GUIDELINES FOR USE OF

WATER QUALITY MONITORS

by A. Brice Gordon and Max Katzenbach

U.S. GEOLOGICAL SURVEY

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PREFACE

A series of manuals on techniques describe methods used by the U.S. Geological Survey for planning and conducting water-resources investigations. The material is arranged under major subject headings called books, and is further subdivided into sections and chapters. Book 8 is on instrumentation, and Section D is on instruments for measurement of water-quality and sediment. The unit of publication, the chapter, is limited to a narrow field of subject matter. "Guidelines for Use of Water-Quality Monitors" is the first chapter to be published under Section D of Book 8.

This Chapter was prepared with the assistance of several hydrologists of the Geological Survey as a means of documentation and making available the procedures used by the Geological Survey for establishing monitor stations, servicing and calibrating monitors, and processing and quality control of data. Supplements will be prepared as the need arises and issued to the public as they become available.

CONTRIBUTORS

The authors recognize the significant contribution of the individuals listed below to the content and preparation of this manual.

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The time and effort spent by Mary Amos and Staci Baker in the typing and preparation of this manual is gratefully acknowledged.

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ILLUSTRATIONS

TABLES

This manual does not supercede any previous publication.

CONVERSION FACTORS FOR INTERNATIONAL SYSTEM OF UNITS (SI) AND INCH-POUND UNITS OF MEASUREMENTS

To convert	To	Multiply by
inch	millimeter (mm)	25.4
foot	meter (m)	0.3048
gallon per minute (gal/min)	liter per minute (L/min)	3.785
cubic foot per second (ft^3/s	cubic meter per second (m^3/s	0.02832
micromho (μmho)	microsiemens (μS)	1.

DECIMAL EQUIVALENTS			
1/64 = 0.0156	17/64 = 0.2656	33/64 = 0.5156	49/64 = 0.7656
1/32 = 0.0312	9/32 = 0.2812	17/32 = 0.5312	25/32 = 0.7812
3/64 = 0.0469	19/64 = 0.2969	35/64 = 0.5469	51/64 = 0.7969
1/16 = 0.0625	5/16 = 0.3125	9/16 = 0.5625	13/16 = 0.8125
5/64 = 0.0781	21/64 = 0.3281	37/64 = 0.5781	53/64 = 0.8281
3/32 = 0.0937	11/32 = 0.3437	19/32 = 0.5937	27/32 = 0.8437
7/64 = 0.1094	23/64 = 0.3594	39/64 = 0.6094	55/64 = 0.8594
1/8 = 0.1250	3/8 = 0.3750	5/8 = 0.6250	7/8 = 0.8750
9/64 = 0.1406	25/64 = 0.3906	41/64 = 0.6406	57/64 = 0.8906
5/32 = 0.1562	13/32 = 0.4062	21/32 = 0.6562	29/32 = 0.9062
11/64 = 0.1719	27/64 = 0.4219	43/64 = 0.6719	59/64 = 0.9219
3/16 = 0.1875	7/16 = 0.4375	11/16 = 0.6875	15/16 = 0.9375
13/64 = 0.2031	29/64 = 0.4531	45/64 = 0.7031	61/64 = 0.9531
7/32 = 0.2187	15/32 = 0.4687	23/32 = 0.7187	31/32 = 0.9687
15/64 = 0.2344	31/64 = 0.4844	47/64 = 0.7344	63/64 = 0.9844
1/4 = 0.2500	1/2 = 0.5000	3/4 = 0.7500	1 = 1.0000

GUIDELINES FOR USE OF WATER QUALITY MONITORS

By A. Brice Gordon and Max S. Katzenbach

ABSTRACT

This manual contains methods and procedures used by the U.S. Geological Survey (USGS) for collecting specific conductance, dissolved oxygen, water temperature, and pH data for ground water, streams, lakes, reservoirs, and estuaries by means of permanently installed, continuously recording, water quality monitors. The topics discussed include the selection of monitoring sites, selection and installation of shelters and equipment, and standard methods of calibration, operation and maintenance of water-quality monitors.

INTRODUCTION

Water-quality monitors with their reading, documentation, and supportive digital processing equipment have undergone rapid technological advances in recent years. The modern monitor records in digital form on perforated tape. Data can be transmitted to a remote terminal unit via telephone, radiotelemetry, or satellite communication systems. Supportive data-processing equipment is currently used to read the data and generate a graphic display. The many improvements in monitor technology have paved the way for monitors to become an increasingly viable means of collecting water-quality data and have resulted in an increase of information at a reduced cost per unit of information when compared with periodic sampling by manual methods. Monitors are particularly useful for providing continuous record of water-quality characteristics, for enforcement requirements, and for detailed information on the temporal behavior of water-quality conditions under a wide range of hydrologic conditions.

It is the purpose of this manual to provide guidelines concerning the selection, installation, and use of monitoring systems and evaluation of data. Guidelines are provided for various situations; however, it must be emphasized that each monitoring site is unique and will therefore require ingenuity on the part of the hydrologist to modify and adapt both hardware and engineering principles provided by this manual to insure that the data collected truly represents the environment to be monitored.

Site selection and installation principles described in this manual apply to monitors that operate on two systems: (1) water to be measured is brought to the sensors, (2) sensors are located in the water's natural environment (in situ). Methods of monitor calibration, operation, and maintenance apply specifically to two water-quality monitors designed by the USGS; the flow-through monitor that utilizes a pumping system to bring water from the stream or other source to the sensors clustered in a tank located in a sheltered environment, and the mini-monitor that is battery operated and utilizes in situ sensors. With some variations, the procedures described for these two USGS monitors may be applied to similar monitors.

As technology develops, this manual will be updated to include methods and procedures for new sensors and equipment that have widespread application.

PREPLANNING

Test equipment requirements

Component instruments and other test equipment and supplies that are portable will be required to assess the suitability of a site for monitoring.

These equipment and supplies include:

1. Thermometer, mercury filled, 0.1°C (degree Celsius) increments, with an accuracy equivalent to National Bureau of Standards thermometer

2. Meter, specific conductance, with ± 1.0 percent accuracy, temperature compensated

3. Meter, dissolved oxygen ± 0.1 mg/L (milligrams per liter) accuracy, temperature compensated sensor (preferred), or Winkler dissolved-oxygen kit (acceptable)

4. Meter, pH, ± 0.1 unit accuracy, temperature compensated

5. Altimeter-barometer, pocket ± 5.0 mm (millimeters) of mercury accuracy

6. Table of "Solubility of Oxygen in Water at Various Temperature and Atmospheric Pressures" (table 1)

7. Stream-gaging equipment

8. Measuring tape, 100-foot.

A self-contained, multimeasurement, field instrument, such as the Hydrolab Model 4041 and others, that is designed to measure temperature, specific conductance, dissolved oxygen, and pH can be used in place of items 1-4.

Site selection

Suitability of a water-quality monitoring site is based on the information required to meet a stated objective. The investigator should have a general understanding of the physical and chemical principles involved in the system to be measured. For example, narrow, shallow, fast moving riffled streams have more opportunity to mix upstream input both horizontally and vertically than wide, deep, slow-moving streams; small, shallow lakes with large inflow systems have less longitudinal and vertical quality variation than large, deep lakes with small inflow systems; a well penetrating several water-bearing zones of different lithologies can have a strong zonal chemical stratification for the unpumped system as opposed to a well penetrating a single or several similar lithologies; a wide estuary with low fresh water inflow may be relatively well mixed compared to a narrow, long, deep estuary with a high volume fresh water inflow.

It should also be remembered that the location of either the water intake or in situ sensor is at a stationary location within the water column, fixed for both a horizontal and vertical position.

Sites should be selected based on the following considerations:

1. Representativeness of the volume sampled relative to the monitoring objective.

2. Ability to be operated under all hydrologic conditions.

3. Availability of electric power.

4. Access by all-weather roads.

5. Shelter and pumping system or probe installation requirements can be met.

6. Avoids safety hazards (nearby high-speed traffic, awkward shelter access, etc.).

Water-quality monitor selection

With the availability of two different monitoring systems, flow through or in situ, a decision must be made as to which type is most appropriate. Obvious system differences immediately apparent are:

1. Quantity of water available

2. Need for electric power

3. Cost of purchase, installation and maintenance.

4. Number and type of measurements to be monitored

System differences which are not so obvious are hydrologic in nature. Waters which have high biologic activity cause rapid fouling of in situ sensors; chlorinating units in flow through systems minimize this impact. On the other hand, highly corrosive waters or waters that are supersaturated with respect to certain dissolved constituents or that carry high sand concentrations can quickly damage the pumping system of the flow through monitor but may have little effect on in situ sensors. These are only a few of the factors to be weighed. Some may be listed, many may be omitted and some that may be listed may, to an ingenious hydrologist, not be a problem at all. The best advice this manual can provide is that a hydrologist should be consulted who is knowledgeable about the hydrologic environment to be monitored and have him describe the various conditions the particular environment will impose on each system and then choose the system with the greatest success potential.

Flow-through monitor

The flow-through monitor is designed for installations where the water is continuously pumped by a submersible pump to the sensors in a sensor tank inside the monitor shelter. The optimum rate of flow of water through the sensor tank is 10 gallons per minute. This rate will ensure a stablized output to the dissolved-oxygen sensor, prevent temperature change, and minimize

Table 1.--Solubility of oxygen in water at various temperatures and atmospheric pressures (mmHg). Oxygen concentration in mg/L.

Temp °C	760	750	740	730	720	710	700	690	680	670
0.	14.6	14.4	14.2	14.0	13.8	13.6	13.4	13.2	13.0	12.8
1.	14.2	14.0	13.8	13.6	13.4	13.2	13.1	12.9	12.7	12.5
2.	13.8	13.6	13.4	13.3	13.1	12.9	12.7	12.5	12.3	12.2
3.	13.4	13.3	13.1	12.9	12.7	12.5	12.4	12.2	12.0	11.8
4.	13.1	12.9	12.7	12.6	12.4	12.2	12.0	11.9	11.7	11.5
5.	12.7	12.6	12.4	12.2	12.1	11.9	11.7	11.6	11.4	11.2
6.	12.4	12.3	12.1	11.9	11.8	11.6	11.4	11.3	11.1	10.9
7.	12.1	12.1	11.8	11.6	11.5	11.3	11.1	11.0	10.8	10.7
8.	11.8	11.8	11.5	11.3	11.2	11.0	10.9	10.7	10.6	10.4
9.	11.5	11.4	11.2	11.1	10.8	10.8	10.6	10.5	10.3	10.2
10.	11.3	11.1	11.0	10.8	10.7	10.5	10.4	10.2	10.1	9.9
11.	11.0	10.9	10.7	10.6	10.4	10.3	10.1	10.0	9.8	9.7
12.	10.8	10.6	10.5	10.3	10.2	10.0	9.9	9.7	9.6	9.5
13.	10.5	10.4	10.2	10.1	10.0	9.8	9.7	9.5	9.4	9.3
14.	10.3	10.1	10.0	9.9	9.7	9.6	9.5	9.3	9.2	9.0
15.	10.0	9.9	9.8	9.7	9.5	9.4	9.3	9.1	9.0	8.8
16.	9.8	9.7	9.6	9.5	9.3	9.2	9.1	8.9	8.8	8.7
17.	9.6	9.5	9.4	9.3	9.1	9.0	8.9	8.7	8.6	8.5
18.	9.4	9.3	9.2	9.1	8.9	8.8	8.7	8.6	8.4	8.3
19.	9.3	9.1	9.0	8.9	8.8	8.6	8.5	8.4	8.3	8.1
20.	9.1	8.9	8.8	8.7	8.6	8.5	8.3	8.2	8.1	8.0
21.	8.9	8.8	8.6	8.5	8.4	8.3	8.2	8.0	7.9	7.8
22.	8.7	8.6	8.5	8.4	8.2	8.1	8.0	7.9	7.8	7.7
23.	8.6	8.4	8.3	8.2	8.1	8.0	7.9	7.7	7.9	7.5
24.	8.4	8.3	8.2	8.0	7.9	7.8	7.7	7.6	7.5	7.4
25.	8.2	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.3	7.2
26.	8.1	8.0	7.9	7.8	7.6	7.5	7.4	7.3	7.2	7.1
27.	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0
28.	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	6.9	6.8
29.	7.7	7.6	7.5	7.3	7.2	7.1	7.0	6.9	6.8	6.7
30.	7.5	7.4	7.3	7.2	7.1	7.0	6.9	6.8	6.7	6.6

Table 1.--(cont.)

