in control structures are required.
2. The control structures must be designed to accommodate electric or hydraulic hoists. Each structure has to be located near a source of power for the hoist. With the lack of commercial power, gas and solar or thermal power can be considered, but these alternatives are expensive to install and operate. The gates and hoists must be designed to withstand the increased number of actuations resulting from automatic operation.
3. The communication system is also an important item for consideration. Both the quality and number of channels have an impact on the type of control and the speed at which the system will operate. Our experience shows that multiple conductor, shielded, buried, voice-grade devoted channels provide excellent results. Such channels are being recommended for installation where possible for both new construction and upgrading existing canals for automation.
4. Another problem area pertains specifically to existing systems to be upgraded. The problem is a matter of expense in the tradeoff between modifications to the canal and the degree of automation. The modifications may include any or all of the following:
 - a. Relocation or addition of check structures
 - b. Installation of stilling wells
 - c. Construction of control buildings

- d. Upgrading of existing or installation of new communications circuits
- e. Installation of electric or hydraulic gate hoists
- f. Installation of gate hoist controllers
- g. Modification of gate structures to accommodate gate hoists

5. Maintenance is required for any canal system. A manually operated system requires that the gate hoist mechanism be cleaned and oiled. Electric hoists require oiling for the motor and gear train. The gate pivots require grease. There are many tasks under the heading of maintenance and as the control methods are made more automatic, maintenance requirement becomes more complex.

For the manually operated canal, the operators can learn to perform maintenance and some repair. With simple automation systems such as Littleman controller systems and relay logic remote control and telemetering systems, electricians are required.

As a system becomes more automatic using microprocessors, minicomputers, digital communications, and solid-state relays, the level of maintenance skill necessary increases, requiring electronics technicians with special training and special equipment.

Delta-Mendota Canal

The Delta-Mendota Canal was automated in the mid-1960's. Many of the requirements for automation were provided during the original construction of the canal. The state-of-the-art was just moving into minicomputer control but was still based on slow pulse code communications.

The Delta-Mendota Canal control system remotely operates 13 checks and 3 wasteways. A normal scan of the system takes 10 to 60 minutes and can accomplish a control function in 13 to 60 seconds. The desired mode of control was remote control of the gates with telemetering to provide feedback of control and system monitoring.

Procurement of the system was by Government invitation for bids with the basic functions of the system and the interface to the existing equipment described in the invitation for bids. The technical requirements of the system paralleled those used in petroleum pumping plant and hydroelectric powerplant control.

The supervisory control system has served well and has provide a considerable improvement in the response of the canal to changing water needs. Due to the age of this system and the desire to integrate this canal into a centralized computer-based system, a

more modern system is being planned to replace the existing system. The solicitation placed the burden of implementation (to provide the correct interface and timing) primarily on the successful bidder.

This remote supervisory system has served well in providing control for the canal. It would be desirable to incorporate this system into a larger system; however, this would be difficult for a number of reasons. The system operates very slowly compared to modern control equipment systems. It is also difficult to modify or change existing control procedures. Utilizing the existing system would require a special interface and hardware and could seriously affect the response. Studies are now underway to design and procure modern systems to replace the existing control and telemetering system.

Implementation of the Delta-Mendota Canal control system was a relatively easy task because some form of automation was anticipated. Automation at that time consisted primarily of remote control and telemetering. This type of control was readily available in oil pipeline and electrical generation control systems. Automatic control was not desired or available, and both operator and control system response was fast enough to maintain control. As canal utilization has increases, faster control or automatic control is required and a system designed specifically for canal control is required.

Planning indicates the need for the utilization of microprocessor or minicomputer control to provide the desired flexibility and speed. A two-way data link is also being considered to allow operation of the canal from a larger central control site.

