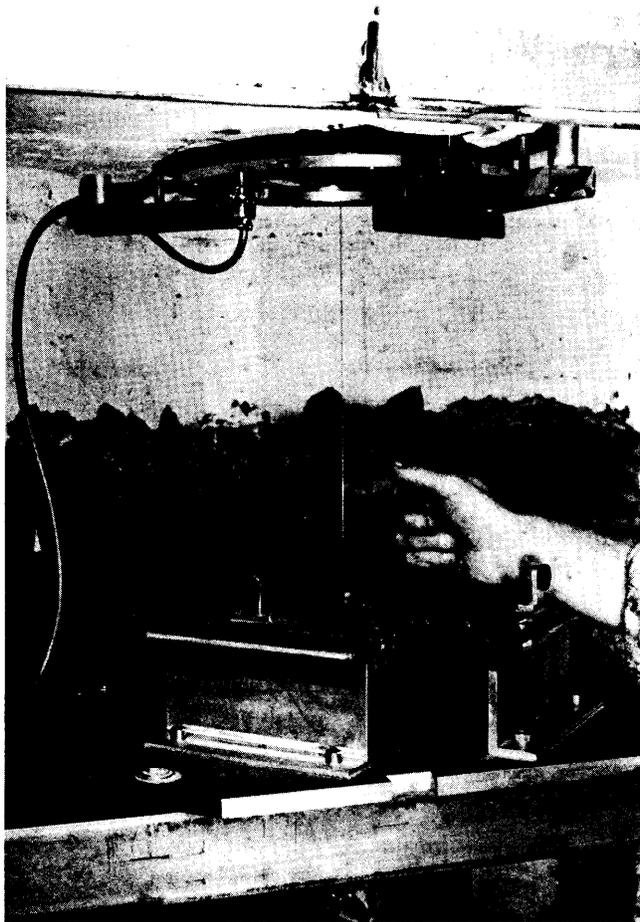




REMR TECHNICAL NOTE CS-ES-2.1

AUTOMATED SYSTEM FOR MONITORING PLUMBLINES IN DAMS



Typical cutout at a plumbline location. The sensor used with the automated system is hidden from view, except for the bottom, since it is installed up in the plumbline well. This type of installation does not interfere with the manual sighting system which, as shown here, can be left in place.

existing reading apparatus, or it can be installed during new dam construction.

ADVANTAGES: The advantages of the system are many:

PURPOSE: To describe an automated plumbline monitoring system that can be used for reading plumblines in concrete dams.

APPLICATION: Plumblines have been used in Corps of Engineers' dams to monitor horizontal deflections for many years. Typically, vertical wells are cast into a dam during construction, and plumblines are suspended in these wells from near the top of the dam. Positions of these plumbline wires are measured at various monitoring elevations in the dam to record deflections. In the past, this monitoring task has been accomplished by sending a reading party to the dam which must visit each reading station and record the location of the plumbline in the reading well by aligning a target, the plumbline, and viewscope crosshairs. The micrometer reading is then transferred to a field data sheet, and the reading party moves on to the next reading station.

An automated plumbline monitoring system has been developed that will accomplish the reading of all plumbline stations in a given dam under the command of a microcomputer, and will record all the data on disk or send the data to another computer for manipulation or plotting. The system can be installed in any existing reading station without disturbing any part of the

- a. Plumblines in a dam can be read from a remote location, such as a District office, by means of a terminal that is connected to a computer at the site, thus eliminating the need to send a reading party to the dam.
- b. Automated reading of the plumblines eliminates the possibility of misread micrometers and misrecorded movement data that are inherent with a reading party copying information onto a data sheet.
- c. Use of the automated system ensures that information taken from the plumblines is recorded and processed in a matter of minutes, rather than over an entire day.
- d. Since data reduction can be done by computer, delays normally encountered in reducing and plotting data by hand can be eliminated.