Temp °C	660	650	640	630	620	610	600	590	580	570
0.	12.7	12.5	12.3	12.1	11.9	11.7	11.5	11.3	11.1	10.9
1.	12.3	12.1	11.9	11.7	11.6	11.4	11.2	11.0	10.8	10.6
2.	12.0	11.8	11.6	11.4	11.2	11.1	10.9	10.7	10.5	10.3
3.	11.7	11.5	11.3	11.1	10.9	10.8	10.6	10.4	10.2	10.0
4.	11.3	11.2	11.0	10.8	10.7	10.5	10.3	10.1	10.0	9.8
5.	11.1	10.9	10.7	10.5	10.4	10.2	10.0	9.9	9.7	9.5
6.	10.8	10.6	10.4	10.3	10.1	9.9	9.8	9.6	9.5	9.3
7.	10.5	10.3	10.2	10.0	9.9	9.7	9.5	9.4	9.2	9.1
8.	10.2	10.1	9.9	9.8	9.6	9.5	9.3	9.1	9.0	8.8
9.	10.0	9.8	9.7	9.5	9.4	9.2	9.1	8.9	8.8	8.6
10.	9.8	9.6	9.5	9.3	9.2	9.0	8.9	8.7	8.6	8.4
11.	9.5	9.4	9.2	9.1	9.0	8.8	8.7	8.5	8.4	8.2
12.	9.3	9.2	9.0	8.9	8.7	8.6	8.5	8.3	8.2	8.0
13.	9.1	9.0	8.8	8.7	8.5	8.4	8.3	8.1	8.0	7.8
14.	8.9	8.8	8.6	8.5	8.4	8.2	8.1	7.9	7.8	7.7
15.	8.7	8.6	8.4	8.3	8.2	8.0	7.9	7.8	7.6	7.5
16.	8.5	8.4	8.3	8.1	8.0	7.9	7.7	7.6	7.5	7.3
17.	8.3	8.2	8.1	8.0	7.8	7.7	7.6	7.4	7.3	7.2
18.	8.2	8.0	7.9	7.8	7.7	7.5	7.4	7.3	7.2	7.0
19.	8.0	7.9	7.8	7.6	7.5	7.4	7.3	7.1	7.0	6.9
20.	7.8	7.7	7.6	7.5	7.4	7.2	7.1	7.0	6.9	6.7
21.	7.7	7.6	7.4	7.3	7.2	7.1	7.0	6.9	6.7	6.6
22.	7.5	7.4	7.3	7.2	7.1	7.0	6.8	6.7	6.6	6.5
23.	7.4	7.3	7.2	7.0	6.9	6.8	6.7	6.6	6.5	6.4
24.	7.3	7.1	7.0	6.9	6.8	6.7	6.6	6.5	6.3	6.2
25.	7.1	7.0	6.9	6.8	6.7	6.6	6.4	6.3	6.2	6.1
26.	7.0	6.9	6.8	6.7	6.5	6.4	6.3	6.2	6.1	6.0
27.	6.9	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9
28.	6.7	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8
29.	6.6	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7
30.	6.5	6.4	6.3	6.2	6.1	6.0	5.9	5.8	5.7	5.6

the accumulation of biological growth and sediment in the sensor tank. The components of the flow-through monitor are shown in figure 1. The wall-mountable unit contains the following components:

1. Programmer

2. Signal conditioners

3. Electronic buffers

4. Power supplies

5. Standby batteries

The flow-through monitor comes equipped to measure the following parameters within the ranges of calibration and accuracies indicated:

Parameter	Ranges	Accuracy
Temperature	0° to 50°C -10° to 40°C -5° to 95°C	± 1 percent of full scale or ± 0.5°C, whichever is less.
Specific conductance	0 to 100 µmho/cm 0 to 1,000 µmho/cm 0 to 10,000 µmho/cm 0 to 100,000 µmho/cm	± 3 percent of full scale over the temperature range of 0° to 40°C.
Dissolved oxygen	0 to 10 mg/L 0 to 15 mg/L 0 to 20 mg/L	± 1 percent of full scale or ± 0.1 mg/L, whichever is greater.
pH	0 to 10 0 to 14	± 1 percent of full scale or ± 0.1 pH, whichever is less, over the temperature range of 0° to 40°C.

Duplicate sensors and signal conditioners can be added, as needed, because the monitor is capable of measuring up to 10 parameters. Parameters may be recorded in any sequence, however, the sensors must be connected to the matching signal conditioner in the desired sequence.

Electrical specifications of the monitor are:

1. 110 volts ac, 3-wire, safety grounded, a ground-fault interruptor

2. Two 12-volt standby batteries: Burgess TW-2 (preferred), Burgess 2684 (acceptable), or equivalent

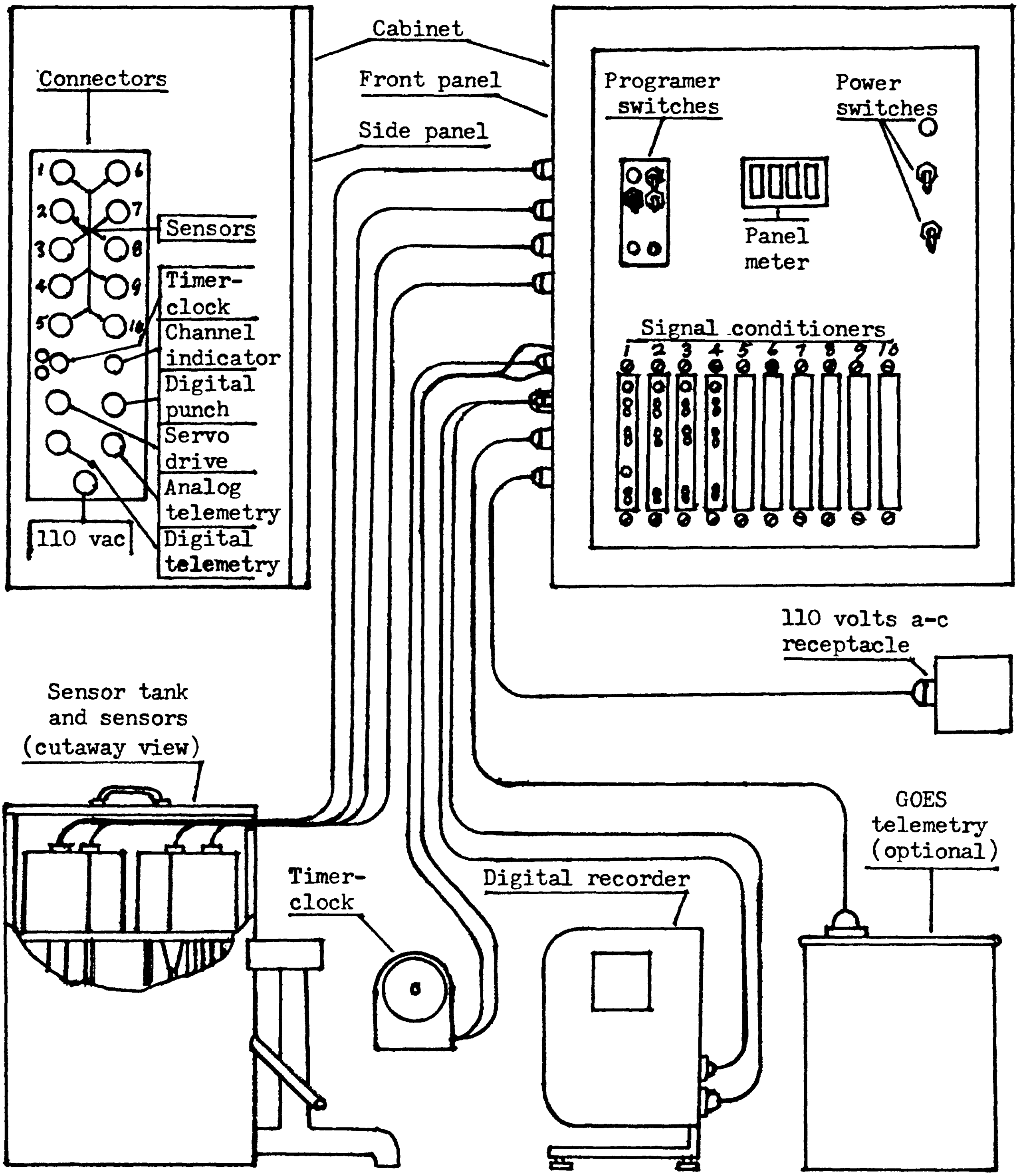

Figure 1.--Diagram of flow-through monitor.

3. One 3-ampere circuit breaker for chassis protection

4. One 1-ampere fuse: Little fuse 3AG1A or Buss MDL1

5. Analog telemetry output signals, ranging from 0 to 5 volts, from each of the 10 channels

6. Ambient temperature operation range: -40° to 55°C.

The dimensions of the components of the monitor are:

1. Cabinet: 24 inches wide by 16 inches deep by 30 inches high

2. Sensor tank: 13 inches outside diameter by 18 inches high

3. Sensor-tank shelf: 12 inches diameter with six 3-inch holes for sensors

4. Sensors: 3.5 inches outside diameter by 5 inches high with 10-foot electronic cables.

Optional equipment available for use with the monitor are as follows:

1. Telemetry:

   Satellite telemetry by use of the analog telemetry output and the GOES (geostationary observational environmental satellite) platform as shown in figure 1.

2. Additional parameters:

   Air temperature by use of sensor and signal conditioner the same as used to measure water-temperature values. Sensors and signal conditioners for other parameters will be developed as the need warrants.

Pumps for flow-through monitor

An integral part of the flow-through monitor system is the pump. Any of the several types of pumps on the market can be used. A pump must be able to overcome pipe restriction and friction and deliver the optimum flow rate of water (10 gallons per minute) up the vertical lift distance from the surface of the source and through the sensor tank. No water will flow through the sensor tank if the sum of the head losses due to vertical lift, pipe restrictions, and friction equals or exceeds the developed head of the pump. Characteristics of the pump are furnished by pump manufacturers to assist in evaluating the suitabiltiy of pumps for delivering the required flow rate of water through the sensor tank.

The pump should be resistant to the wear caused by pumping suspended sediment (silt and sand). Many of the pumps are designed to pump sediment-free ground water and are not suitable for pumping water containing even low concentrations of suspended sediment. Centrifugal pumps are the least susceptible to change from pumping water containing suspended sediment. Sump and bilge centrifugal pumps with double mechanical shaft seals provide the longest life when in continuous service.

Submersible centrifugal pumps should be used for the primary pumping system of flow-through monitors. Several suitable brands of pumps are available. The dimensions of the pump will determine the diameter of the pumping well required to install the pump. For example, the Prosser Model 91011-9 with 0.75 hp (horsepower) motor and Model 91311-7 with 1 hp motor are both 5.375 inches in diameter, 15.25 inches long, and weigh 21 pounds and are easily installed in a 6-inch diameter well.

Nonsubmersible pumps are not recommended for use as the primary pumping system for flow-through monitors. The reduction of atmospheric pressure resulting from the suction of the pump in lifting the water can cause a change in the water quality. For example, suction lift causes noticeable reduction of dissolved-oxygen concentration. A suction lift pump might be used as a backup pumping system to be used when the submersible pump fails during high flow and cannot be retrieved for repair until the stream reaches a lower flow.

The intake of the pump should be provided with a screen to filter out debris that could damage the pump. The screen provided with the pump is usually too small and becomes plugged in a very short time. The screen should be constructed of 16-gage stainless steel perforated with 0.1875-inch diameter holes on 0.3125-inch staggered centers. If severe corrosion is a problem, plastic (PVC) could be used. A screen 24 inches long and with sufficient diameter to either attach to the pump intake or to the intake line of the pumping well will provide enough openings to prevent restriction of flow or premature plugging. Further discussion and illustration of screens is included in subsequent sections.

Mini-monitor

The mini-monitor is designed to be battery operated with the sensors placed directly in the stream or other body of water (in situ). It may be operated also as a flow-through monitor with the addition of a pumping system, flow-through sensor tank, and 110 volt ac power for the pump. The mini-monitor system consists of a waterproof, battery-operated electronics package, a digital input-output recorder, and sensors with extension cables (fig. 2). Operation begins when a signal is received from an internal crystal timer; the monitor selectively scans, measures and records the values on digital tape, and then, to conserve battery power, turns off until the next recording interval.