Corning Canal

The Corning Canal is approximately 34 km long with a maximum capacity of 14 m³/s and 12 single-gated check structures. The canal was initially operated manually with a Littleman-type controller at the first check structure. The smaller capacity at the downstream end of the canal required adjustment each time there was a change in flow. An automatic downstream mode of operation was desired to provide automatic demand-type operation. The Corning Canal was selected as the site to conduct experiments for demand automatic downstream control. Preparation of the canal included installing local-automatic control switches, providing communications between check structures and the Red Bluff Office of the canal headworks, and preparation of combination stilling well-control buildings to provide water level information and protection for the equipment. The EL-FLO controllers considered for this canal were at that time in the development stage. The EL-FLO controller was developed through a research contract with the University of

California at Berkeley. The EL-FLO concept was further tested at the Bureau of Reclamation in Denver where two working models were built and tested. When problems developed in the first controller equipped with a hydraulic filter, an all-electronic version was designed. After further testing, a contract was issued for fabrication of 20 EL-FLO controllers.

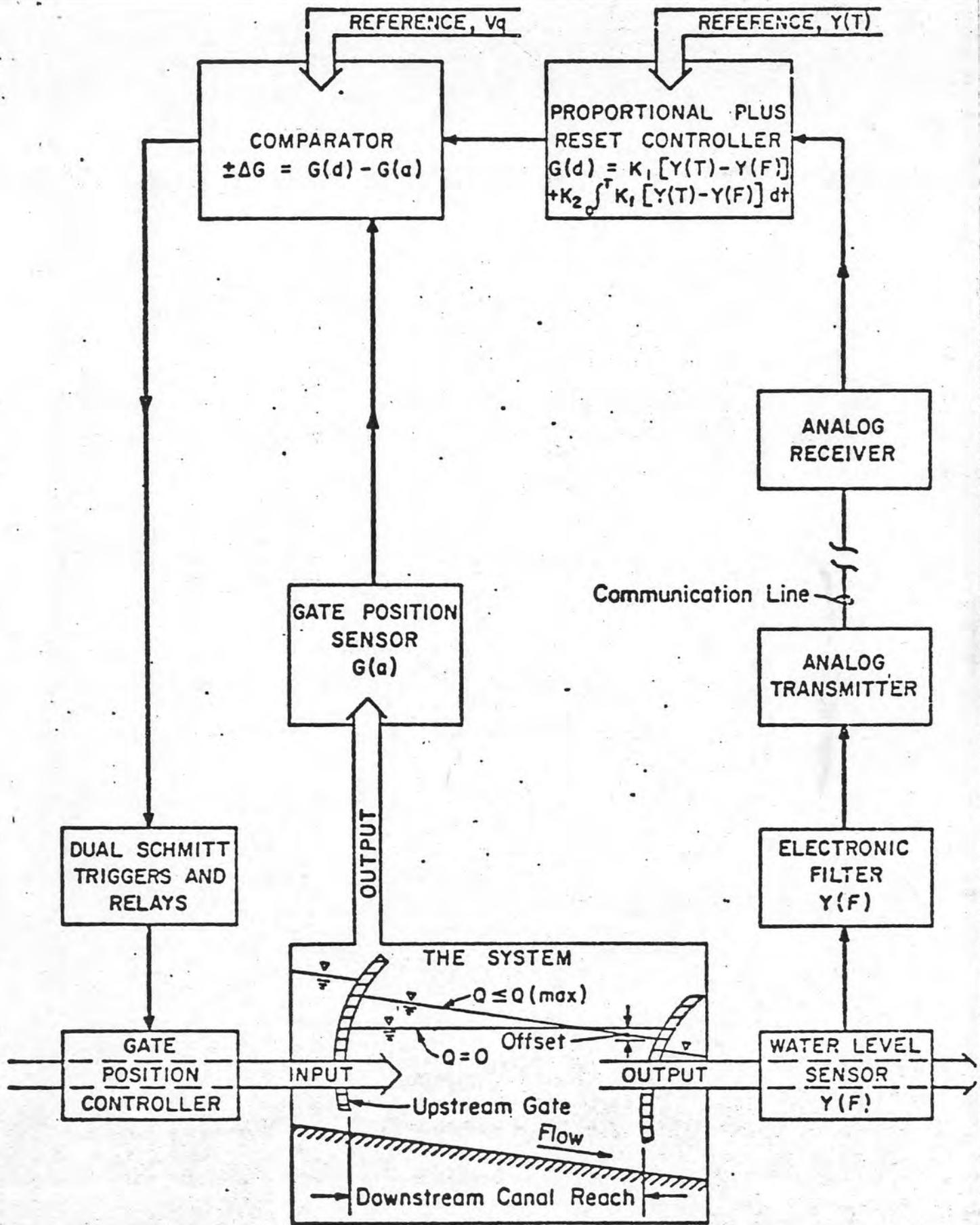
Installation was accomplished by the Bureau of Reclamation. Two communications channels were provided which consisted of two shielded cables. The communications channels have several overhead spans. The controller parameters were preset prior to installation; however, several controller parameters had to be recalculated. The first 2-month period of operation was better than expected, but the next month of operation proved the controllers to be vulnerable to electrical disturbances from lightning. The first electrical storm disabled 10 of the controllers. Modifications have been made to improve the controllers' resistance to lightning and similar disturbances. Studies will continue in an effort to make the controllers more resistant to electrical interference. The overhead spans in the communications channels and insufficient lightning protection for the incoming power supply are believed to be the primary causes of the failures.

