Automated instrumentation at some U.S.B.R. dams

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Mesures automatiques dans des barrages américains (U.S.B.R.)

Automatische Ueberwachung von amerikanischen (U.S.B.R.) Staudämmen

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SUMMARY
In 1979, the Bureau of Reclamation began a program to automate the acquisition, storage, transmission, and evaluation of instrumentation data from selected major dams. This paper presents the status of that program and the philosophy used to develop the program and to select which dams to be included.

RESUME
En 1979 le Bureau of Reclamation a commencé un programme pour automatiser l'acquisition, l'accumulation, la trasmission et l'évaluation des donnés tirés de quelques grands barrages. L'article presente le programme et la philosophie employée pour le developper ainsi que pour le choix des barrages.

ZUSAMMENFASSUNG
1979 hat der Bureau of Reclamation ein Programm angefangen um die Erwerbung die Sammlung, die Fernsehsendung und die Einschätzung, deren Daten, die aus großen Dämme ausgewählt werden, zu automatisieren. Dieser Artikel beschreibt das Programm und wie es entwickelt wird und wie die Dämme ausgewählt werden.

1. INTRODUCTION

The primary and most important purpose of monitoring a dam with various instruments is to provide necessary information for assessing the performance of the dam for control purposes, for any indications of adverse conditions, and for continuing evaluation of the structural safety of the dam during construction, reservoir filling, and service operations (USCOLD 1986).

Most instrumentation devices can now be read with automated equipment. Over the past 2 decades, electronic technology has developed the necessary computer equipment, mini-pressure transducers, data logger equipment, and radio and satellite transmittal devices to provide the accuracy, dependability, and economically affordable systems desired.

The advantages of the automation of observations are quite clear. Although the design, installation, use, and maintenance of any automatic or partially automatic system require a thoroughly developed technology basis, the implementation of automation is much to be desired. Automation will prove inevitable whenever the automatic equipment can perform the operations required at greater speed, lower cost, and with less errors than the human operator. (ICOLD 1982)

There is, however, a valid concern that automating instrumentation at a dam may lead to over reliance on the measured results and the consequent neglect or elimination of human judgment either at the site or in the office. Human onsite observations might be minimized or evem eliminated. Adopting this philosophy could lead to a false sense of security and may represent a threat to the safety of a dam. These factors need to be recognized and avoided.

In general, advantages of automating the data collection and processing of structural behavior instrumentation at a dam include:

- Decreases labor required to measure, reduce, and portray data
- Decreases elapsed time between measurement and interpretation of data
- Provides automatic warning if limiting values for readings are exceeded
- Allows more frequent readings without significant increased cost
- Automatically transmits data to another location for evaluation
- Decreases errors in data collection and reduction
- Enables continuous long-term collection of data at the required intervals
- Enables direct entry of data into a computer data base
- Enables readings to be taken at times when equipment is not accessible due to high water or severe weather conditions

In addition to the previously discussed possible minimization of human observations, automation is also somewhat limited in regard to the following:

- Displacement measurements by geodetic methods
- Measurements of the thickness of ice in the reservoir
- The appearance or extent of new cracks in concrete or embankment dams
- The appearance of new seepage leaks

2. USBR AUTOMATION PROGRAM

The U.S. Bureau of Reclamation has long recognized the importance of instrumentation in the design, construction, and operaiton of dams under its jurisdiction. During the last 10 years, an increased emphasis has been placed on the timely use of instrumentation data for surveillance and analysis of USBR dams. Early instrumentation systems relied on manual input of hand-recorded data which was transmitted by mail, but recent emphasis has been given to automation of many of these devices with electronic transmission of data. The dam monitoring automation program encompasses a wide range of areas, from landslide surveillance to embankment and concrete dam instrumentation throughout the Western United States.