The mini-monitor comes equipped to measure the following parameters within the ranges and accuracies indicated:

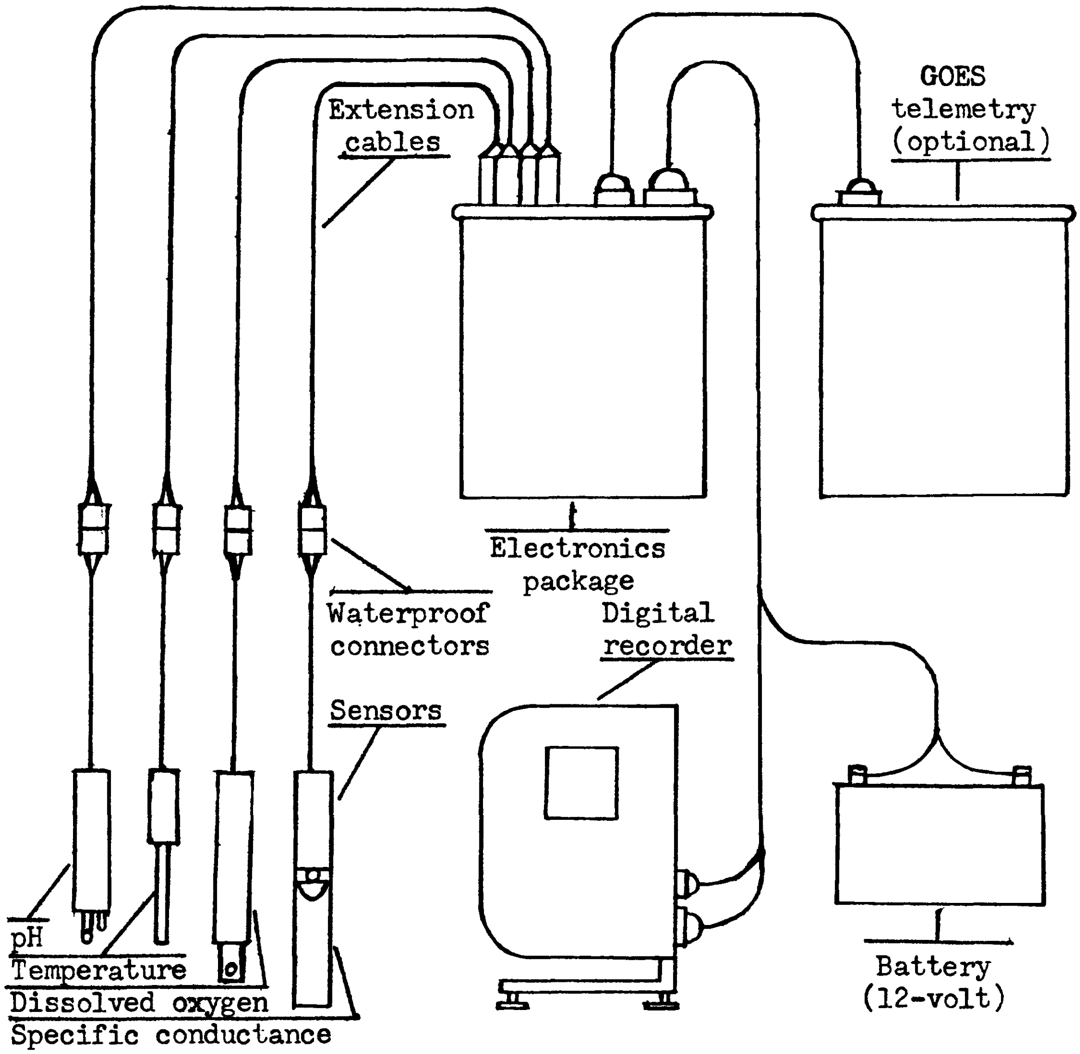

Figure 2.--Diagram of mini-monitor system.

Measurement	Ranges	Accuracy
Temperature	0° to 50°C Other ranges by special request.	Within ± 1 percent of full scale or ± 0.5°C, whichever is less.
Specific conductance	0 to 100 µmho/cm 0 to 1,000 µmho/cm 0 to 10,000 µmho/cm 0 to 100,000 µmho/cm	Within ± 3 percent of full scale in a temperature range of 0° to 40°C.
Dissolved oxygen	0 to 10 mg/L 0 to 15 mg/L 0 to 20 mg/L	Within ± 1 percent of full scale or ± 0.1 mg/L, whichever is greater.
pH	0 to 10 2 to 12	Within ± 1 percent of full scale or ± 0.1 pH, whichever is less, in a temperature range of 0° to 40°C.

Electrical specifications of the mini-monitor equipment are:

1. Battery type: External 12-volt drycell or lead-acid battery with at least a short-term capacity of 2 amperes. Two 6-volt batteries can be used in series. Recommended dry cells are two 6-volt Eveready Hotshot 1461 or equivalent.

2. Battery Demands: Three demands will be placed on the batteries used. Operating voltage range: Instrument will maintain its accuracy and precision specification within the operating voltage of 10 to 14 volts. (Warning: Do not use a 15 volt battery or two 7.5-volt batteries in series.) Battery comsumption: Less than 2 ampere hour per month to record four parameters at 1-hour intervals. Current consumption: In standby mode, 250 microamperes; average recording current per parameter, 1.3 amperes for 0.75 second; signal conditioners, 0.1 ampere by each.

3. Fuses: Two AGC fuses, 0.5 ampere and 1.5 amperes, located on the multiplexer board, internal.

4. Analog output: 0- to 5-volt analog output is on during scan and record cycle only.

5. Timer: Crystal, internal, 250 microamperes continuous, 4 minutes per month accuracy.

6. Recorder: External, Leupold and Stevens digital input and output 16-channel paper tape recorder, 1.3 amperes for 0.75 second per punch.

7. Ambient temperature operation range: -40° to 55°C

The dimensions of the components of the mini-monitor are:

1. Electronics package: 10.5 inches diameter by 10 inches high, or 15.5 inches high with cables connected.

2. Sensors: Temperature, 0.75 inch diameter by 7.5 inches long; specific conductance, 1.4 inches diameter by 10.5 inches long; dissolved oxygen, 1 inch diameter by 6.75 inches long; pH, 1.5 inches diameter by 14.5 inches long.

3. Cables: Sensor cable, 10 feet long; extension cables; 100-foot sections; maximum allowable length, 1,000 feet from sensor to electronics package; connectors, 1.5 inches diameter by 3 inches long.

4. Recorder: Digital, Leupold and Stevens, 12.5 inches wide by 8 inches deep by 12.5 inches high.

The following optional equipment is available for use with the mini-monitor:

1. Telemetry:

   Satellite telemetry by use of the analog telemetry output and the GOES platform as shown in figure 2.

2. Additional parameters:

   The mini-monitor is designed to measure only four parameters but other parameters may be substituted for any of those supplied with the monitor. Air temperature can be measured by use of the sensor used for water temperature. The required temperature range can be obtained by special request. Any parameter for which the need warrants could be added with the development of a sensor and the required electronics.

Selection of shelters

Protection of the monitor equipment from damage is of prime importance. The type and size of the shelter required for a water-quality monitor depend, basically, on the amount of hydrologic equipment that is to be housed in the shelter. Future requirements should be considered also. A shelter that is only slightly larger than what is currently needed may not be adequate for future needs. Other factors to be considered are (1) climatic conditions of the geographic location, (2) type of hydrologic system to be monitored (stream, lake, reservoir, ground water, estuary), and (3) physical limitations of the selected site (streambank, bridge, raft on a lake, reservoir, or estuary) and (4) the degree of protection the equipment and measurement require.

Flow-through monitor

A shelter, 4 feet wide by 6 feet long by 8 feet high, will house the flow-through monitor and support equipment, and will provide adequate working space for field personnel. If the shelter is also to house stream-gaging equipment, a shelter, 6 feet wide by 8 feet long by 8 feet high, will be needed. A shelter, 8 feet wide by 10 feet long by 8 feet high, should provide space for most of the equipment currently available for collection of hydrologic data in conjunction with the flow-through water-quality monitor without requiring additional space for future needs. The additional cost is relatively small when compared to the added floor space and convenience.

Shelters may be constructed of concrete block, brick, metal, wood, fiberglass or a combination of one or more of these. The prime objective of a shelter is to protect the expensive equipment from being damaged by either natural catastrophes or vandalism. The most frequent type of vandalism concerns the use of the shelter for firearm target practice. A shelter constructed of concrete block or brick offers good protection from vandalism, but is not as easily removed as a shelter constructed of metal, wood, or fiberglass when the station is discontinued. The door of the shelter is usually most vulnerable to vandalism involving firearms and should be lined with a bulletproof steel plate or a bulletproof laminated plastic and secured by a lock that will withstand considerable abuse, including high-powered bullets.

Mini-monitor

Factors to consider for selection of a shelter to house the mini-monitor is basically the same as for the flow-through monitor except for size. The mini-monitor is relatively small and can be installed in most existing surface-water stream-gaging shelters. Some of the smaller stream-gaging shelters, such as the 42-inch diameter steel shelter, is probably too crowded. A shelter, 4 feet wide by 6 feet long by 8 feet high, usually will accommodate the mini-monitor and stream-gaging equipment. When planning to use an existing stream-gaging shelter, consideration must be given to placing the in situ sensors into the stream. The sensors cannot be placed in the stilling well to collect water-quality data because the water is semistagnant and may contain oil and antifreeze. If a separate shelter is to be used to house the monitor equipment, a look-in type shelter a minimum of 30 inches square by 36 inches high, will provide sufficient space. However, the smaller shelters provide little or no protection for servicing the monitor during inclement weather and, therefore, larger shelter may be more desirable.

INSTALLATION

Installation of shelters

After the site and the equipment that will be required have been selected by use of the prescribed criteria, the shelter can be installed. The following sections describe two types of installations that may be used. CAUTION: The construction of the shelter may include the use of electric power tools. Water or wet surfaces and high-voltage electricity is a lethal combination; therefore, great care must be exercised when using 110-volt a-c or 220 volt a-c equipment. Use of a ground-fault interruptor between the tool plug and the power source is recommended. Keep all electric power tools dry and properly insulated, including the power cables. Should an electric power tool fall into a stream, do not attempt to retrieve it before disconnecting it from the power source (portable generator or commercial line). Do not begin maintenance or installation of the pump or the high-voltage components of the monitor until it is certain that the electric power is disconnected. When installing electrical circuits in the shelter, be sure that all circuits are properly grounded and a ground-fault interruptor is installed. Circuit panels and breakers should be installed as near the work area as possible.

Flow-through monitor

The flow-through monitor requires 110-volt a-c electrical service. The shelter, however, should be supplied with a 220-volt a-c service, which can be divided into two 110-volt circuits, and have 220 volts available if it is needed. By having two 110-volt circuits, the possibility of overloading a circuit is reduced. The number of electrical outlets will be determined by individual requirements, but it is better to have more outlets than anticipated rather than too few. Separate outlets should be provided for each of the major appliances, such as the monitor, the pump, the heater, and telemetry equipment. Lightning arrestor protection should be provided also. All electric wiring and installation of electrical equipment must comply with the local building codes and, usually, will need to be inspected before the electric company will provide service.

The shelter should be equipped with adequate lighting. A two-tube, 48-inch, fluorescent fixture will provide sufficient light for a shelter, 4 feet wide by 6 long by 8 feet high. A shelter that is 8 feet wide by 8 feet long by 8 feet high will require two of the above fixtures. Poor lighting makes servicing difficult and can result in errors.

Sufficient insulation should be installed in the walls and ceiling of the shelter to protect against extreme heat and cold. In areas where air temperatures are below freezing for extended periods of time, a thermostatically controlled heater should be installed to prevent freezing of the water in the sensor tank or the standard solutions that may be stored in the shelter. The shelter should be well ventilated. The installation of forced-air ventilators such as wind turbine or electric exhaust fan, with filters in the air vents to prevent dust from entering the shelter may be required in some areas. There may be some areas where high humidity will cause condensation of moisture on the equipment in the shelter and require the use of a dehumidifier or air conditioner.

A shelf, constructed from 2 thicknesses of 0.75-inch plyboard 20 inches wide, installed across the long side of the shelter about 44 inches from the floor will provide sufficient space for the monitor, digital recorder, and, perhaps, the sensor tank. Additional shelves may be installed on other sides of the shelter for writing space and for storage of calibration standards, distilled water, and tools. Servicing the monitor is more efficient if the location of the monitor, recorder, sensor tank, and writing space are in close proximity.

Installation of a monitor shelter attached to a bridge is sometimes necessary. For example, figure 3 shows a monitor shelter, 6 feet wide by 8 feet long by 8 feet high, anchored to a pier and side of a bridge. This shelter also houses the surface-water stream-gaging equipment. The shelter is mounted on the downstream side of the bridge about 40 feet above the streambed and is supported by channel iron and angle iron attached to the bridge pier. The top of the shelter is below the roadway level and the bottom is above flood stage. The system uses a pumping well and a submersible pump installation. The well is a 10-inch inside diameter PVC pipe attached to the bridge pier by angle iron, and extends from the floor of the shelter platform to about 3 feet below the streambed (figure 4). The lower end of the pipe is capped. A 3-inch inside diameter PVC pipe extends from the pumping well to a point of optimum depth and streamflow. The 3-inch pipe is the intake and is capped and perforated with sufficient 0.19-inch holes to allow water to flow in freely and to filter out debris. The submersible pump is retrieved by a steel cable and winch that is attached at the top of the well. The top of the well and the winch are housed in a locked enclosure for security purposes. The pump can be retrieved and serviced or replaced at any stage of streamflow that the bridge is accessible. The shelter could be installed over the top of the well, eliminating the need of a separate cover for the top of the well and the winch. If a 1/4 inch flexible tie line is attached to the pump hose, the pump can be pulled out of the well by the hose and tie line and the winch will not be needed. The hose and tie line connection to the pump should be double-clamped to prevent it from disconnecting when the pump is pulled from the well.

The principal advantages of a bridge installation are that the shelter is close to the water, above flood-stage, and often permits sampling the stream at a point more representative of the mean cross-sectional water-quality values. The major disadvantages are that supplying electric power to the shelter may be difficult, and heavy traffic on the bridge may make installation of the shelter and equipment and servicing of the monitor inconvenient and possibly dangerous.

