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APPLICATION OF A MICROPROCESSOR SYSTEM TO STREAM MONITORING*

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ABSTRACT - Low-level liquid wastes originating from the Oak Ridge National Laboratory (ORNL) are discharged, after treatment, into White Oak Creek, which is a small tributary of the Clinch River located in east Tennessee. Samples of White Oak Creek discharges are collected at White Oak Dam by a continuous digital proportional water sampler and analyzed weekly for radioactivity. The sampler contains a control system with a microprocessor that has been programmed to solve nonlinear weir equations. This system was designed and installed at ORNL by the Instrumentation and Controls Division and was tested by the Environmental Surveillance and Evaluation Section of the Industrial Safety and Applied Health Physics Division. The control system was designed to measure water flow rates from 0 to 334 ft^3/sec to within 0.1%. Results of our test program and possible applications to other liquid sampling needs are discussed.

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BRIEF DESCRIPTION OF WHITE OAK AREA

White Oak Creek (WOC) and Melton Branch tributary surface streams, which flow through the Oak Ridge National Laboratory (ORNL) reservation, receive treated low-level radioactive liquid waste which originates from various Laboratory operations. The creek receives additional low-level liquid waste generated by seepage of radioactive materials from intermediate-level liquid waste holding ponds, hydrofracture sites and solid waste burial grounds. Before converging with Clinch River, both streams flow into White Oak Lake (WOL), a 20-acre (8-ha) impoundment formed in 1943. White Oak Lake serves as the final settling basin for ORNL waste management. The lake was created using a highway fill dam, forming White Oak Dam (WOD), see Fig. 1. The spillway was constructed of a steel sheet piling wall driven in the form of a square around the upstream end of the concrete culvert forming a weir through which WOC flows. A vertical sliding gate is used to control flow water at elevations between 744 and 750 feet above sea level. Water from WOL discharges through the weir at an average flow rate of 15 ft^3/sec (425 liters sec^{-1}) with minimum of $\sim$ 3 ft^3/sec to a maximum of $\sim$ 1000 ft^3/sec. The creek meanders for approximately 0.6 miles (1 km) and empties directly into the Clinch River.

The criteria for acceptable amounts of pollution discharged into the environment have been repeatedly lowered. In order to characterize accurately the concentration of pollutants in the environment, a large number of samples are often needed. Logistic and economic problems of sample collection establish practical limitations on the number of samples taken. In order to determine whether the Laboratory's discharges meet federal water-quality standards, monitoring the quality and quantity of the liquid effluent is required. The importance of monitoring WOD, which is the last control point for the liquid discharges from ORNL, require flow-proportional sampling. This sampling is controlled by a microprocessor.

INTRODUCTION TO MICROPROCESSORS

A microprocessor (μP) is the vital part of a microcomputer. It is the central processing unit which performs the calculating and decision functions, and in microelectronics μP's are fabricated on a single silicon substrate of very small size (half a centimeter on a side). These μP's, along with memory and peripheral circuitry, form the complete microcomputers whose complexity falls somewhere between conventional minicomputers and small hand-held calculators. These complete microcomputer systems are assembled on a board whose area does not exceed this page. Microprocessors can lower the cost and increase the flexibility of electronic equipment. When many functions must be performed, μP's can be used economically to replace or upgrade handwired or random-logic designs involving scores of standard digital equipment (To76).