The automated plumblines monitoring system consists of sensor units, repeater units, and a controller. It can be configured for use on dams having any size and number of monitoring stations because of its modular design; the cost of installing a system becomes more efficient with the greater number of units. Measurement resolution is much higher with the system than with manual reading because of the method of operation of the instrument. The manufacturer states that the sensor is capable of resolution to ± 0.0001 in. Further, the measurements are fully objective and not subject to the idiosyncracies of different instrument readers. The specifications of the instrument state repeatability to ± 0.0002 in. The system is conservatively designed using no moving parts to wear or become fouled with debris. Also, no periodic calibration and only minor installation calibration are needed.

LIMITATIONS: The sensor of the automated plumblines monitoring system is a highly precise instrument and is also somewhat delicate. Its location in the plumblines well makes it vulnerable to damage by any solid debris that may fall down the well. The instrument is protected against water falling down the well, but ice or any other solid debris (e.g., spalled concrete) could damage the sensor. Updrafts rising in the well, caused by the cut-out doors to two reading stations being left open at the same time, may carry water upwards in the plumblines well. In instances such as these, the water can settle on optical surfaces that have been protected from falling water but not rising water, thereby reducing the operating capabilities of the instrument. If this is a common occurrence, then the sensor will need to be cleaned periodically.

PERSONNEL REQUIREMENTS: Use of the automated plumblines monitoring system greatly reduces the need for operating personnel performing this task. With the exception of installation and maintenance personnel, none are needed. The system reads and records the position of the plumb wire automatically either on manual command or periodically under the command of a computer program.

EQUIPMENT:

- a. Principle of operation. The system works on the principle of interrupting light beams to determine where the plumblines wire is located. Each unit contains two sets of sensors to identify the X and Y location of the plumblines. The sensors consist of a

solid-state photodiode array line-image camera and LED (light-emitting diode) light source for each of the X and Y axes. These LED light sources produce parallel beams of light or a shadow on the cameras. This image is in turn interpreted as either lit (where there is no shadow) or unlit (where the shadow of the plumb-line appears) and documents the location of the plumb wire. The information is then sent to a computer terminal at the dam for further data processing.

- b. Repeater box. Because of long distances involved in monitoring plumblines in dams, the instruments are connected through repeater units which condition the signal as it travels from instrument to computer. These repeaters allow almost any combination of sensors as well as unlimited flexibility in position of the sensors and in their distances from the controller.
- c. Computer equipment. The signal from the sensor is sent to a microcomputer-controller at the dam where it is processed to extract the position data. The image from the camera is corrected to get an enhanced, corrected image. The computer-controller, which is supplied as part of the system, is capable of controlling up to 24 sensors. Additional equipment that will be needed includes a printer if hard copy information is required at the dam-site, a modem to connect the site computer to a host computer elsewhere, and the required interfacing cables.
- d. Manufacturer and distributor. At present, the system is being manufactured on an order-by-order basis by its designer: Spectron Engineering, 800 West 9th Ave., Denver, CO 80204.
- e. Availability. Since the instruments are made to order, there is an understandable delay between order and delivery. Parts and electronic boards are ordered to custom fit the equipment to the purchaser's needs, and incur a great amount of availability delay. Assembly of the sensors takes about 1 month, and final assembly at the site also takes about 1 month. The manufacturer states that a delay of from 4 to 6 months from order date can be expected.
- f. Costs. The cost of the system is highly related to the quantity of sensors and repeaters that are ordered. Because the controller is a major part of the expense of the system, a system that consists of 1 sensor, 1 repeater, and 1 controller will have a higher relative cost than a system that has 10 sensors, 10 repeaters, and 1 controller. For example, using a price quote that was accurate as of July 1984, a system that included 1 sensor, 1 repeater, and 1 controller would cost about \$19,000 to \$20,000, whereas a system that has been purchased by the Corps for use at Lock and Dam 26 consisting of 2 sensors, 3 repeaters, and 1 controller (including all installation, customizing, hardware, and cables) cost \$25,900.
- g. Availability of specifications. The manufacturer has system specifications and will include them with the installed system. Since the systems are built to specifications, the statistics on each will vary from system to system.

REFERENCE: a. Automatic plumblin monitoring system. L. Carpenter,
T. Hutchcroft, and N. Herz. In: Water Power and Dam
Construction, Vol 39, No. 6, pp 47-50, Jun 1987.