A streambank installation is most commonly used. In hilly or rolling terrain, the shelter can be placed on a high streambank located above the expected flood stage or, if the site is a low, broad flood plain, the shelter can be mounted on piers to place it above expected flood stage. A streambank installation should be at a place where the shelter is accessible at any stage of the stream.

Figure 3.--Monitor and stream-gage shelter mounted on a bridge pier. Photograph by C. T. Welborn.

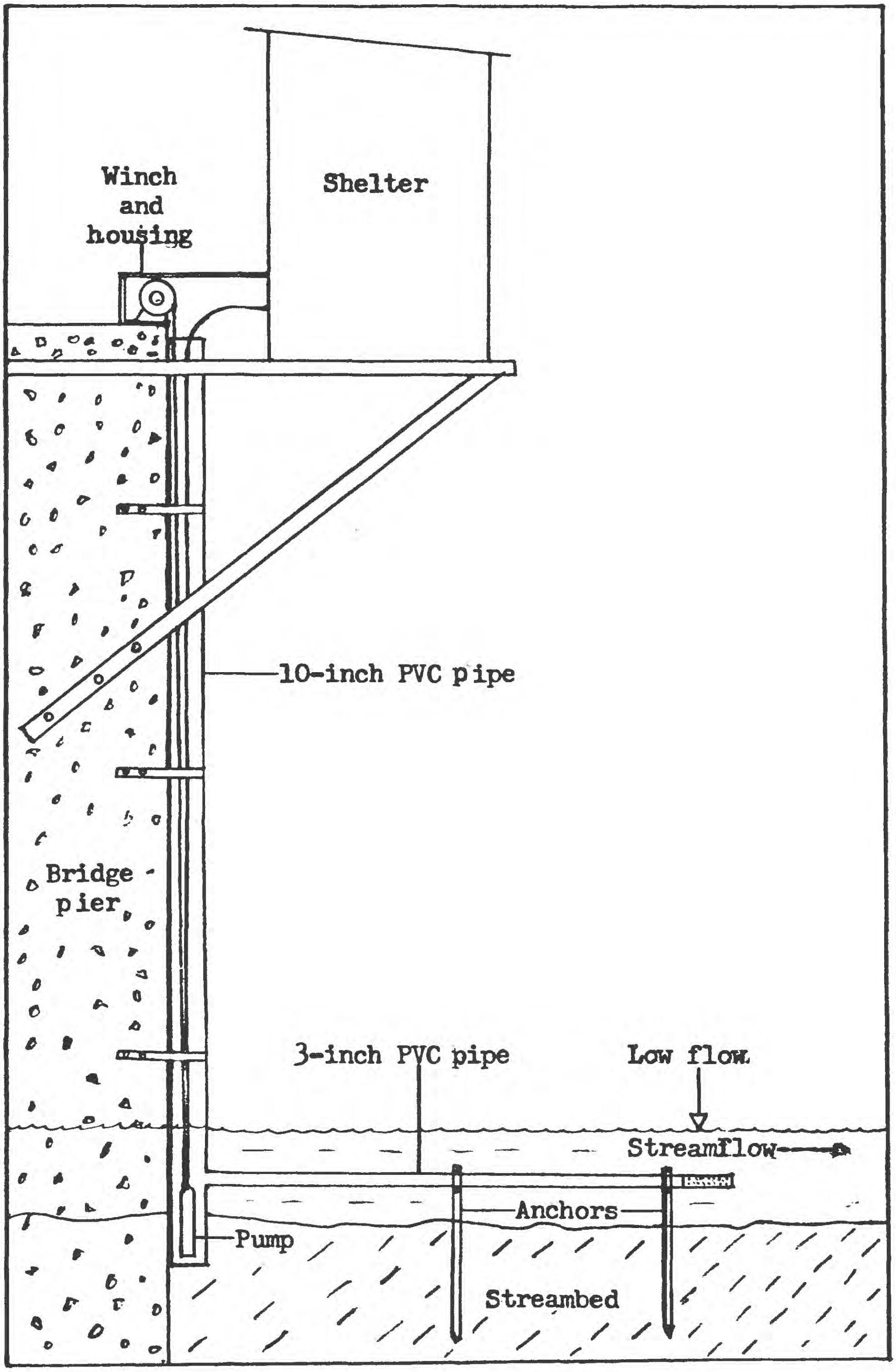

Figure 4.--Pumping well and intake for water-quality monitor.

Two streambank installations are shown in figure 5. The shelters, 6 feet wide by 6 feet long by 8 feet high, are mounted on bases constructed of 4-inch angle iron that had sufficient height to clear flood stage. The angle iron bases are anchored to concrete footings that extended approximately 3 feet below the surface of the ground. Accommodations for the pumping system were made before the footing was poured by burying two 4-inch inside diameter PVC pipes about 3 feet deep and extending into the stream to the point of optimum flow, about 1 foot below the 7-day, 10-year low-flow stage. A 90-degree, 4-inch inside diameter sweep ell was connected to the shelter end of each of the 4-inch pipes and sections of 4-inch pipe were connected to the upper end of the ells to extend through the floor of the shelter. These pipes were installed to house the intake and exhaust lines of the pumping system. For added protection against freezing and vandalism, a section of 24-inch inside diameter corrugated pipe was installed around the 4-inch pipes to extend from the floor of the shelter to about 2 feet below the surface of the ground. After the pipes were installed, the footing was poured and construction of the shelters completed.

A shelter, 6 feet wide by 6 feet long by 8 feet high, installed on the streambank at a bridge abutment is shown in figure 6. The design of the bridge made installation on a bridge pier impractical. Two 4-inch PVC pipes were installed as described above. Other types of installations and shelters are shown is figure 7. A major problem of a streambank installation is the installation of the pumping well so that the submersible pump can be retrieved and serviced during high flow.

Installation of pumping wells

Installation of pumping wells is usually an integral part of preparing the site for a flow-through monitor. A pumping well mounted to a bridge pier such as shown in figure 4 can be used for most bridge-pier installations. Streambank installations have a wide variation of conditions that determine the type of installation to be used, but accessibility to the pump at all stages of the stream is the prime consideration. Excavation for the pumping well and the shelter footing in the streambank installation can be done more quickly and efficiently by use of a back-hoe or other similar equipment.

A streambank installation in which the pump slides down the sloping part of the well into the pump chamber is shown in figure 8 (Thomas E. White and Sherman Brown, U.S. Geological Survey, written communication, 1969). The angle of the required slope depends in part on the smoothness of the inside surface of the pipe. A slope of not less than 30 degrees from the horizontal usually will be sufficient. The pump is connected to the sensor tank by a fabric-reinforced hose and can be used to push the pump through the casing. The sweep of the curve in the well must be sufficient to allow the pump to move freely. To flush out the accumulated sediment in the bottom of the well, an auxilliary pump is used to pump water from the stream through the backflush pipe into the pump chamber while the pump is in the position shown. The accumulated sediment is suspended and flushed back through the intake of the well. Installation such as this have proved to be troublesome and have required considerable maintenance and replacement.

Figure 5.--Streambank installations of steel shelters mounted on angle-iron bases. Photographs by R. P. Frehs.

Figure 6.--Streambank installation of steel shelter mounted on a concrete slab and footing. Photograph by R. P. Frehs.

Figure 7.--Two additional types of streambank installations employing angle-iron bases. A. Steel shelter mounted on wingwall of bridge. B. Fiberglass shelter mounted on abutment of bridge. Photograph by R. P. Frehs.

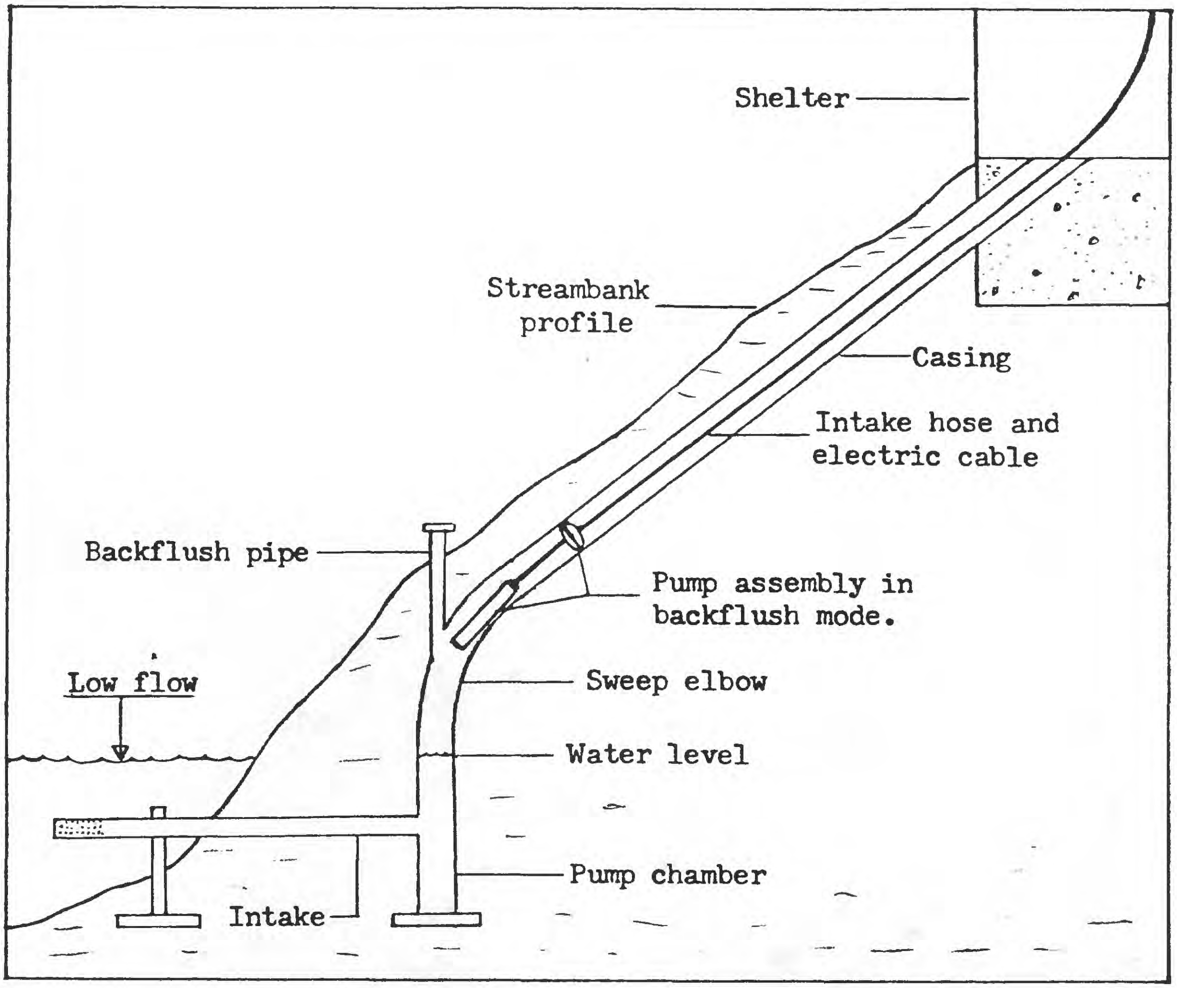

Figure 8.--Streambank installation of underground pumping well. (Modified from T. E. White and S. Brown, U.S. Geological Survey, written communication, 1969.)

Two similar streambank installations are shown in figure 9. Installation of the well so that the pump is above the intake (fig. 9A) can be used where the stream depth does not fall below the level of the pump in the well. The installation of the pumping well as shown in figure 9B can be used for streams that become very shallow at low flow. Although not shown in these figures, the screened intakes should always tunnel downstream to allow self cleaning action by the flow.

A type of streambank installation that can be used on a bulkhead, the wingwall of a bridge abutment, or adapted for use on a bridge pier is shown in figure 10. There may be accumulation of sediment in the pump chamber that will require addition of some method of flushing the well. This can be minimized by turning the screened intake downstream to prevent forcing sediment into the intake.