At the present time, about 20 U.S. companies are now manufacturing some 30 different designs of μP chips, ranging in price from $10 to $300. More than 120 companies are incorporating these chips in microcomputer

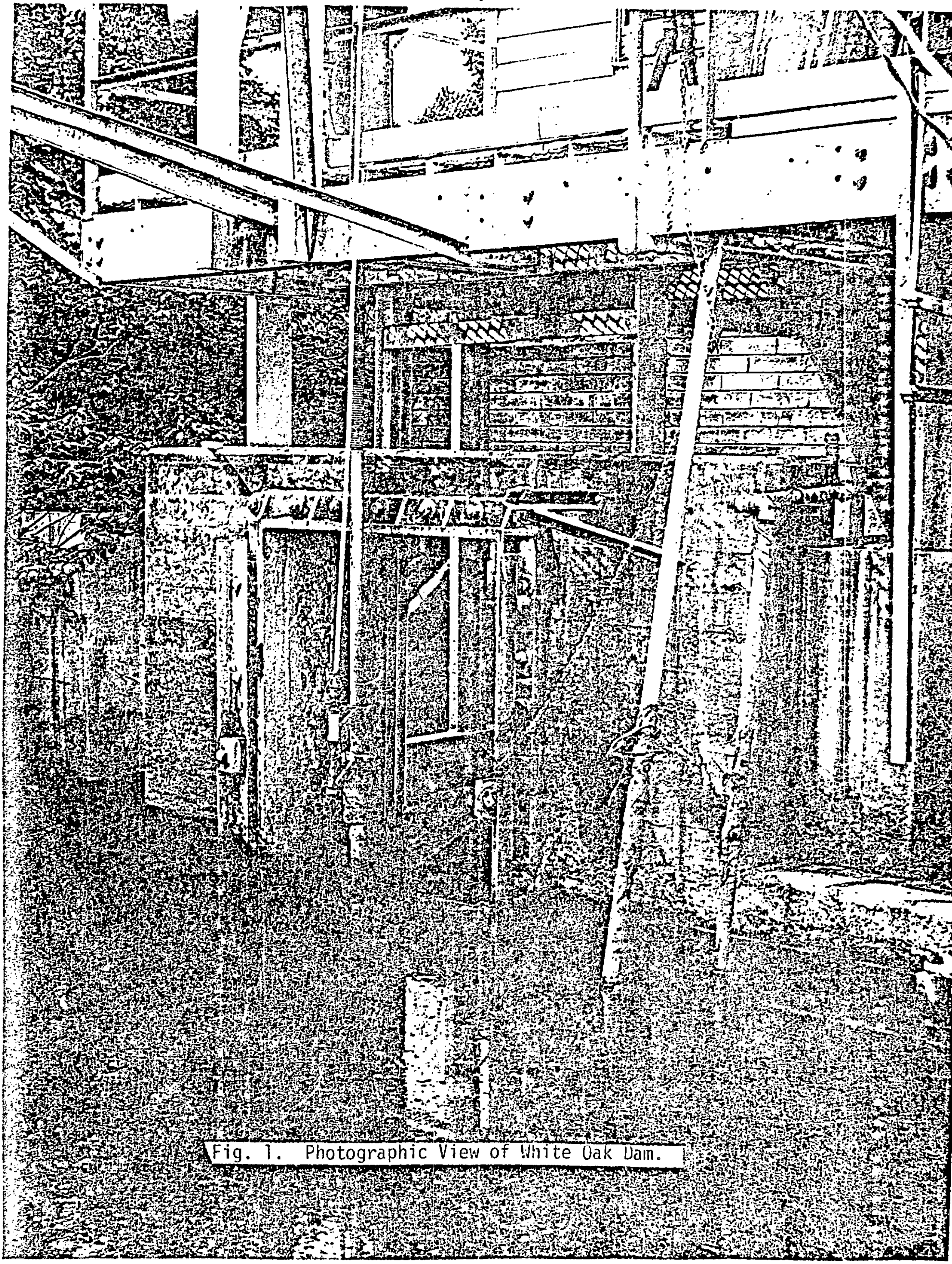

Fig. 1. Photographic View of White Oak Dam.

systems selling for $100 and up, and the number of applications for μP's is proliferating daily in industry, banking, power generation, and consumer products (To77).

