U. S. DEPARTMENT OF THE INTERIOR

Geological Survey

Water Resources Division

SYSTEMS FOR MONITORING AND DIGITALLY RECORDING WATER-QUALITY PARAMETERS

By

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ABSTRACT

Digital recording of water-quality parameters is a link in the automated data collection and processing system of the U.S. Geological Survey. The monitoring and digital recording systems adopted by the Geological Survey, while punching all measurements on a standard paper tape, provide a choice of compatible components to construct a system to meet specific physical problems and data needs. As many as 10 parameters can be recorded by an instrument, with the only limiting criterion being that measurements are expressed as electrical signals.

INTRODUCTION

The mounting concern about water pollution and water-quality control has triggered an ever-increasing demand for accurate, current water-quality data. To meet this demand, the U.S. Geological Survey has turned to the digital computer and other automated methods. The purpose of this paper is to describe automated systems, designed and adopted by the Survey, for continuous monitoring of water quality.

The use of the digital computer is a giant step forward in quickly and accurately processing large volumes of data. However, the data must be in a form the computer can accept. Most of the water-quality monitoring systems currently in operation record data as inked lines or dots on paper charts. The data are then manually extracted from the charts and placed in a computer input form. The Geological Survey is eliminating this manual, time-consuming task by designing and adopting systems for monitoring and digitally recording water-quality parameters. The punched-paper tape from a digital recorder (fig. 1) can be machine processed for the computer. Thus, a truly automated system for collecting and processing large volumes of water-quality data is now available. Another tremendous advantage in using the digital punch for recording water-quality parameters is that the same recorder is currently used by the Geological Survey for recording river-stage and ground-water level data (Carter and others, 1963). Now it is possible to collect surface-water, ground-water, and quality-of-water data in a common form for computer processing.