Although a few devices on USBR dams have been partially automated for a number of years, the first major or "full" automation was accomplished at Monticello Dam in California in 1981. Later, Flaming Gorge, Morrow Point, Crystal, Glen Canyon (all part of the Colorado River Storage Project) and Yellowtail Dams were automated. Figure 1 illustrates this data gathering system for the series of dams on the Colorado River. Now, automation systems are being installed at Calamus, Ridgway, and Navajo embankment Dams. It is anticipated that additional dams will be automated in the future.

The development of the USBR automation program required both the setting of goals and the flexibility to make changes during the development process. It was quickly recognized that a diverse set of needs existed involving the integration of many technical and organizational facets within the USBR. Engineers in the design office require timely presentation of structural behavior data in the form of plots, charts, printouts, etc. in order to ascertain whether the structures meet design criteria. Regional and project office personnel need this information to fulfill their operation and maintenance responsibilites. In addition, personnel at the dams need the data displays of selected instruments for inspection purposes.

To meet these diverse requirements, systems have been designed which provide for the distribution of sensor data within a dam. Data monitors are strategically located throughout a dam and linked to a master station which gathers the information for transmission outside the dam.

2.1 Types of Instruments Automated

With the use of modern electronics, virtually any type of instrument can be automated. For example, a recent article in (USCOLD 1984) the development of an automated plumbline monitor with no moving parts is described. Figure 2 shows the device while Figure 3 illustrates a comparison of automated versus manual readings. The agreement between the two methods is considered to be excellent.

The types of instruments in concrete dams which are presently automated include:

- Reservoir level
- Plumblines
- Stess meters
- Strain meters

- Uplift pressure devices
- Temperature
- Foundation deformation meters
- Seepage flow devices

Instruments either presently automated or soon to be automated in embankment dams include:

- Seepage flow devices
- Vibrating-wire piezometers
- Observation wells
- Reservoir level
- Pneumatic piezometers
- Extensometers
- Pneumatic settlement sensors
- Total pressure cells
- Measurement points

2.2 USBR Criteria for Dam Automation Selection

USBR experience thus far with automation has resulted in a realization of the advantages of automation listed earlier. It is, therefore, anticipated that the automation of readings will continue to increase.

The criteria normally used in the determination of whether to automate or not include:

- Cost benefit criteria. - The systems should be able to pay for themselves in labor savings and other benefits over a reasonable life expectancy of the equipment. Dams containing a large amount of insrumentation can potentially save a much greater amount of labor.
- Accuracy. - It has been shown that accuracy, precision, and reproduceability of results are much improved with automated devices.
- Safety. - It may be desirable at some dams, which have a high risk potential, to install an automatic alarm system together with very frequent scanning of certain instrument readings.
- Accessibility. - Some locations at certain dams may not be accessible during high reservoir level periods and some entire dams may not be readily accessible during severe winter seasons.

Any of these criteria may justify the automation of a system.

3. RESULTS

It is believed that all of the installations to date have been very successful and excellent data are flowing from these dams.

A number of lessons have been learned from the installations thus far. Those include:

- One of the major expense items for the projects was cabling. Cable lengths to provide power to each sensor and carry the analog signal back to the digitizer for recording should be kept to a minimum. From this experience, a system of smaller distributed monitors was envisioned.
- A readout device located near the sensor installation would decrease the time and effort required to install and check out the sensor.
- Each data point should be accompanied by identification information describing its function and location.
- Data from specifically developed microprocessor based instrumentation, such as the plumbline monitor, can be collected at the dam monitor through a digital interface. These data can then be labeled with time information from the system clock and transmitted in the same block of data containing other sensor scans.
- Each data set needs to be identified with location, time, and project designators.
- Each measured electrical signal should be converted into engineering values and units at the time it is scanned.
- The data should be accessible upon demand by an operator, and the system should be programmable at places both inside and outside the dam.
- Security must be provided against unauthorized or accidental intrusion into the system.
- Provisions should be made to test the memory and communications of each monitor.
- User programming of each parameter should be in a question and answer dialog (menu-driven).
- Alarm functions should be provided to alert personnel at the dam and at several other locations of possible structural problems in the dam.
- The cabinet depth should not exceed 1 foot to allow for passage in a 5-foot-wide gallery.
- Field data acquisition equipment should have onboard, battery-backed memory in case of exterior power loss.
- The system should be of modular design so that new instruments and types of data may be added.
- The system should have built in data verification so that obviously incorrect or duplicate data are identified immediately upon entry into the system.
- The system should provide for mathematical reduction of data from all instruments included.
- The system should provide for direct and automatic data entry from data acquisition hardware.
- The software should have the ability to interface with all types of data collection and communications system.
- The system should provide for outside telephone access so that data may be reviewed and additional data added.
- The system should be capable of supporting a wide range of printers and plotters.