DESIGN OF SAMPLING SYSTEM

The microprocessor controlled sampling system for WOD was designed and installed at ORNL by the Instrumentation and Controls Division (Ro75) and tested by the Environmental Surveillance and Evaluation Section of the Industrial Safety and Applied Health Physics Division. The system was so designed that it takes an equal amount of a water sample for each 10,000 ft^3 of water that flows over the weir. The pre-established requirements for the system were that it should measure 10,000 ft^3 of water within 1% and that it should take repeatable water samples at all anticipated flows. The computation of the volume of discharged water involves two different nonlinear relationships between water height and water flow and requires integration. The microcomputer used for the system was the Intel SIM 8-01, utilizing the 8008-1 microprocessor; this system is equipped with 1K of random-access memory and 2K of programmable read-only memory and is on one printed-circuit board. It is interfaced to an analog input signal, a mechanical water sampler, and three control switches. The control program performs a nonlinear conversion from water height to water flow and numerically integrates flow. The program also controls the mechanical sampler and can test most of the system, including itself, for proper operation (Ro75).

The relationship between height (H), in feet above sea level, and water flow (F), in ft^3/sec are given in Roberts(75). There is a point of discontinuity in the relationship between F and H when the water height is above 750 ft (top of dam) above sea level, because the water actually spills over the dam during heavy rains, thus changing this relationship. Since the F and H relation is nonlinear and in two distinct pieces and the stability and calibration accuracy of analog function generators are not sufficient for this application, digital conversion is more accurate and repeatable than analog conversion (Ro75). Also, typical water-flow rates might be anywhere from < 3 ft^3/sec in dry weather to > 1000 ft^3/sec in spring flooding. This dynamic range of > 333:1 is more accurately accommodated by a digital system than an analog one. Further, considering that the flow must be integrated over times as long as an hour between samples, digital integration is preferred to analog, as a digital integrator does not decay or drift over a long period of time (Ro75).

The major computational tasks for this sytem are the conversion from height to flow and the numerical integration of flow. To accomplish this objective, H is converted to F by a table-lookup and linear interpolation method rather than by a time-consuming floating-point solution to the equations given by Roberts(75). The lookup table of flow values corresponding to 251 equally-spaced height values is stored in one 256 x 8 PROM (programmable read-only memories). This lookup table is presented in Table 1; the flow in ft^3/sec times the time between samples in sec

Table 1

Interrelationships Among Elevation, Flow, and Sampling Time

Elevation		Flow		Time Between Samples
Scaled	Actual (Ft)	Scaled	Calculated (ft^3/sec)	(HRS:MIN:SEC)
0	745.00	0.0	0.00	1340: 56: 39
25	745.13	0.1	0.58	4: 48: 41
50	745.25	0.2	1.61	1: 43: 53
75	745.38	0.3	2.93	0: 56: 53
100	745.50	0.5	4.50	0: 37: 03
125	745.63	0.7	6.27	0: 26: 33
150	745.75	0.9	8.24	0: 20: 13
175	745.88	1.1	10.37	0: 16: 04
200	746.00	1.4	12.66	0: 13: 09
225	746.13	1.6	15.10	0: 11: 02
250	746.25	1.9	17.68	0: 9: 25
275	746.38	2.2	20.39	0: 8: 10
300	746.50	2.5	23.23	0: 7: 10
"				
"				
"				
2000	755.00	200.0	1861.0	0: 0: 53

For $H < 750$ ft: ft^3/sec * Time between Samples $\cong$ 10,000 ft^3

For $H > 750$ ft: ft^3/sec * Time between Samples $\cong$ 100,000 ft^3

will always give a product of 10,000 ft^3 regardless of flow. Further, the stored F and H values are scaled to simplify the digital read-out systems; these scaled values correspond to actual values as seen in Table 1.