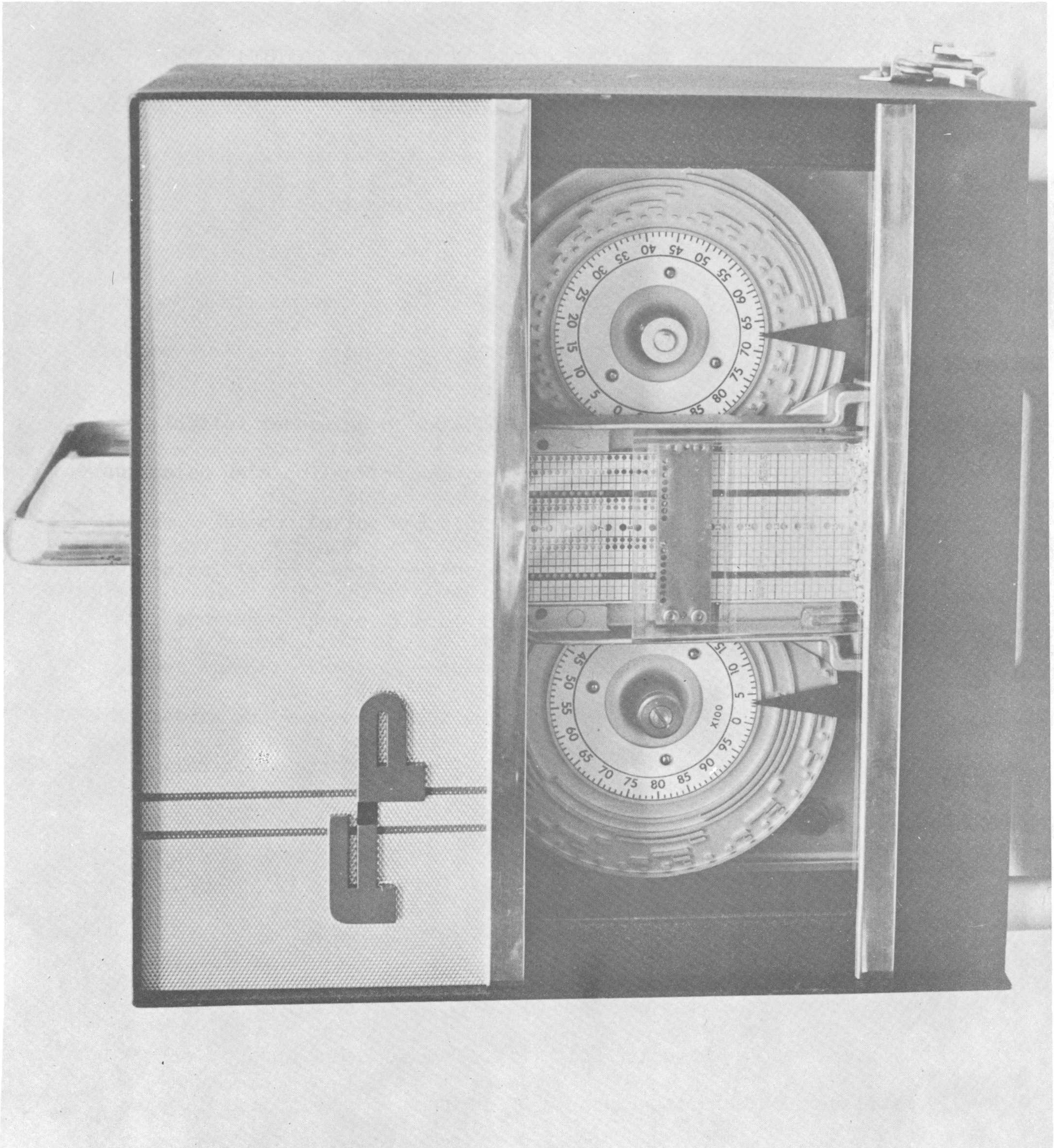

Figure 1.--Digital Recorder

Two different types of systems have now been designed for sensing and recording water-quality parameters utilizing this digital recorder. One type is a modular system which uses potentiometric sensors. In its basic form, it meets the needs of simple in situ monitoring and recording but can easily be expanded to meet more complex requirements. The other type of system uses resistance-type sensors for in situ monitoring in remote locations where only battery power is available.

DIGITAL RECORDER

The digital recorder is basically a device for encoding and digitally recording the rotational position of an input shaft. It can be used to record any event that can be expressed in terms of an angular shaft position. Specifically, the instrument is a slow-speed, punched-paper tape recorder. Consequently, more than one variable can be sequentially recorded on the same instrument, if an electrical means of positioning for each variable and switching between them is provided.

SYSTEMS USING POTENTIOMETRIC SENSORS

The heart of the modular system using potentiometric sensors is a programmed, servo-drive unit (fig. 2). It is designed to accept a maximum of 10 separate channels of input from potentiometric sensors and to automatically program these inputs into the digital recorder. The unit consists of a measuring circuit for each channel, a programmer, a solid-state amplifier, and the drive unit.