Initially, maintenance was accomplished in the research center at Denver with field maintenance personnel merely exchanging electronic equipment component cards. Several months of informal training brought the field maintenance personnel to the level of being able to handle most of the maintenance on their own.

The EL-FLO control algorithm performs very well. Reliability has been somewhat of a problem and a number of prerequisites have been identified for future installations of the EL-FLO controller. A second EL-FLO installation, which has improved features, has proved considerably more reliable. These features include a completely buried multiple pair communications cable, secondary side lightning arresters on the power pole supplying power for the controllers, and a block building for housing the controllers. It is desirable that any electronic controller installation have these features. Figure 1 is a diagram of the EL-FLO control features

Tehama-Colusa Canal

The Tehama-Colusa Canal is presently under construction. The design of the canal included features required for automation. Some of these features are gate hoists with controllers and local-automatic transfer switches, upstream and downstream stilling wells, a multiple pair buried communications cable, a concrete block structure to house the equipment, and encoders to provide gate positions and water levels.



EL - FLO FEEDBACK CONTROL SYSTEM
 . FIGURE 1

Several closed loop automatic control systems are being studied for operation of the Tehama-Colusa Canal. However, a number of check structures have been constructed and are in operation. A control system is required for present efficient operation. A remote control and telemetering system has been purchased for the canal. The system has microprocessor-based remotes and master. Both are programmable to allow modification and expansion of both the number of remotes and the functions of the remotes. The master station also provides for an interface to a minicomputer in which the master station can operate as a remote to the minicomputer. This feature allows the minicomputer to process a complex closed loop algorithm and utilize the system to perform the monitoring and control.

Figure 2 is a diagram of the remote to be installed on the Tehama-Colusa Canal. The microprocessor is a Motorola M-6800 8-bit microprocessor. The digital panel meters are furnished by a separate Government contract and provide A to D (analog-to-digital) conversion. The remote station does not have A to D capabilities in this configuration but A to D conversion can be provided later. The communications link is completed by Vudic model VA335 type modems. Power is provided by a 20-ampere hour battery, float charged by the a-c power provided for operation of the check gates. Battery power provides operation of the remote to monitor conditions when a-c power is out and gates inoperable.