The completed μP system is shown in Fig. 2 as a block diagram (Ro75). Since the digital voltmeter accepts voltages in a range from 0 to 2V, the analog voltage, which is proportional to water height, is scaled to this range. A pulse actuates a digital time that controls the mechanical water sampler when the flow data are summed to an integrated water volume of 10,000 ft^3. Water is sampled by diverting a continuous flow of thoroughly-stirred water, and is pumped from the stream into a container for 3.3 sec (Ro75).

Figure 3 shows the panel display of the completed microprocessing system. The scaled water height and flow numbers (Table 1) are displayed on the front of the system. Controls on the front panel (Fig. 3) include a switch to reset the integrated water volume to zero for the purpose of initializing the system, a display inhibit switch for turning the water-height and water-flow displays off and on, a switch which allows an operator to take a water sample at any time, and a test switch to perform several checks of the system hardware and program (Ro75).

A schematic diagram showing the overall sampling and control system is shown in Fig. 4. The height of the water is measured by a float inside a stilling well. This float is connected to a pulley assembly which translates the vertical movement of the water height to the rotation of the pulley shaft. This rotation of the pulley shaft is connected to a chart recorder for the purpose of backup in determining the integrated flow. A potentiometer connected to the pulley shaft also produces an analog voltage proportional to the water level. The analog voltage is then scaled to a range from 0 to 2V for acceptance by the digital voltmeter (Ro75). As stated previously, when the flow data is summed to an integrated volume, a pulse activates the timer for control of the solenoids on the mechanical water sampler. The mechanical funnel directs the water sample into either the low ($H < 750$ ft) or high ($H > 750$ ft) flow-sample container once the solenoid is activated. The water is collected in two 55-gallon stainless-steel drums for a one-week period. One drum receives the sample during low-flow conditions, the other during high-flow conditions.

Several alarm set points are built into the μP system (i.e. pump failure, power failure, etc). These alarm signals are transmitted to the Environmental Monitoring (EM) Control Center using telephone lines.

In addition, the creek activity is monitored on a "real-time" basis using five submerged G-M tubes in a lead-shielded adjustable head pot (see Fig. 4). The signal from these tubes is transmitted over telephone lines to the EM Control Center.