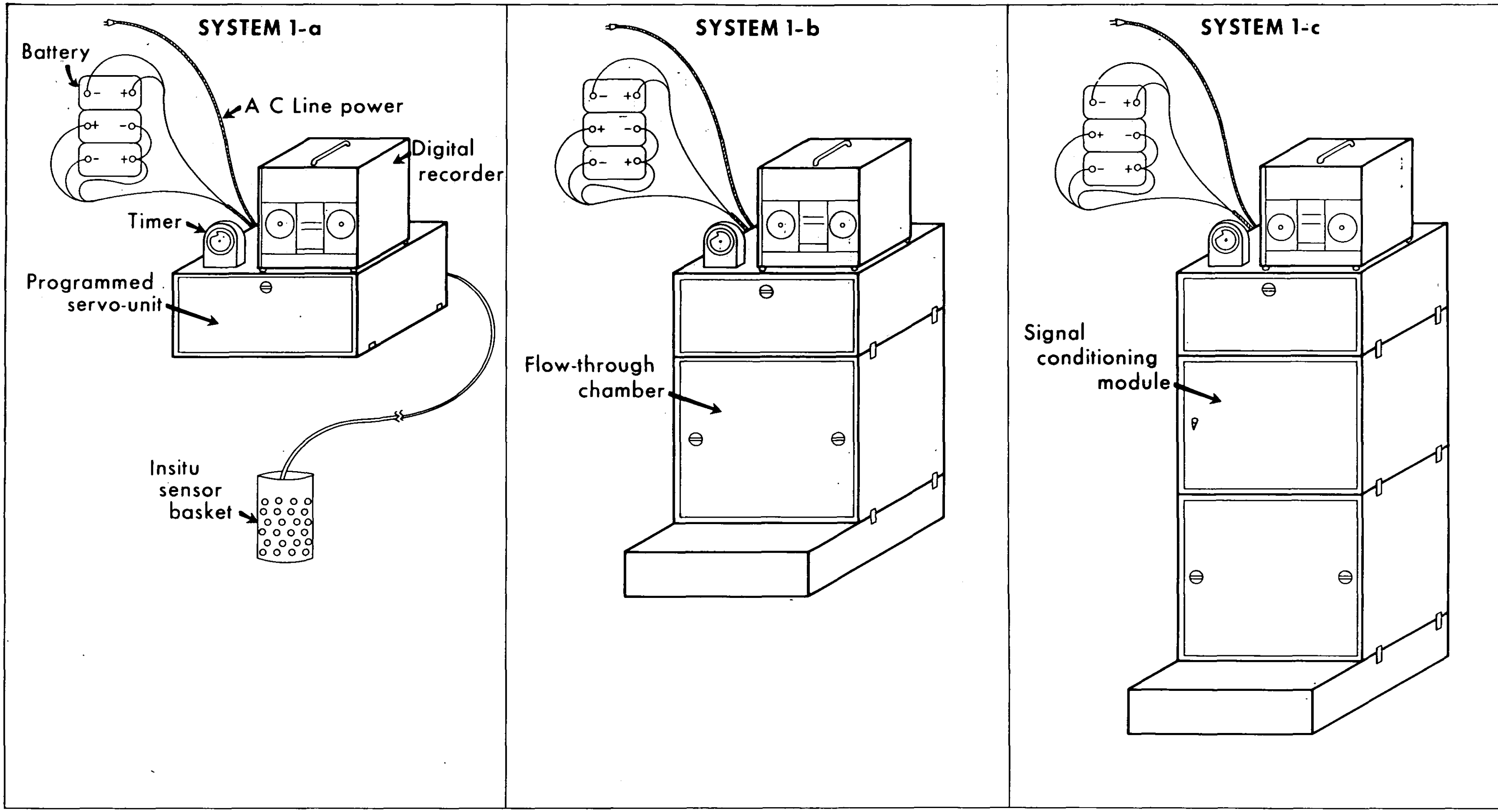

Figure 2.--Potentiometric System

Each channel has an individual, interchangeable measuring circuit to accommodate the variable inputs from different sensors. These circuits are precision resistor networks for voltage adjustment; thus each circuit has individual span and zero adjustments. Circuits, up to the maximum 10 channels, can easily be added to or removed from the system in the field. The 10 circuits share a common amplifier and slide wire through the programmer.

The programmer is a mechanical switching mechanism which is activated by an external timer at selectable intervals of 15, 30, or 60 minutes. (The timer is the standard timer used with the digital recorder by the Geological Survey.) The programmer, in turn, switches power to the system and indexes the operation to Channel 1. A servo-system positions the tape punch to the proper value; a punch command signal is issued, and Channel 1 is recorded. The system is then indexed to Channel 2, if active, and the above sequence is repeated until all active channels have been indexed and recorded. At the completion of the punch command for the last active channel, the punch command circuit is inactivated, the programmer motor drives through any inactive input channels to the initial index position and all power to the system is switched off. Each channel requires approximately 30 seconds for indexing, balancing, and recording. Any number of sequential channels from 1 to 10 may be selected by the user. A dial indicates which channel is being recorded or if the programmer is inactive.