4. CONCLUSIONS

The USBR's experience with automation this far has been very encouraging from the standpoints of accuracy, precision, repeatability, and in terms of durability of the equipment. It is envisioned that additional installations will continue to be made in the future.

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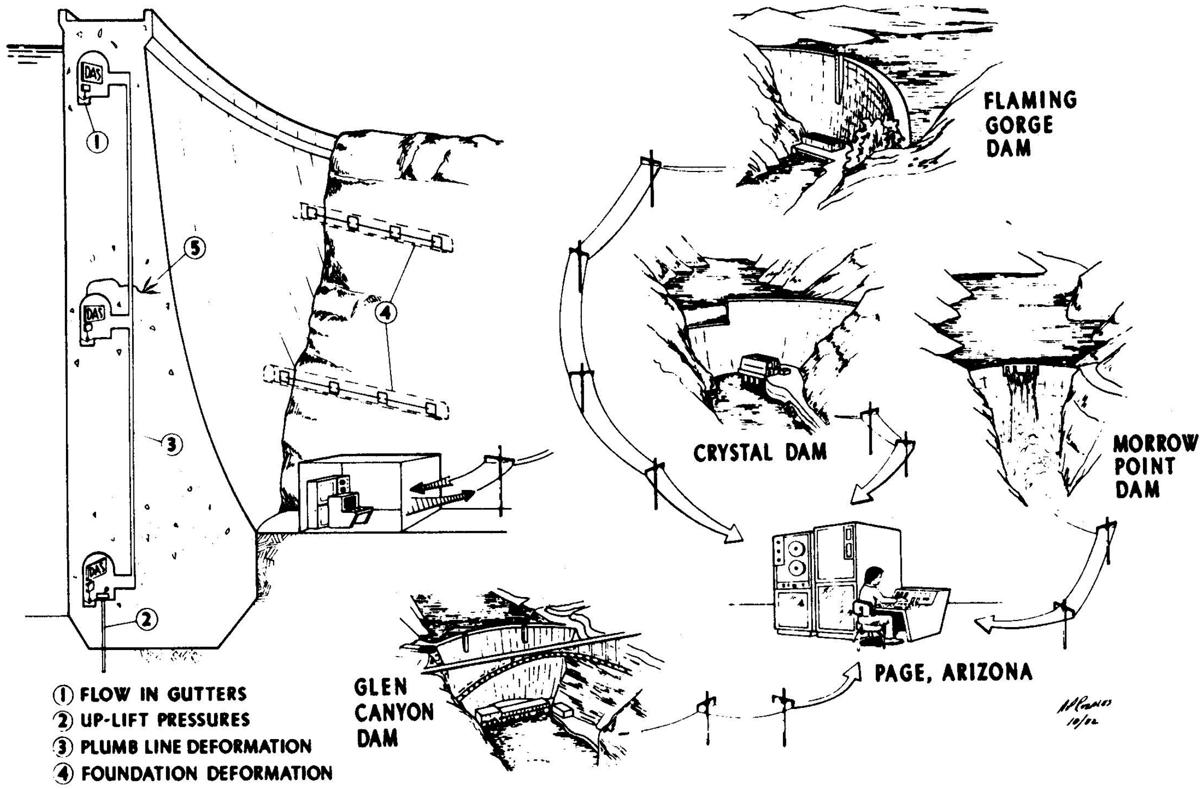