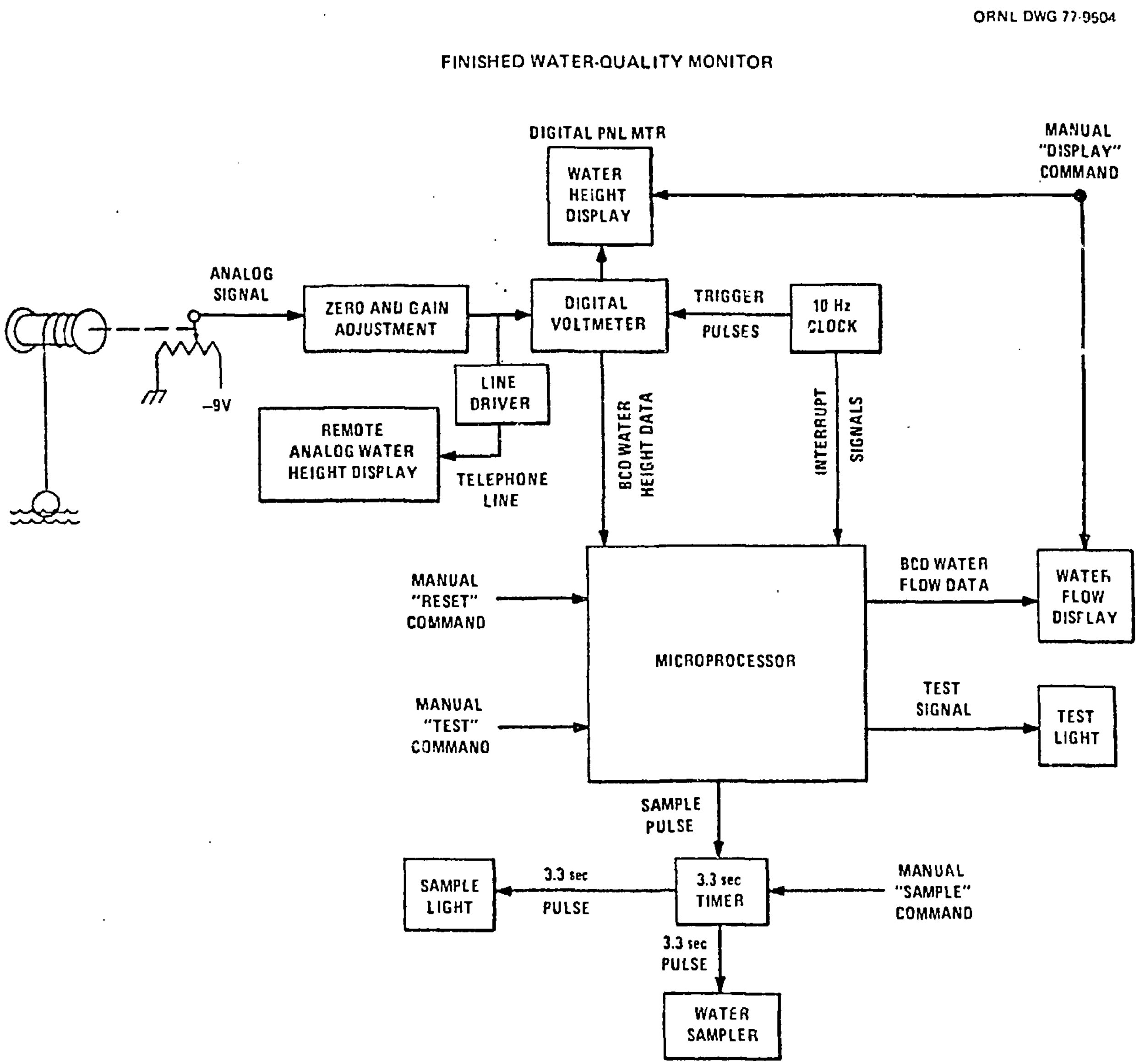

Fig. 2. A Block Diagram of The Finished Microprocessor.