The amplifier is a solid-state, chopper-stabilized, servo amplifier. The chopper may be bypassed on Channels 1 and 2 so that sensors with alternating current output, such as specific conductance, may be fed directly into the amplifier.

The drive unit for the digital recorder is a separate power head mounted to the recorder frame. No modification of the recorder is required for this mounting. A drive gear mounted directly on the shaft of the punch unit is driven by reduction drive from the motor which also positions the slide wire of this unit. The output of the drive unit, 10 revolutions of the shaft position, is linearly proportional to the input variable.

Three manually-actuated switches are provided in the system, so that it can be inspected and serviced without a break in operations. One switch stops the programmer motor on any channel for calibration, inspection, and adjustment. A spring return switch overrides the timer between recording periods and actuates the programmer to sequence through all of the channels. A second spring return switch indicates a fixed test value and provides a quick check of the amplifier and drive unit.

The power requirements for this unit can be met by three 7.5-volt dry cell batteries or a-c line power with battery as stand-by. Both capabilities are an integral part of the unit. Battery life is longer than 30 days when 4 channels are utilized.

Figure 2 illustrates various combinations employing the programmed servo-drive unit. System 1-a consists of the digital recorder, timer, the programmed servo unit, and in situ sensors. This system can be operated from battery power. However, if more than four input channels are used, the power requirements become excessive for extended battery operation and a-c line power should be used.

System 1-b is identical to System 1-a, except that a submersible pump is used to pump the water to a sampling chamber. This chamber has seven parallel compartments for housing sensors. Thus, each sensor receives water that has not been contaminated by the other sensors. Because of the pumping, power requirement is high and a-c line power must be used. System 1-b has two distinct advantages over 1-a. The placement of the sensors in a sampling chamber makes it more convenient to inspect and service them, and more protection is provided for the rather sizable investment in the sensors.

System 1-c is identical to System 1-b, except that a unit containing individual amplifiers for each channel is added. These amplifiers are used to condition the low-level signals and make them available continuously so they may be telemetered. In Systems 1-a and 1-b, the single amplifier is time-shared and signals are available in conditioned form for only a brief period, hence System 1-c is recommended when telemetry is planned.

Since there are no identifying codes for the various channels, it is highly desirable for punches to remain in proper sequence. An interruption in power could result in the loss of an unknown number of channels of information. This would not only interrupt the data sequence but would also disrupt the time correlation. To preclude this from happening, these systems have provisions for stand-by battery operation.

POTENTIOMETRIC SENSORS

A variety of data sensors are commercially available for use with the potentiometric systems described above. Among them are sensors to determine water temperature, wet and dry bulb air temperatures, specific conductivity, dissolved oxygen, oxidation-reduction potential, pH, turbidity, sunlight intensity, wind velocity, and wind direction. The outputs of all of these sensors are linearly proportional to the variable being measured and are automatically compensated for temperature variations. A brief description of each of these sensors follows:

1. Temperature sensors - Temperature is sensed by a thermocouple which produces a linear d-c millivoltage output proportional to the temperature (°F).

2. Conductivity sensor - The conductivity sensor consists of six electrodes (two current electrodes and two parallel pairs of voltage-measuring electrodes) arranged to make the a-c millivoltage output of the sensor essentially independent of algae growth and dirt accumulation. An integral temperature compensator automatically refers all measurements to 25°C, according to the standard potassium chloride-conductivity relationship. The output of this sensor is linearly proportional to specific conductivity (micromhos at 25°C).

3. Dissolved Oxygen sensor - The dissolved oxygen sensor is a polarographic transducer which senses the amount of dissolved oxygen in the water sample and produces a proportional d-c millivoltage output. It is temperature compensated for water temperature changes from 32°F to 90°F to produce a linear output proportional to the concentration (parts per million) of dissolved oxygen.