Fig. 1 Schematic drawing of integrated dam monitoring system

Fig. 2 Plumbline monitoring system
prior to installation

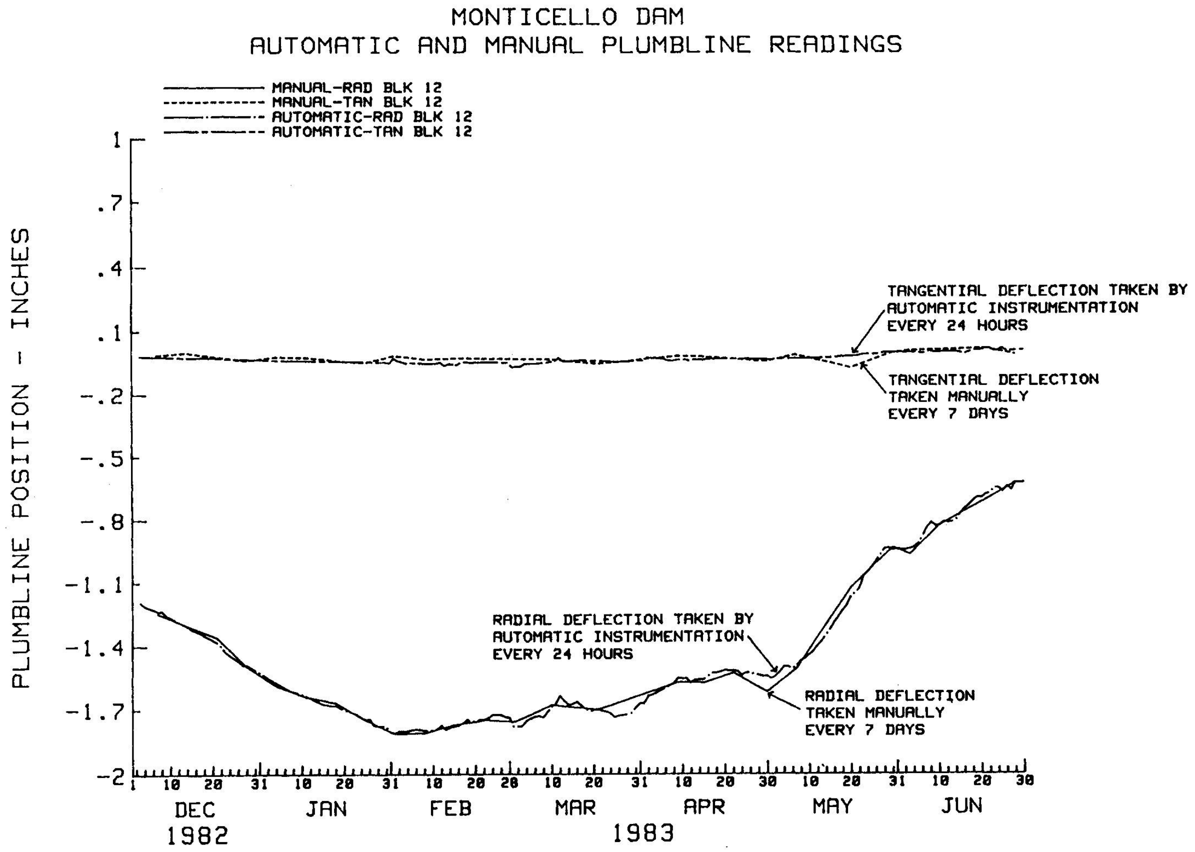

Fig. 3 Comparison of plumbline readings taken automatically and manually

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