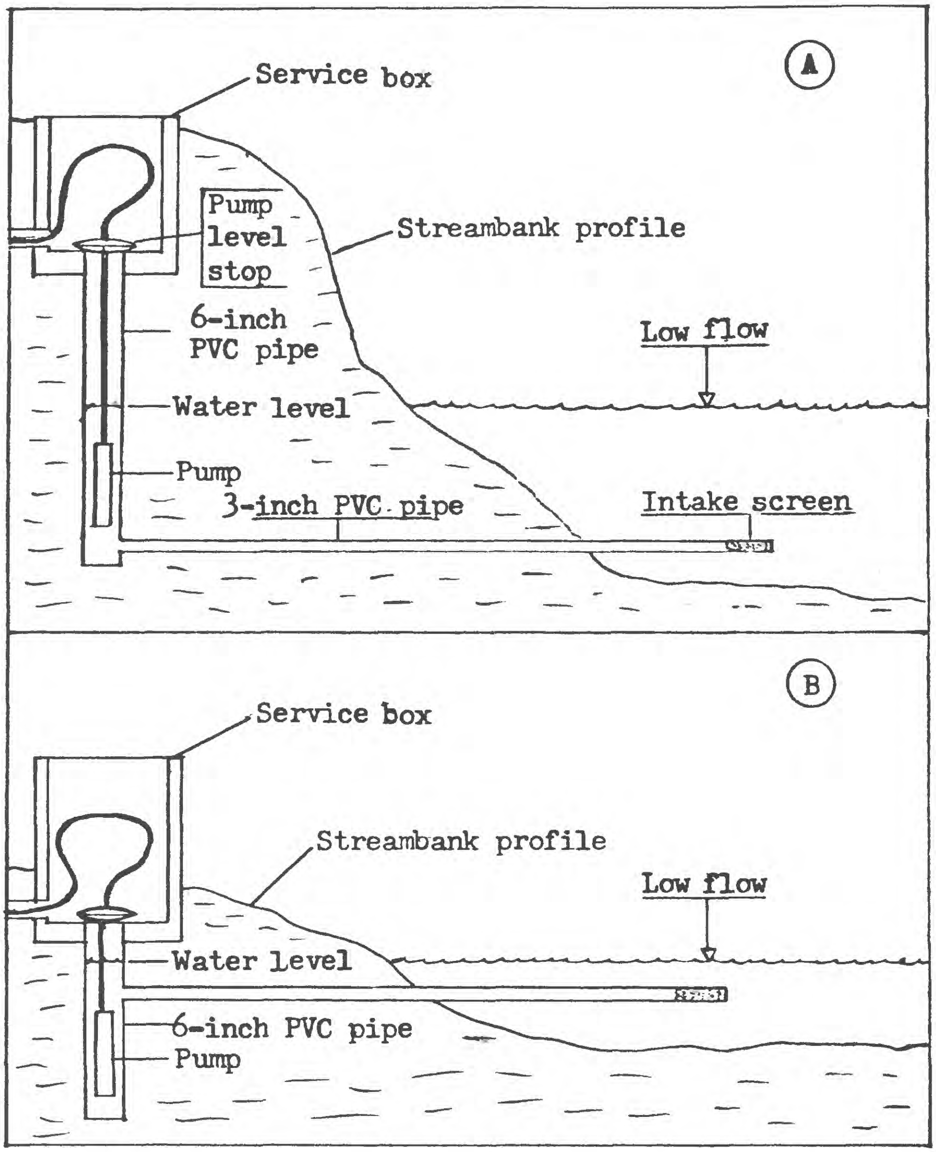

Figure 9.--Two examples of streambank installations of pumping wells with service boxes. (Modified from Anderson and others, p. 268, 1970.)

The diameter of the pipe used for the well depends on the diameter of the submersible pump. There should be sufficient clearance to allow the pump to move freely in and out of the well. The diameter of the well, however, should be much larger than the diameter of the pump; otherwise stagnation of the water may occur in the well because the inflow of water is not sufficient to cause continued turn over of the water in wells.

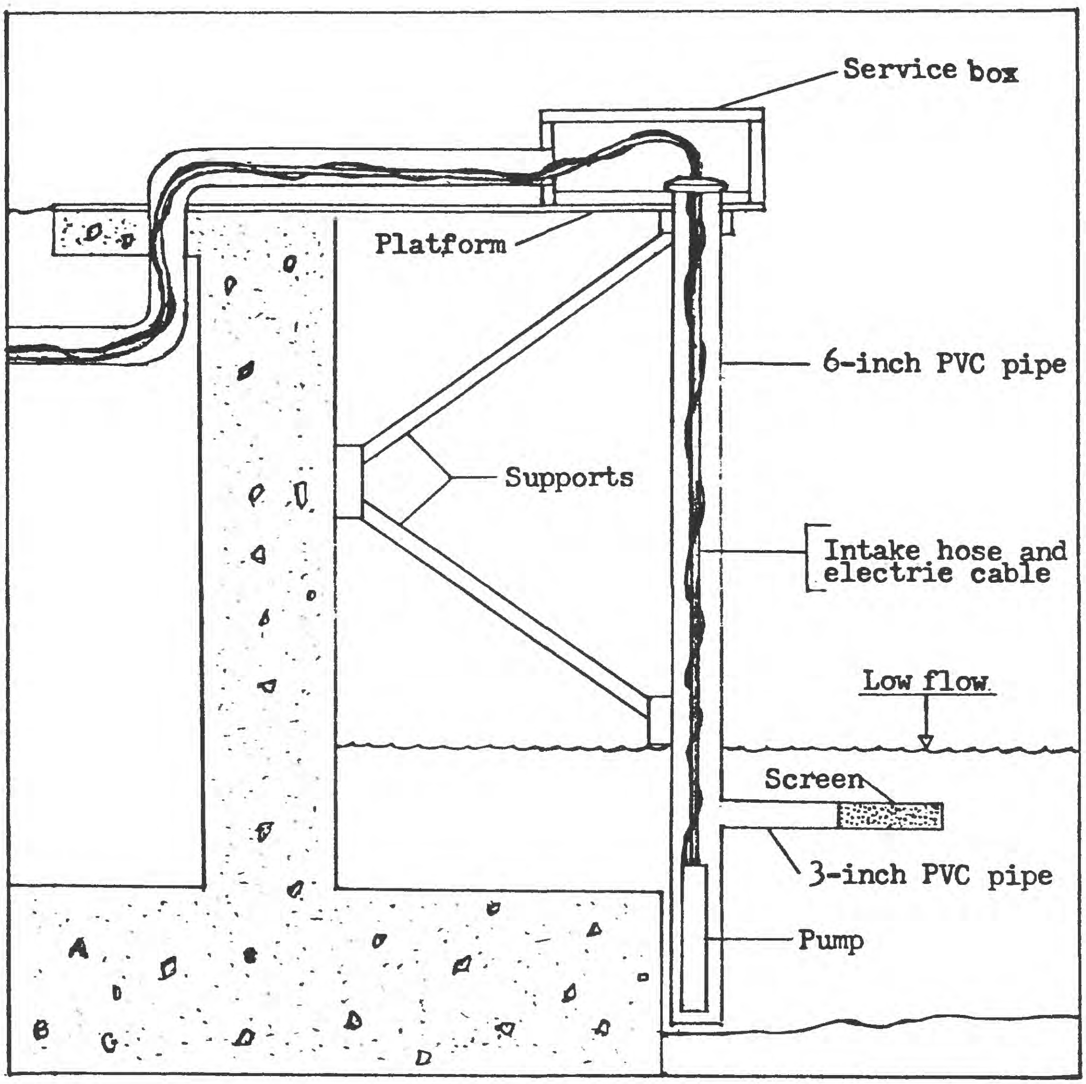

Figure 10.--Installation of pumping well on a bulkhead. (Modified from Anderson and others, p. 269, 1970.)

A flushing system that can be installed as a part of the pumping well is shown in figure 11. When the system is in the operating mode and the bypass valve is closed, all of the flow from the submersible pump goes to the sensor tank and any excessive flow can be diverted through the bypass. When the system is in the maintenance mode to flush the accumulation of sediment out of the pump chamber, the valve to the bottom of the pump chamber is opened, the bypass valve is opened completely, and the valve to the sensor tank is closed. Part of the flow from the pump returns to the pump chamber to flush the sediment and the remainder flows through bypass. The sediment is then pumped out gradually through the bypass and the process is continued until the pump chamber is free of accumulated sediment (Thomas E. White and Sherman Brown, U.S. Geological Survey, written commun., 1969). The pipe used for the flushing system should be at least 0.75-inch inside diameter PVC pipe but 1.50 inch is recommended. The valves should be gate or ball valves to prevent restriction of the flow of water.

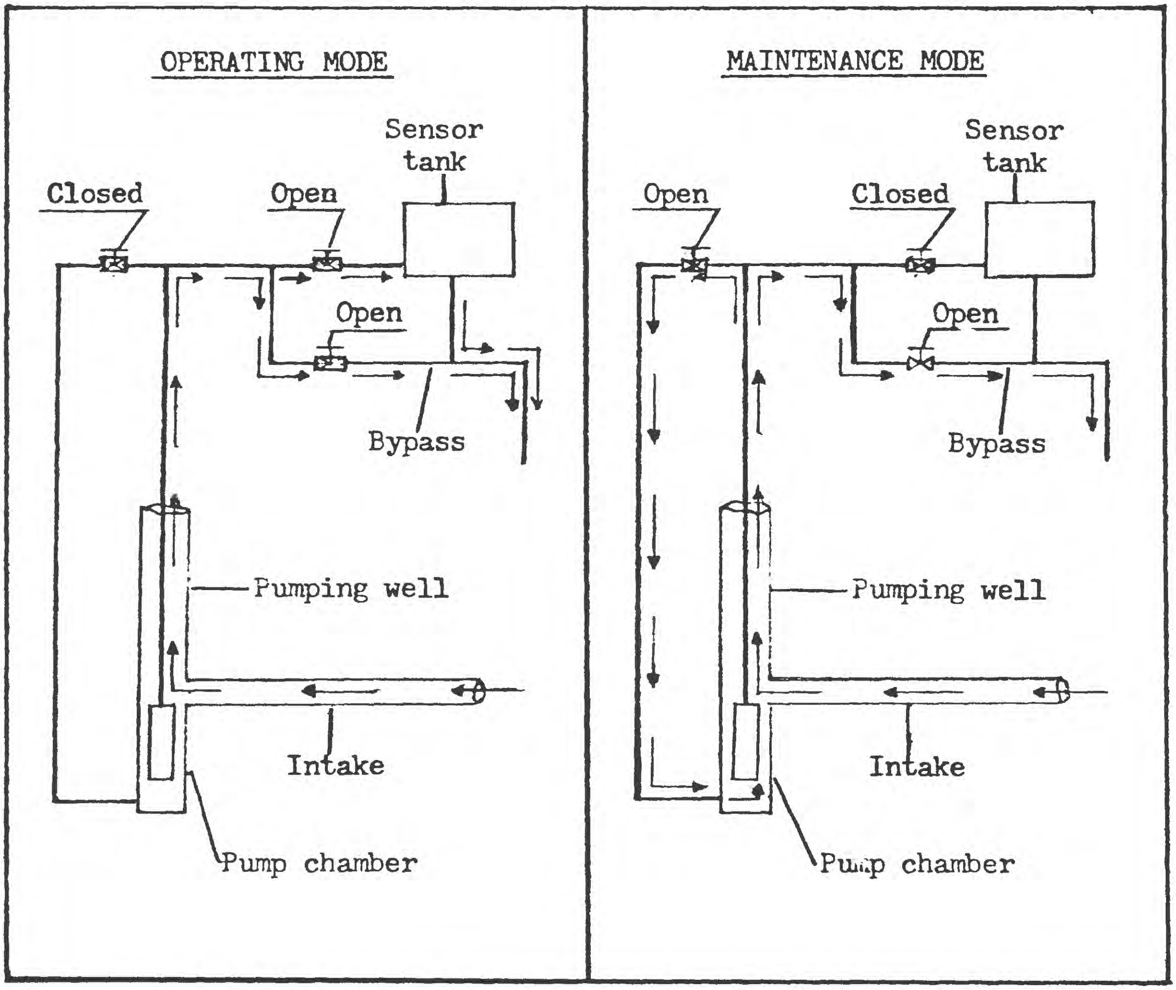

Figure 11.--Operating and maintenance modes of flushing system. (Modified from T. E. White and S. Brown, U.S. Geological Survey, written communication, 1969.)

A part of the installation of pumping wells, not shown in figures 8, 9, 10, and 11, is a means of returning the water to the stream. A 4-inch inside diameter PVC pipe installed underground and downstream from the pumping well will provide a gravity-discharge of the water to the stream.

Mini-monitor

The requirements for the installation of a shelter for a mini-monitor are about the same as for the installation of a shelter for the larger flow-through monitor. The basic differences are that the shelter required for the mini-monitor probably will be smaller and a pumping system is not needed.

Two views of a typical installation of an in situ monitor shelter on the downstream side of a bridge pier are shown in figure 12. The platform, attached to the bridge pier, was constructed of expanded-metal grating and angle iron. The size of the platform depends on the size of the shelter and the amount of space required for personnel to service the monitor. A ladder may be installed for safe access to the platform or a light-weight ladder may be carried in the field vehicle. If the ladder is installed, a locked cover over the platform and ladder should be provided for security and safety purposes and the ladder should be installed to allow for 7 inches clearance between the ladder and any solid structure behind it.

The sensors of the mini-monitor must be placed in the stream so that the water can flow freely around them but will be protected from damage by debris. A 4-inch inside diameter PVC pipe, mounted on a bridge pier as shown in figure 13, will provide protective housing for the sensors. The lower end of the pipe is perforated with sufficient 1-inch holes to allow the water to flow around the sensors. This type of installation will make retrieval of the sensors for servicing possible at all stages of the stream when the shelter is accessible. This is a good choice of an installation in areas where the water in the stream does not freeze. In areas where water does freeze other types of installation must be considered because the sensors will freeze in place and cannot be retrieved for servicing.