A typical remote provides the following telemetered quantities and controls:

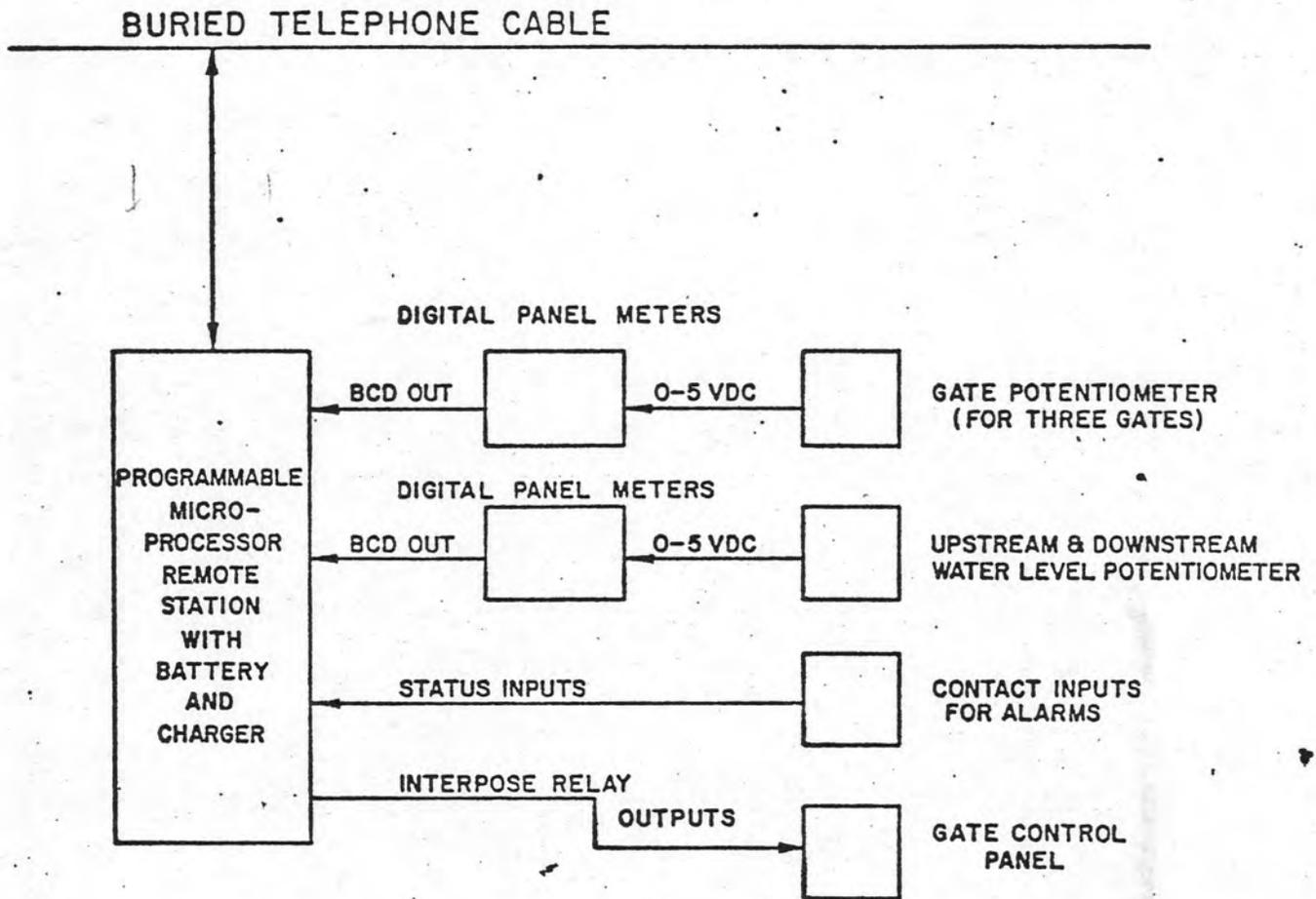
1. Telemetering

- 3 - Gate positions
- 2 - Water levels
- 4 - Water level alarm limit points
- 16 - Alarm points
- 2 - Derived alarm points