4. Oxidation-Reduction Potential sensor - The ORP sensor assembly uses a platinum-potential electrode and a reference electrode. The output from this sensor is connected to an impedence-matching signal conditioner which produces a usable d-c output.

5. pH sensor - The pH sensor consists of a glass electrode, a reference electrode, and a thermocompensator which automatically corrects for temperature variations. The output from this sensor is connected to an impedance-matching signal conditioner which produces a usable d-c output.

6. Turbidity sensor - The turbidity sensor is housed in a separate sampling tank attached to the system. The sensor is mounted with its viewing end about a quarter of an inch above the water level. To minimize accumulation of sediment, water enters the tank near the center; a portion flows out over the spillway near the top, and the remainder flows through a drain at the bottom. The optical sensor head contains an incandescent lamp, lens system, photocell, compensating network, and regulated power supply. The photocell detects the amount of light reflected from particles in suspension in the water sample and supplies a d-c millivoltage output proportional to the amount of material in suspension.

7. Sunlight Intensity sensor - A 10-junction pyrheliometer is used as a sunlight intensity sensor. A thermopile in contact with concentric silver rings having black and white surfaces senses the temperature differences and converts them into a d-c millivoltage signal proportional to the sunlight intensity.

8. Wind Velocity sensor - The wind velocity sensor is a standard Weather Bureau cup-type anemometer driving a d-c tach generator. Its output is a d-c voltage linearly proportional to rate of rotation.

9. Wind Direction sensor - The wind direction sensor is a weather vane which positions a guide-wire to produce an output voltage proportional to direction.

SYSTEM USING RESISTANCE-TYPE SENSORS

The system for recording from resistance-type sensors (fig. 3) is a less complex system than the modular systems already described and is designed for in situ operation only (Smoot, 1965). Being less complex, it has a lower power requirement, and lends itself well to battery-powered operation in remote locations. This system consists of a digital recorder, timer, the sensors, and a programmed servo-drive unit somewhat similar to the one previously described for the potentiometric system.

The programmed servo-drive unit of this system is also designed to accept up to 10 separate channels of input and automatically program them into the digital recorder. This unit consists of a programmer, a solid-state oscillator, amplifier, discriminator, switch, three of the arms of a Wheatstone bridge, and a drive unit.

The programmer and the drive unit operate in a manner similar to the potentiometric system. The output of the oscillator is used to energize a Wheatstone bridge. Three arms of the bridge are made up of several fixed resistors and the precision slide wire in the drive unit.