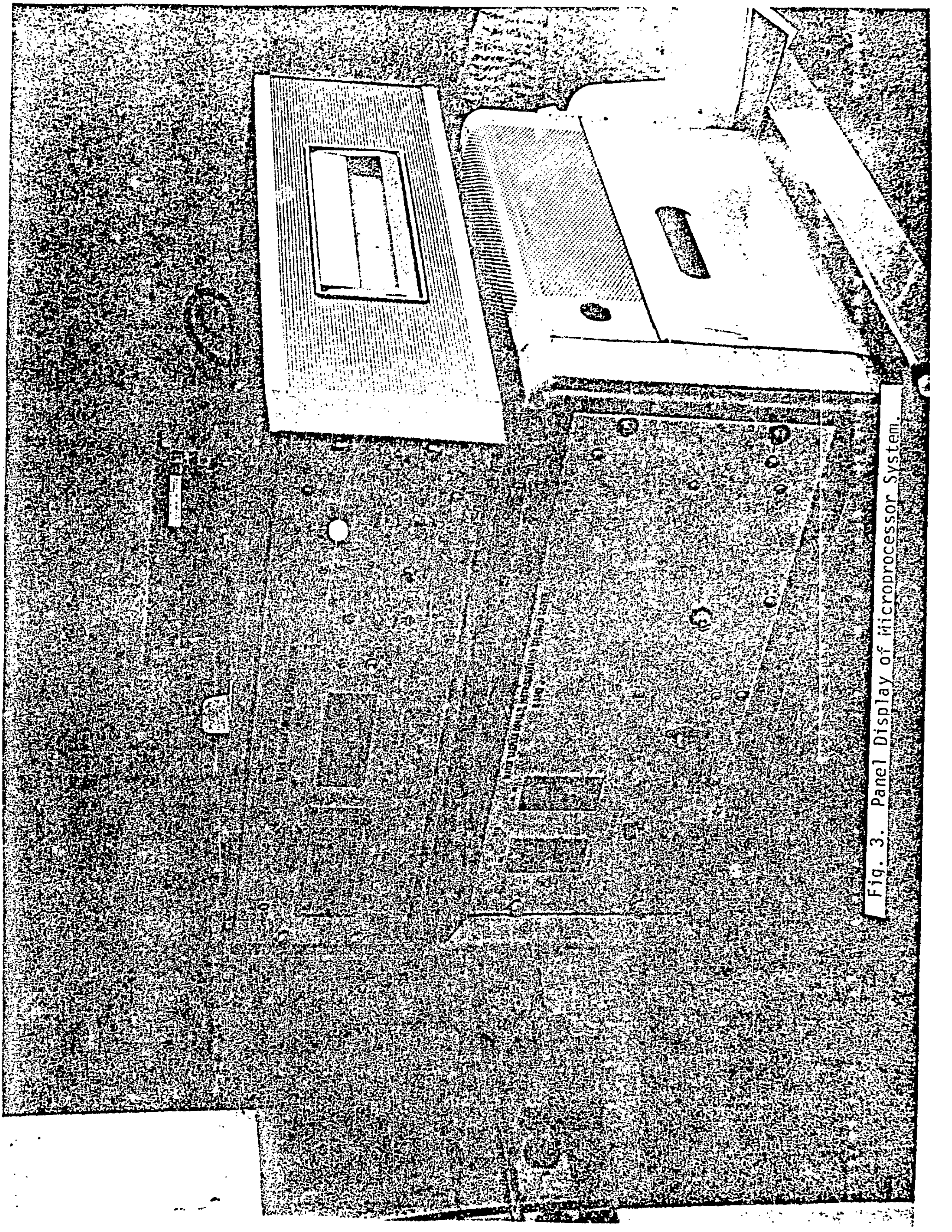

Fig. 3. Panel Display of Microprocessor System.