2. Control

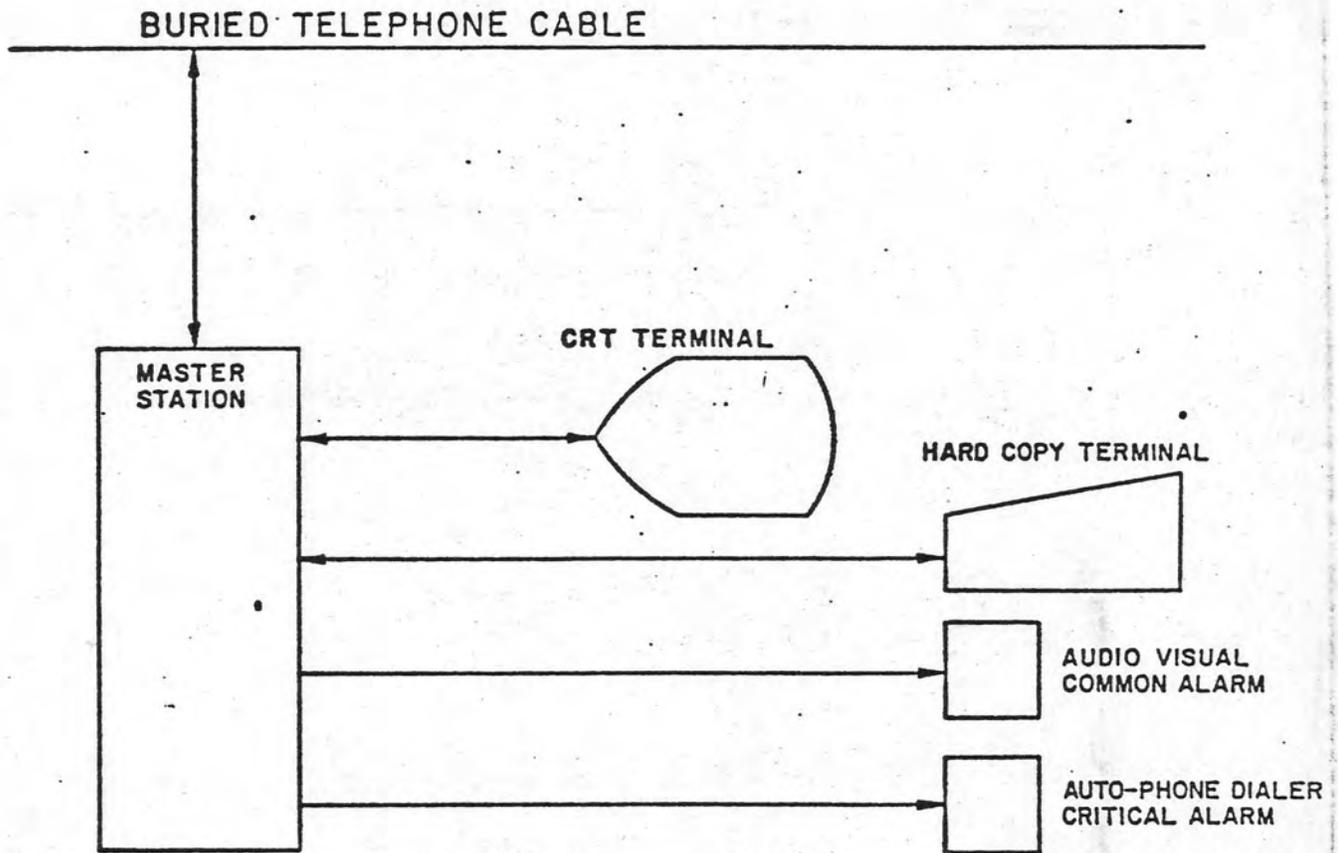
- 3 - Gate raise-lower
- 1 - Emergency raise-lower
- 4 - Limit set for water level alarms
- 4 - Control values

Figure 3 is a diagram of the master station. The master station utilizes the Motorola M6800. The man-machine interface is provided by a CRT (cathode ray tube) video display with an alpha-numeric keyboard, a paper printout terminal with an alpha-numeric keyboard,



Remotes are 8-Bit Motorola M-6800 systems with programmable read only memory. Remotes can be expanded or modified as required. Multi-turn potentiometers are used for mechanical position inputs. The analog signal drives digital panel meters with binary coded decimal output.