The major problem of a streambank installation of the mini-monitor is locating the sensors so that they can be adequately protected, retrieved easily for servicing, and are at the optimum location for making measurements. If the streambank is steep enough, approximately 45 degrees from the horizontal, and the optimum measuring point is near the streambank, a 4-inch diameter PVC pipe can be installed as shown in figure 14.

If the streambank is not steep enough or the point of optimum flow is not near the streambank, the type of installation of the sensor housing shown in figure 15 may be used. When the shelter is installed, two 4-inch inside diameter PVC pipes are buried side by side from the shelter to the edge of the stream at low flow. One of the pipes is used for the drain hose and the other is extended into the stream to the point of optimum flow and a depth below the 7-day, 10-year low flow stage. At this point, a 4-inch PVC tee is connected perpendicular the streambed. A section of perforated 4-inch PVC pipe, long enough to house the sensors at optimum depth, is connected to the lower end of the tee. A 6-inch section of 4-inch PVC pipe (schedule 80) threaded on one end is connected to the upper end of the tee with the threaded end up. A threaded 4-inch PVC cap (schedule 80) is used to cover the unit after the sensors have been installed. The cap can be removed to give access to the sensors for servicing. A length of 4-inch by 1-inch channel iron or a steel fence post is driven into the streambed and attached to the tee to anchor the unit in the stream. Steel fence posts should be installed to support the pipe between the streambank and the tee if the distance is over 10 feet. An electrician's snake can be used to pull the sensor cables through the pipe. Sufficient cable should be left in the shelter to allow the sensor connectors to be pulled out at the tee to service or replace the sensors. This type of installation will protect the sensors

Figure 12.--Shelter and sensor housing for mini-monitor attached to downstream side of bridge pier. A. Upper view. B. Lower view. Photographs by C. T. Welborn.

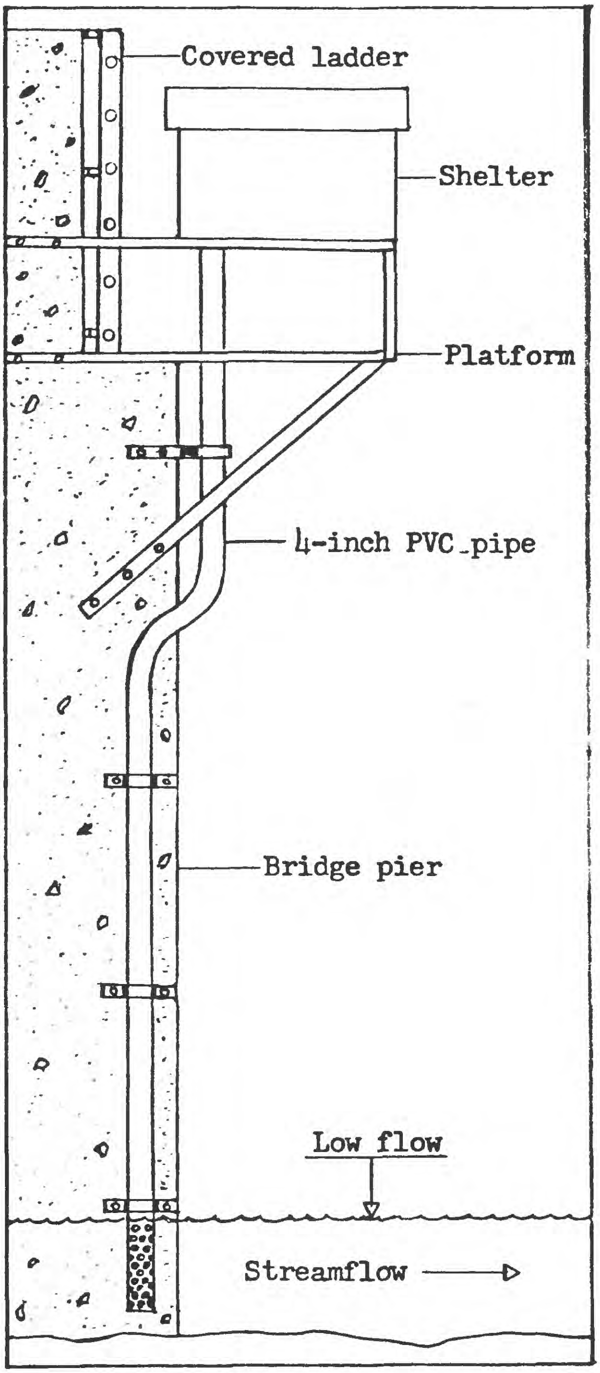

Figure 13.--Detail of bridge pier installation.

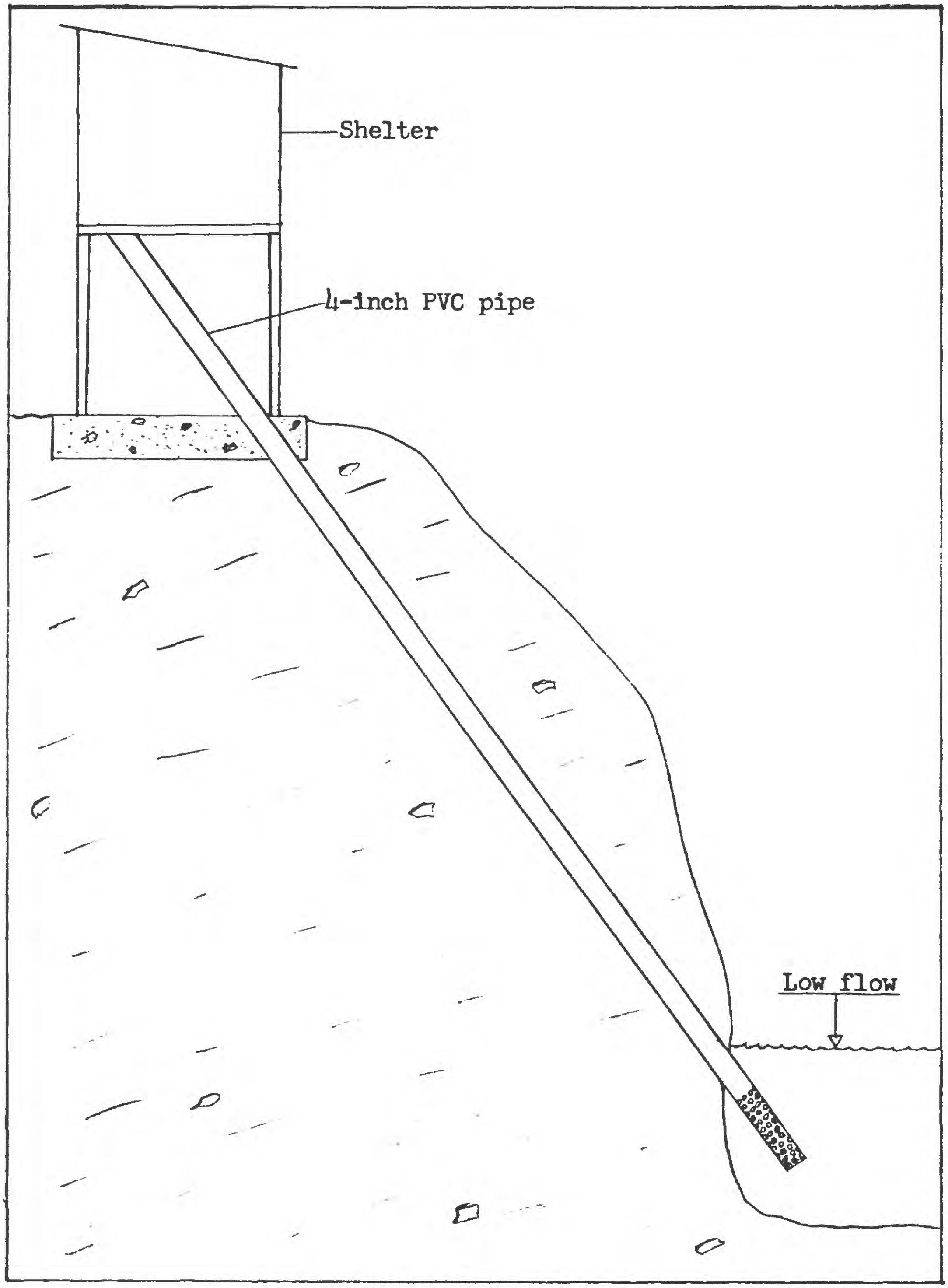

Figure 14.--Streambank installation of shelter and sensor housing for the mini-monitor on a steep bank.

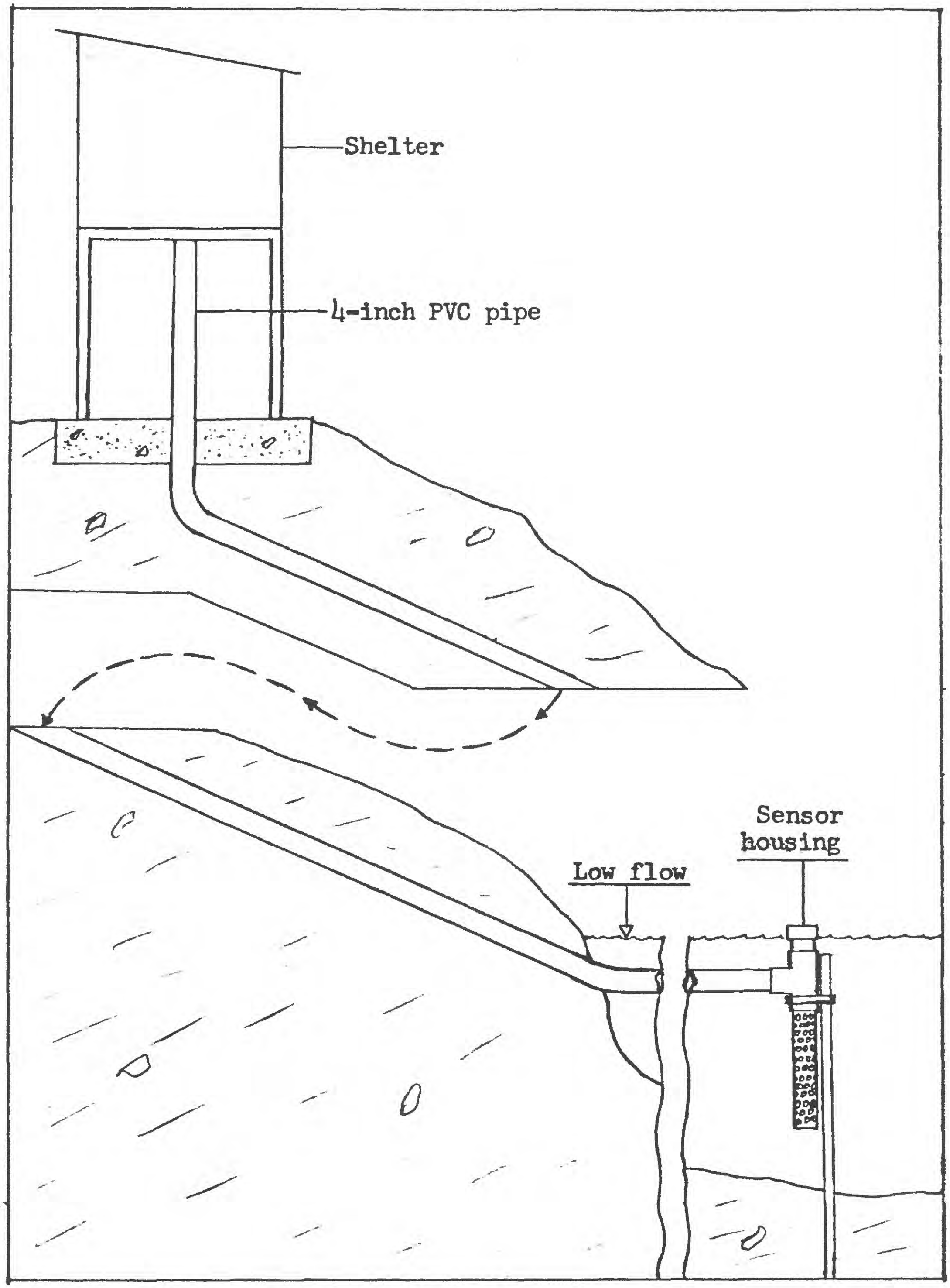

Figure 15.--Streambank installation of shelter and sensor housing for the mini-monitor on a gently sloping bank.

from being washed out. The major disadvantage of this installation is that the sensors cannot be serviced at all stages of the stream and may require a boat for servicing.

NOTE: The 4-inch inside diameter PVC pipe is schedule 40, unless specified otherwise. The wall thickness of 4-inch PVC pipe (schedule 40) is 0.25 inch and the inside diameter is 4 inches. All schedule 40 connectors are slip-joint and are permanently connected by use of PVC cement. Schedule 80 PVC pipe and connectors may be obtained for either threaded or slip-joint connections. The inside diameter of 4-inch PVC pipe (schedule 80) is slightly less than 4 inches, but the outside diameter is the same as 4-inch PVC pipe (schedule 40); therefore, 4-inch PVC pipe (schedule 80) will mate with 4-inch PVC connectors (schedule 40).