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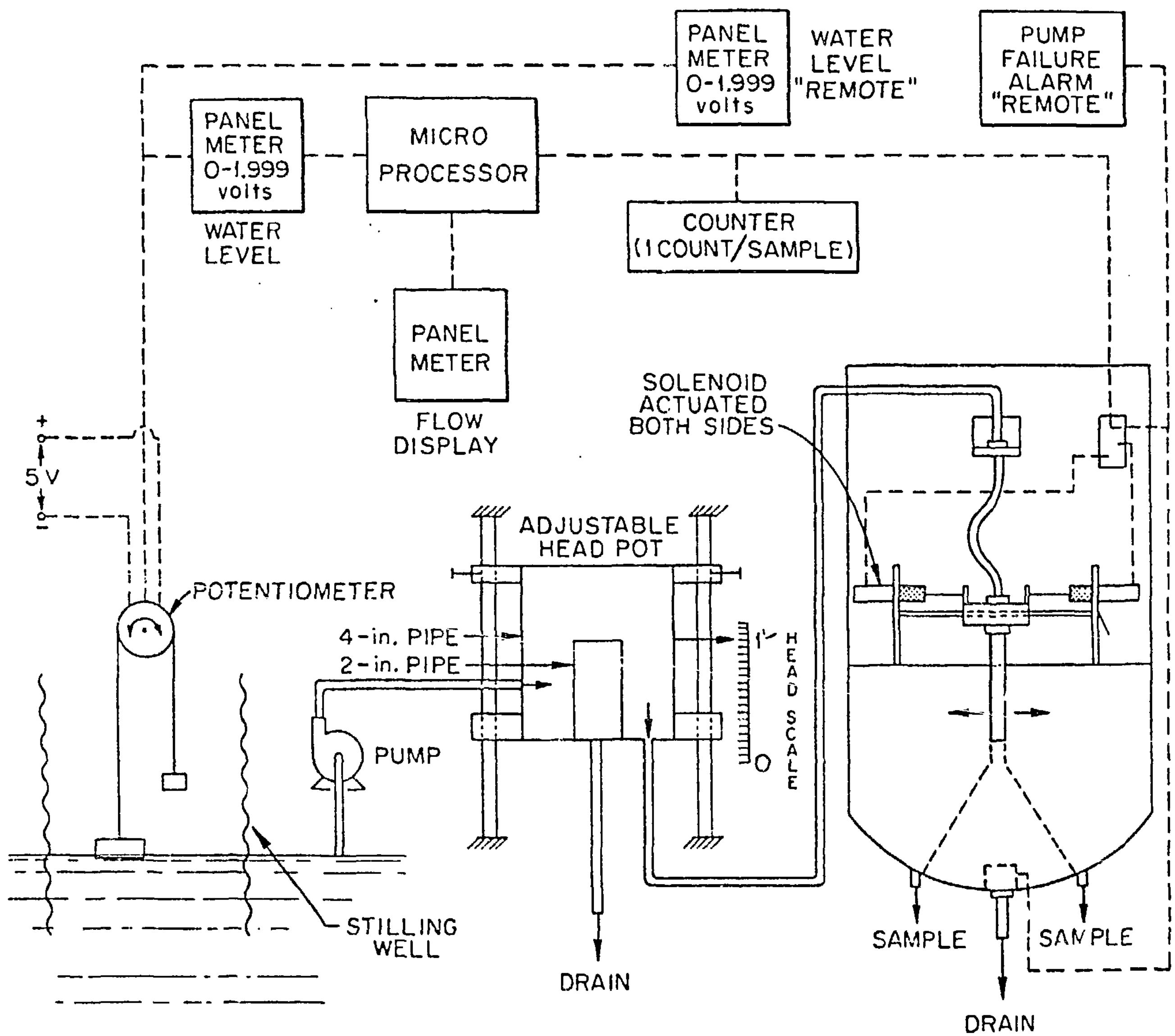

Fig. 4. Schematic of Total Sampling System.

OPERATING EXPERIENCE

The stream monitoring system described has been in operation since September, 1976, as part of the routine water sampling program performed by the Environmental Surveillance and Evaluation Section at ORNL. This water sampler is particularly important because the location of the sampler is at WOD, which is the last control point for the liquid discharges from ORNL. The original system costs were fairly low ($10,000-$20,000) and thus far, the reliability of the instrument has been approximately 90%.

Several tests, using a chart recorder system connected to the pulley shaft for determining the integrated flow, have shown the μP system to be working correctly in the past. The major operational difficulties encountered have been in the areas of voltage changes, telephone transmission, and temperature variations. The latter has become a significant problem recently, and the system is presently being reevaluated. A backup system that takes a sample at regular time intervals is used when the μP system is not operational. Another problem area is accurately determining the relationship between F and H when the water height is above 750 ft; in this case, the water actually spills over the dam. Because the uncertainty greatly increases during these conditions, water samples are collected separately for evaluation.

SUMMARY

A stream monitoring system incorporating an Intel 8008-1 μP has been designed, built, installed, and operated at ORNL. A μP was chosen over hard-wired logic, as a μP has programmable arithmetic capability as well as a lower cost of construction. Further, a μP can be salvaged and reprogrammed for use in another system when it is removed or replaced. The biggest operational difficulties encountered thus far have been in the areas of voltage changes, telephone transmission, and temperature variations. This system, however, has shown itself to be a reliable instrument in the past, and various test programs have shown the μP to be operating as designed. This system has been found to be a remarkable tool for environmental monitoring in obtaining a water sample that is truly proportional to the stream flow. We feel this type of system would be applicable in those cases where flow-proportional or redundant samples are needed, i.e., stack monitoring, air sampling, liquid effluent monitoring, etc.

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