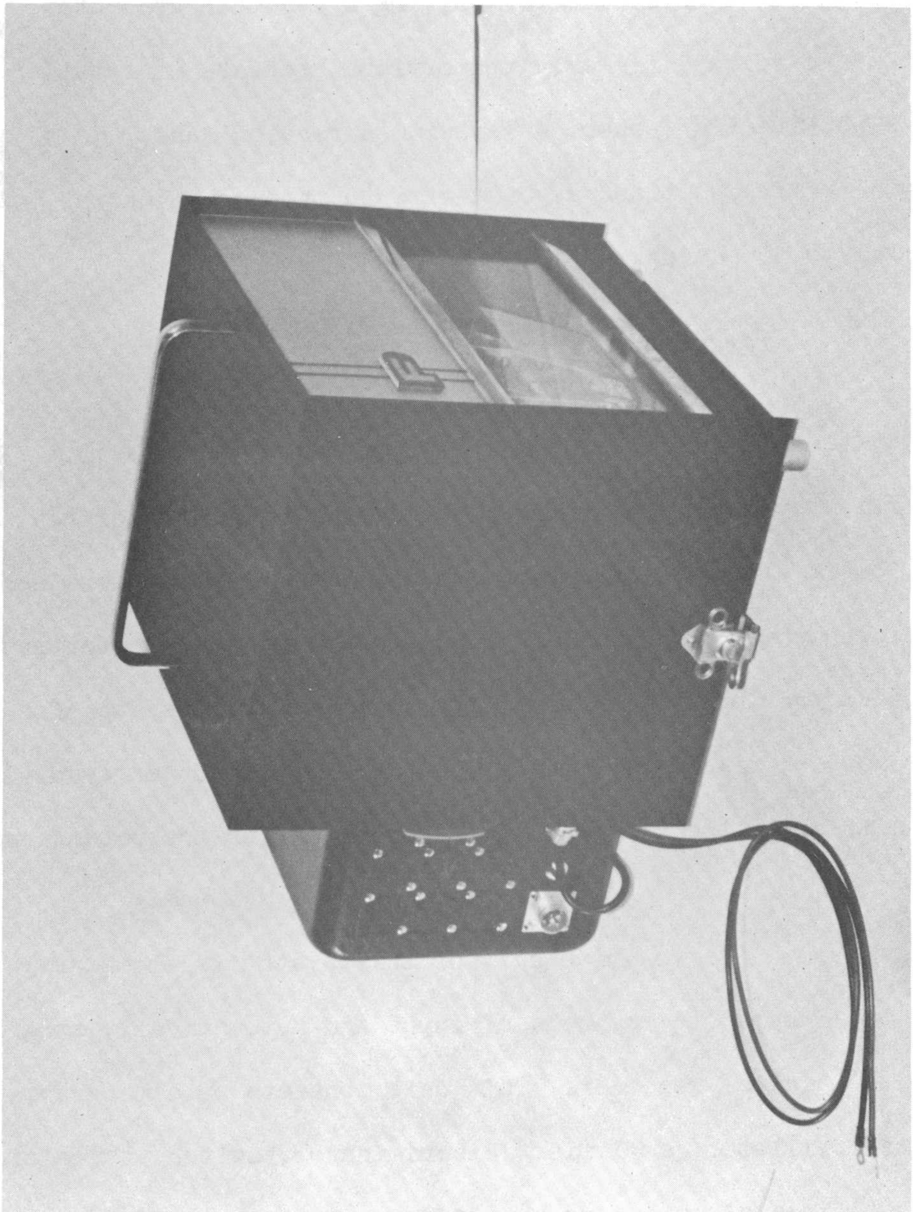

Figure 3.--System for Recording from Resistance-Type Sensors

The bridge is completed by the programmer sequencing the various sensors into the fourth arm. Any imbalance or error signal from the bridge is amplified. The signal is then compared to the original signal from the oscillator in the discriminator. The output of the discriminator is a d-c voltage which is dependent upon the direction of bridge imbalance. The signal activates the motor of the drive unit which positions the slide wire, thus balancing the bridge and positioning the recorder for punching.

RESISTANCE-TYPE SENSORS

Several data sensors of the resistance type are commercially available. Among them are sensors for water temperature, wet and dry bulb air temperatures, specific conductivity, and soil moisture. A brief description of each of these sensors follows:

1. Temperature sensors - Thermister probes, temperature sensitive resistors, are used for sensing all the above-mentioned temperatures.

2. Conductivity sensor - Water conductivity is sensed by dip-type cells consisting of two carbon or platinized nickel electrodes. These cells are available in a wide range of cell constants.

3. Soil moisture - A soil moisture cell consisting of a plaster-of-paris block with embedded screen electrodes can be used as a relative soil moisture sensor with this system. This type of cell is most accurate in the range from field capacity to vegetal wilting point.

SUMMARY

The development of the two types of monitoring systems now makes it possible to record digitally many common water-quality parameters. A great degree of flexibility and versatility is afforded by the systems in recording a variety of variables on a single-paper tape in a digital format with a fixed, known-time relationship. Equally as important, data are in a usable form for the complex computations and correlation analyses by electronic data processing.

ACKNOWLEDGMENTS

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