An installation that may be used on either a streambank or a bridge pier is shown is figure 16. Separate housing is installed for each sensor by use of 2-inch inside diameter PVC pipe, which will provide sufficient clearance for the sensor to slide down the pipe to the stream. Any curves in the pipes must be of sufficient sweep to permit the sensors to move through them without binding. Several 0.5-inch holes are drilled in the lower ends of the pipes to allow water to flow around the sensors. The sensors can be retrieved separately and serviced or replaced. In cold regions where heaving freezing occurs the sensors may freeze in place. In such areas other types of installations must be considered. Although shown as a bridge pier installation, this type of installation may be adapted for use as a streambank installation similar so that shown in figure 14. Whatever method is used, the sensor housing must be anchored firmly to prevent it from being torn away by debris.

A look-in shelter mounted on a section of 24-inch culvert pipe with a walkway installed to provide easy access is shown in figure 17. A shelf fastened to the handrail provides writing space. A sensor housing composed of a section of 4-inch perforated PVC pipe anchored into the streambed is shown in figure 18. The housing for the sensor cables must be anchored to the streambed to prevent it being washed away.

Installation of water-quality monitors

Flow-through monitor

The flow-through monitor can be placed in the shelter several different ways. The monitor cabinet may be mounted either on the wall by use of the hangers provided on the back or bolted to the shelf to secure it from tipping when the front panel door is opened. An efficient arrangement of the monitor system showing several optional features is illustrated in figure 19. The sensor tank is placed directly below the monitor cabinet and sits on a drain box, an optional accessory. The sensor tank drains directly into the drain box, which is connected to the water drain hose. The drain box, 16 inches wide by 32 inches long by 5 inches high, may be constructed of 18-gage copper sheet. Expanded sheet metal mounted on top of the drain box will provide the platform on which the sensor tank sits.

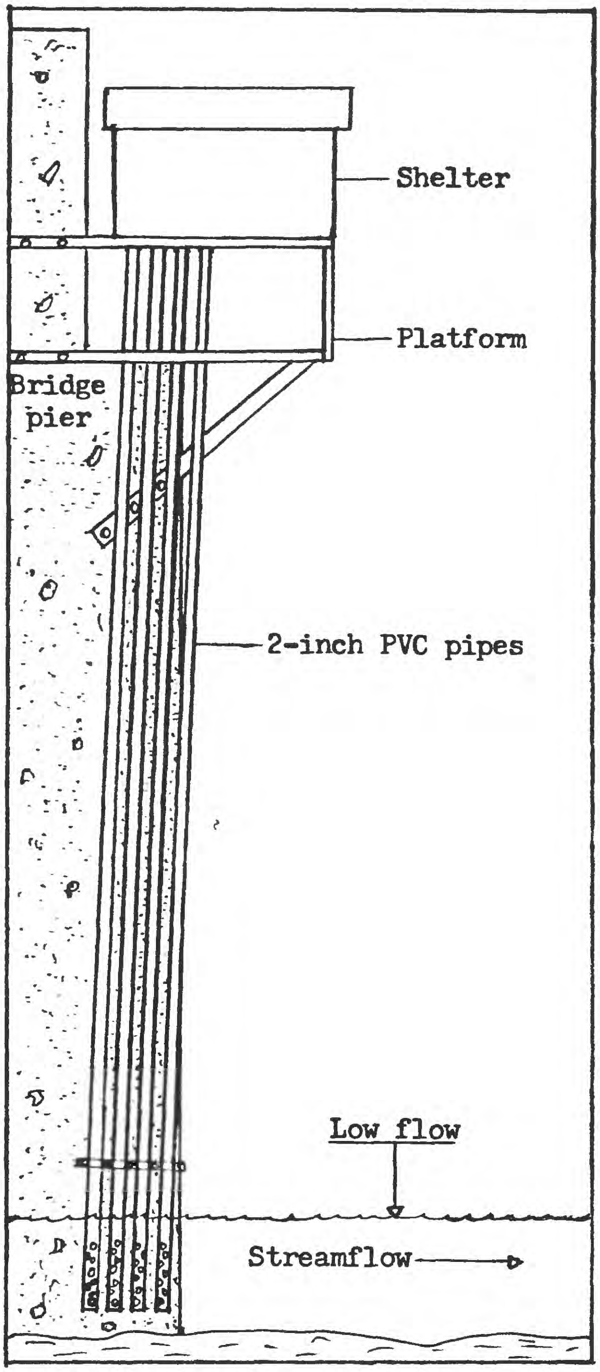

Figure 16.--Bridge-pier installation of shelter and separate housings for each mini-monitor sensor.

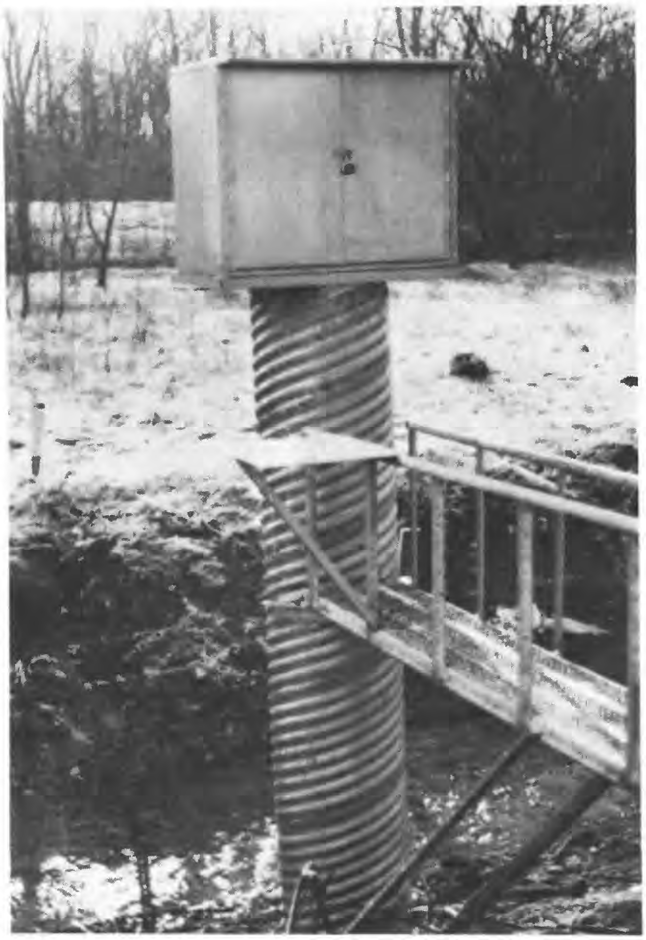

Figure 17.--Look-in shelter mounted on culvert pipe. Photograph by R. P. Frehs.

Figure 18.--Sensor housing mounted in streambed. Photograph by C. T. Welborn.

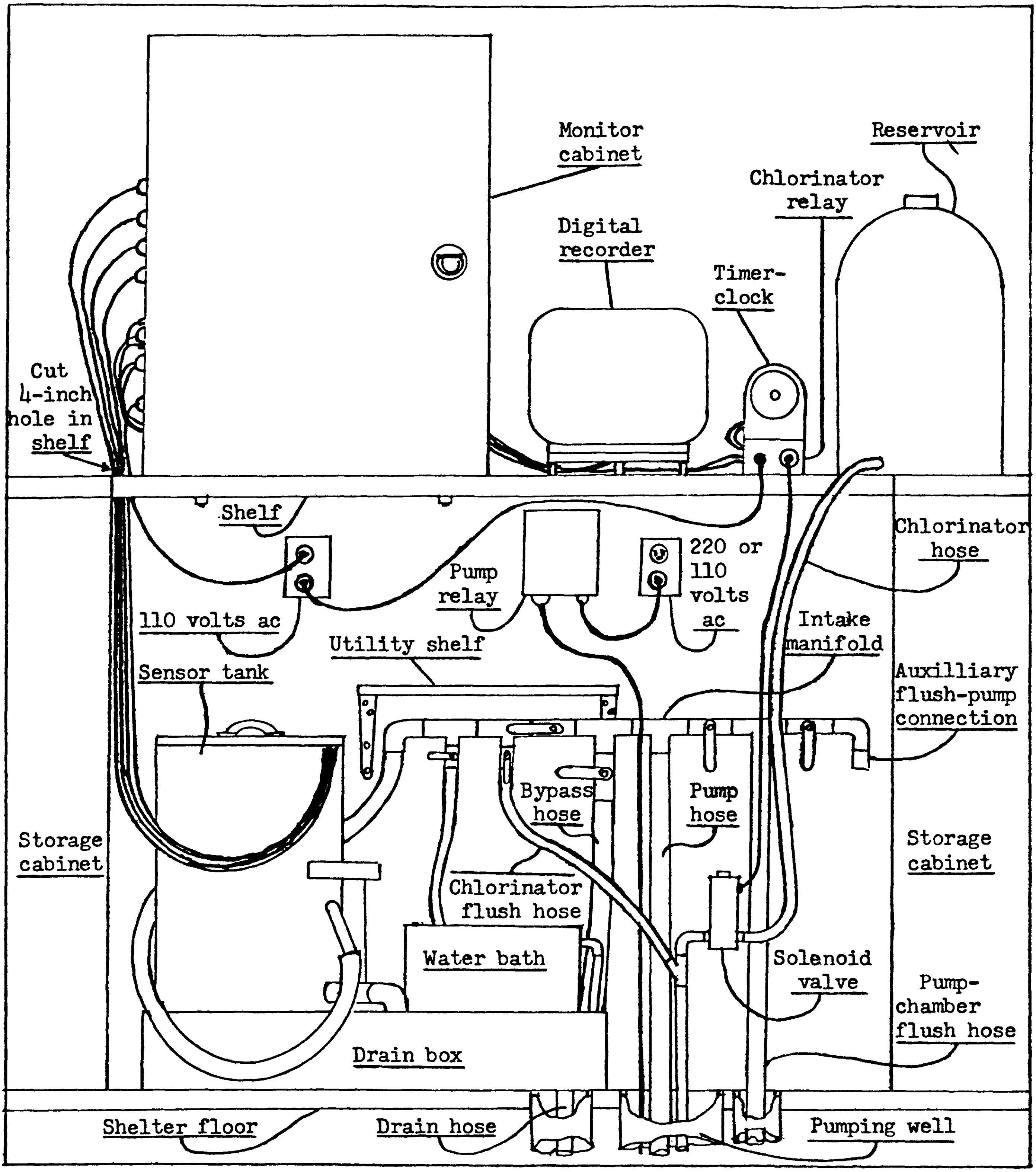

Figure 19.--Flow through monitor, pumping system, pump-chamber flushing system, and chlorinator system installed in 6-foot-square by 8-foot-high shelter.

Another optional accessory is a small utility shelf, 5 inches wide by 18 inches long by 0.5 inches thick, into which four equally spaced 3-inch holes have been cut, can be mounted as shown in figure 19 to accomodate the sensors while they and the sensor tank are being cleaned.

A water bath, 5 inches wide by 12 inches long by 6 inches high, also an optional accessory, may be constructed of 18-gage sheet copper. It may be placed on top of the drain box as shown in figure 19. Stream water flows through the water bath and into the drain box. The containers of pH buffers and specific conductance standard solutions can be placed in the water bath to bring the solutions to the same temperature as the stream water, thus eliminating respective sensor adjustment for temperature during calibration checks.

Connect the sensors, digital recorder, and timer-clock to the indicated connectors on the monitor cabinet. Each sensor must be connected with the same numbered position of the corresponding signal conditioner in the front panel of the monitor cabinet. A 4-inch-square hole, cut in the shelf, will keep the sensor cables out of the way. CAUTION: Do not connect the electric power until all other connections have been made properly.

Pumping system

Care must be taken when a submersible pump is installed to protect the public and the field personnel from electric shock. The electric cables to the pump must be enclosed and not accessible by unauthorized persons.

The submersible pump requires some preliminary connections. A 1-inch fabric reinforced rubber hose is connected to the pump outlet by use of two stainless-steel hose clamps. Waterproof, in-line connectors are spliced into the electric cable 3 feet from the pump and the splice must be waterproofed. The number of wires in the connector depends on the requirements of the individual pump. The connectors are added to facillitate replacement of the pump. In addition a nylon line should be connected to the pump to reduce strain on hose, clamps and electric cable during insertion and removal. The length of the pump hose, electric cable and nylon line must be sufficient to lower the pump to the proper depth in the pumping well and still have enough cable and hose to connect them to the respective connections in the shelter. The pump hose is connected to the intake of the sensor tank by use of a stainless-steel hose clamp. The pump is then lowered into the pumping well to the proper depth in the pump chamber as shown in figure 20. To complete the pumping system, a 1- or 1.25-inch drain hose is installed. The hose is fed to the stream through the 4-inch inside-diameter PVC pipe that was installed as conduit for the hose. The hose is then connected to the outlet of the sensor tank or, to the outlet of the optional drain box as shown in figure 19.