**TEHAMA COLUSA CANAL
CANAL CHECK REMOTES
FIGURE 2**



The master station is an 8-Bit Motorola system with both CRT and paper terminals for man-machine interface. Future development includes a dynamic display board and interface for a minicomputer. Programmable read only memory can be modified to accommodate future changes.

TEHAMA COLUSA CANAL
 MASTER STATION
 FIGURE 3

a paper printout terminal with an alpha-numeric keyboard and two alarm signals. Additional communications ports are provided for a future display board, a telephone circuit, and a minicomputer.

Software for the system will provide a display of data on the CRT, format for printout, and coded control commands. The master station can complete a 4-word status scan for 40 stations in less than 60 seconds and a complete data scan in approximately 6 minutes.

The supplier of the above equipment is interested in the development of automatic control algorithms that can be incorporated into this system. Development of control algorithms will continue at the Engineering and Research Center. It is planned that in the future such an algorithm can be incorporated into this system.

CONCLUSIONS

Increasing demands for water emphasize the need to control canals with maximum efficiency and minimum losses. Increased flows lessen the available storage in the canal and control adjustments are required more often. Efficient operation may be possible only with automatic or supervisory control. The canal control system must also be more responsive to sudden changes in flows such as emergency shutdowns or loss of power. This is necessary to prevent loss of water or damage to property.

Site Preparation

Whether a canal is designed for automation or is being upgraded for automation, certain minimum requirements are necessary for successful incorporation of automatic remote control equipment. A reliable source of power must be available. This under normal circumstances would be commercial a-c power, although alternatives are available such as solar and thermal. Adequate lightning protection must be provided. A secure multiple channel communication circuit is required for most control systems. The most reliable system is a multiple circuit shielded cable buried adjacent to the canal. Channels should be a minimum of voice grade to provide real-time performance. A suitable structure should be provided to house the equipment and provide work space for servicing.

Maintenance Requirements

Canal maintenance in the past has been primarily electrical-mechanical and has been performed by electricians. With the shift to automation more electronics equipment and computer equipment is being incorporated into control systems. This has raised the skill levels required

to service the equipment, which in turn requires training of electricians or hiring of electronic technicians to perform the required maintenance and repair.

Other alternatives are to contract the entire maintenance of the system or to have electronic technicians perform card level maintenance and contract for card repair.

All result in an increased cost over maintenance for a conventional operation with manual control, local automatic control (such as Littleman or Colvin control), or slow-scan pulse-coded remote control.

The Changing System

As canal utilization changes due to change in service area, water users, or seasonable demands, different control modes may be desirable. The daily schedule may warrant the use of different control modes. For example, during the day when a large staff is available, frequent flow changes may be made, while during the night the operation may require just a few small changes. Control system could accommodate this by utilizing remote supervisory control during the day and automatic control at night. A flexible system that can be modified or upgraded can be a definite advantage. Then the best qualities of remote and automatic control are available. The Tehama-Colusa Canal is being automated in this way. The cost of providing the flexibility using microprocessors is competitive with hardwired logic or analog, and it has the advantage of being able to be modified or reprogrammed. Adoption of this equipment is a two-sided issue. It generally costs more to operate and maintain the equipment. The reduction in operating personnel on the canal is offset by the need for more skilled, hence more highly paid maintenance personnel. The best justification for automatic remote control is the responsive control that it provides. Less storage available in canals due to greater utilization, short response times necessary to react to emergency and weather changes and frequent shortages of water, make fast, responsive control important. In addition, with the increasing costs of manpower it is desirable to provide as much automatic operation.

The three examples presented illustrate a trend to more complex automated control. The Tehama-Colusa Canal control system in its ultimate form provides both remote control and telemetering and full automatic control. This trend is typical in petroleum, hydroelectric, and many other previously manually operated facilities. Microprocessors have reduced control system costs so that such systems are feasible for small canal systems. Development and implementation of automatic remote control systems for other Bureau of Reclamation canals will be based on the result of these applications.