The pumping system shown in figures 19 and 20 includes a multipurpose intake manifold that provides two types of pump-chamber flushing systems. One system operates similar to that shown in figure 18 by use of an auxilliary pump that is connected as indicated in figure 19 and pumps water from the

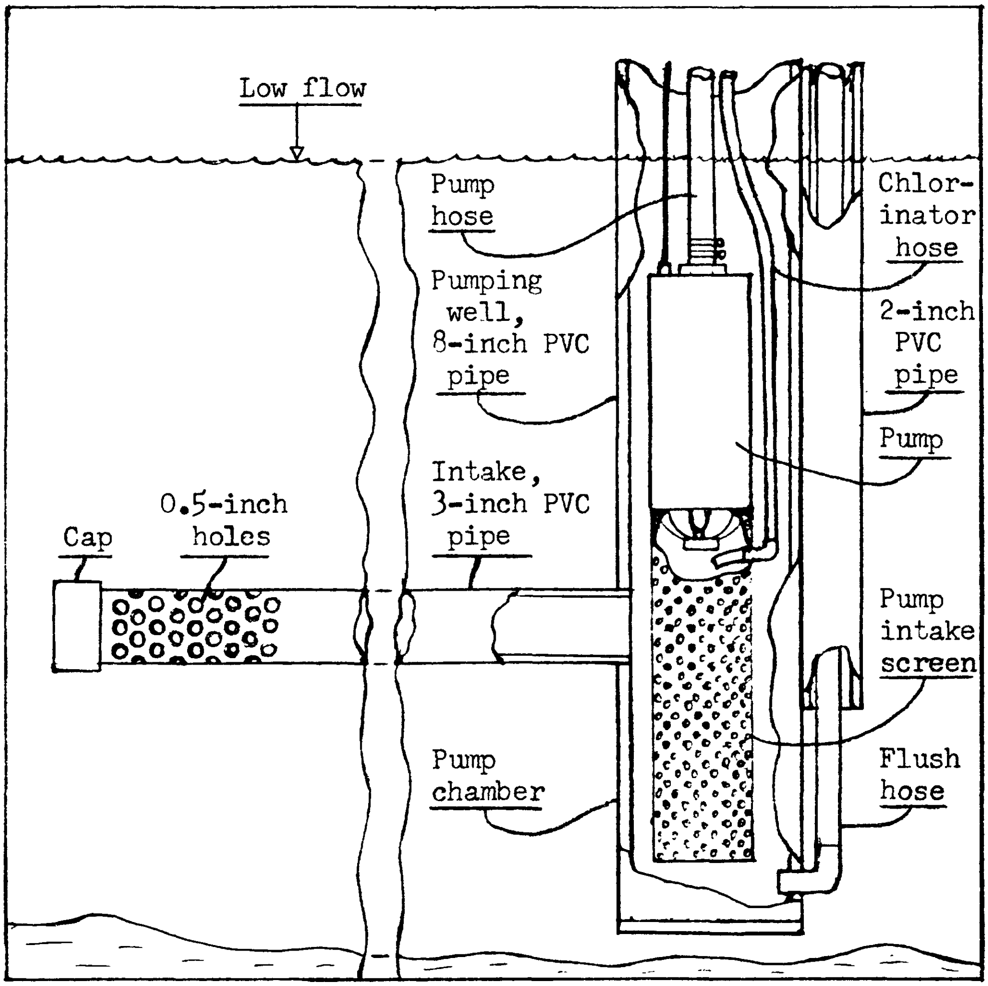

Figure 20.--Pumping well for flow-through monitor that includes pump-chamber flush system and chlorinator system.

stream. The valve adjacent to the auxilliary flush-pump connection is opened and water flows through the pump-chamber flush hose. The accumulated sediment is flushed out through the pumping-well intake shown in figure 20. When the flushing procedure is completed, the valve is closed and the auxilliary pump disconnected. The primary pumping system should be turned off during the flushing operation.

The other pump-chamber flushing system incorporated into the intake manifold operates as shown in figure 11 by use of the submersible pump in the primary pumping system. The three valves of the intake manifold that are shown adjacent to the submersible pump hose in figure 19 are used to channel the water as shown in figure 11. This flushing system is more convenient to use unless the auxilliary flush pump is installed as a permanent part of the pumping system. Sediment particles that are too large to pass through the pump-intake screen will need to be flushed out occasionally, through the pumping-well intake by use of the auxilliary pumping system. By installing the intake manifold as shown in figure 19, either system may be used as conditions dictate.

In regions where air temperature is below freezing for extended periods, all water lines that are not buried below the frost line or are completely exposed, as in bridge-pier installations, should be wrapped with heat tape and foam-rubber insulation to prevent freezing. In addition foot valves and other water retaining designs should be avoided so that lines will drain if the pump should fail.

Streams that carry a large amount of sediment may cause the sensor tank to fill with sediment in a short time. The collection of sediment can be reduced by cutting a 0.5-inch hole in the center of the rubber stopper that is in the bottom of the tank to allow the sediment to drain out of the tank as it settles to the bottom. The tank should remain full if the flow rate is at least 6 gallons per minute. If the pump should fail, this modification will allow all of the water to drain out of the tank and the sensors will become dry. However, the prevention of sediment accumulation may be of greater importance. The drastic changes in parameter values, should pump failure occur and the water drains out of the tank, will indicate the time of failure. The change in the specific conductance should be particularly noticeable.

Serious consideration should be given to the installation of a chlorinator (sodium hypochlorite injection) system at some locations. Where sewage effluent or other nutrient-rich water is prevalent in a stream, biological growth will thrive and accumulate in the intake line, in the sensor tank, and on the sensors. The accumulation of biological growth will greatly affect the accuracy of the data. Biological activity in the pumping system reduces the dissolved-oxygen concentration in the water by a few tenths to a few milligrams per liter. The accumulation of biological growth will reduce the inside diameter of the intake line, and consequently will reduce rate of flow to the sensor tank. The dissolved-oxygen sensor is flow-sensitive, therefore, the reliability of the dissolved-oxygen data is affected. Injection of a small amount of household bleach (5 percent sodium hypochlorite solution) into the pumping system at predetermined intervals will greatly reduce or eliminate biological growth. The chlorinator should not be used in lieu of good housekeeping or proper maintenance practices but rather to reduce interferences from biological growth in the system between maintenance visits.

An automatic chlorinator system is shown in figures 19 and 20. The reservoir, a 5-gallon, polyethylene bottle with a 0.375-inch tubing connector near the bottom, contains the 5-percent sodium hypochlorite solution. The hose used to connect the system is 0.375-inch-inside-diameter (0.5-inch-outside-diameter) polyethylene tubing and is connected as shown in figures 20 and 21. A 0.375-inch Y-connector is used to connect the chlorinator hose to the chlorinator flush-hose that connects to the intake manifold through the chlorinator hose to flush out all of the sodium hypochlorite solution that is released periodically by the solenoid valve. The chlorinator hose is connected to the pump-intake screen as shown in figure 20 by drilling a 0.375-inch hole in the screen near the pump intake and inserting a 0.375-inch

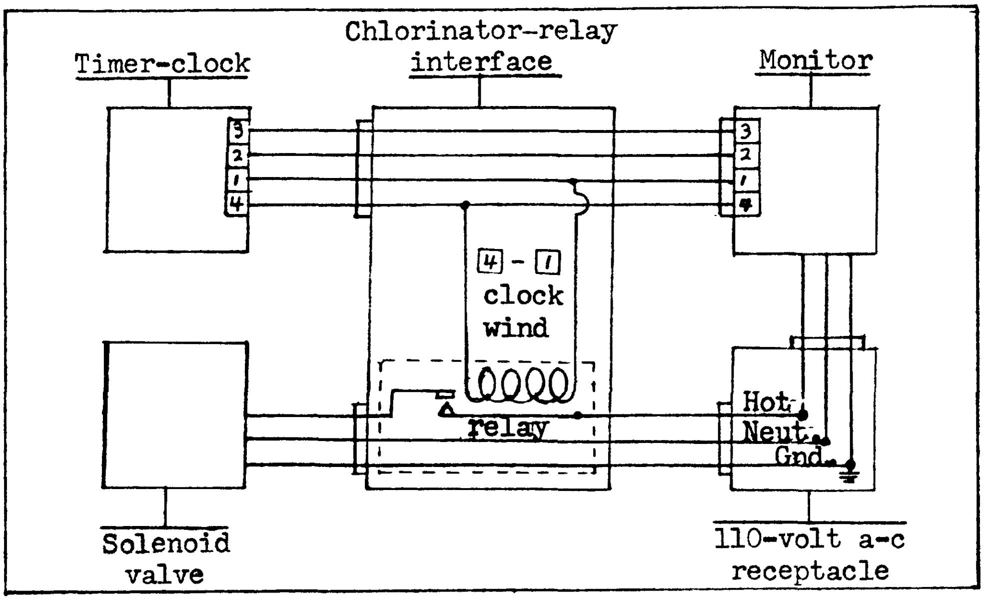

Figure 21.--Block diagram of electronic circuitry of chlorinator.

elbow tubing connector into the hole. A 2-inch piece of the polyethylene tubing is installed on the connector inside the screen to secure it in the screen. The elbow is then connected to the chlorinator hose.

The chlorinator system connects to the monitor as shown in figures 19 and 21. The timer-clock connects to the monitor through the chlorinator-relay interface and activates the monitor hourly. After the data for all the parameters are recorded, a clock-wind voltage is supplied to the timer clock by the monitor through the interface. This voltage activates the relay in the interface and engages the solenoid valve that is connected to a 110-volt ac receptacle through the interface as shown in figures 19 and 21. When the solenoid valve is engaged, it remains activated for 6 seconds to allow 15 milliliters of the 5 percent sodium hypochlorite solution in the reservoir to flow through the chlorinator hose to the intake of the submersible pump. (CAUTION: This specification should not be exceeded!) The sodium hypochlorite solution mixes with the stream water and flows through the pump, the pumping system, the sensor tank, and the drain hose back to the stream. Stream water is pumped through the system for 1 hour and flushes out all of the sodium hypochlorite before the time clock activates the monitor again and the procedure is repeated. Stream water flows continuously through the chlorinator water supply hose to remove all of the sodium hypochlorite solution from the chlorinator hose below the solenoid valve (fig. 19). There should be no interference from the sodium hypochlorite, and the reduction of biological growth should greatly improve the overall accuracy of the collected data. The chlorinator system will require a cycle adjustment if a monitor that reads and records data more frequently than hourly is used.

A streambank installation of a pumping system without a pumping well is shown in figure 22. The portion of the pumping system installed in the shelter is similar to that shown in figure 19. The pump-chamber flushing system, of course, can be eliminated, but the other parts of the intake manifold remain the same. The chlorinator system is the same as shown in figures 19 and 20, except for a minor change at the pump. Two 4-inch PVC pipes, buried side by side, extend from the shelter to the stream. The downstream pipe houses the drain hose and ends near the streambank, and the upstream pipe houses the pumping system and extends to the point of optimum depth and flow as shown in figure 22.

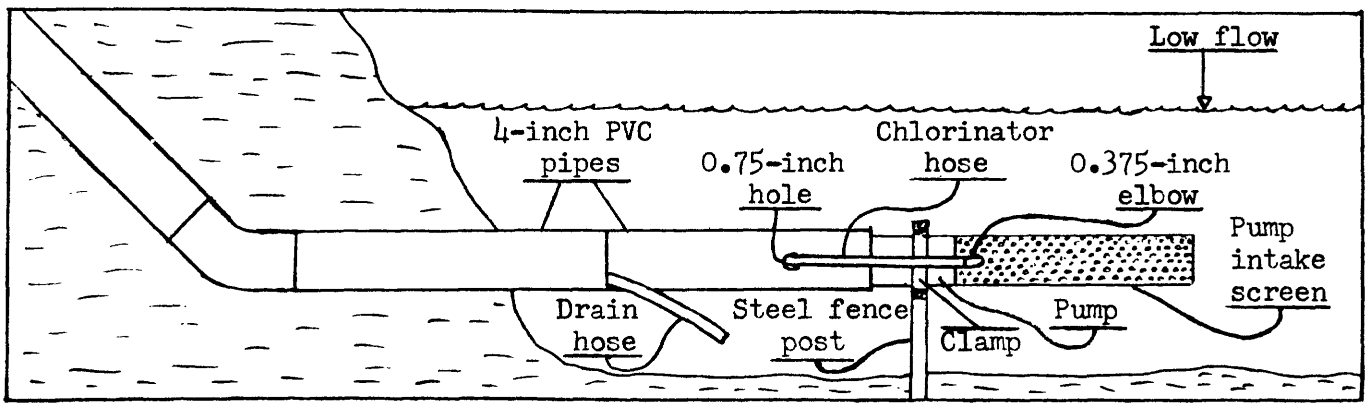

Figure 22.—Streambank installation of pumping system and chlorinator system.

To install the pumping system, pump hose, electric cables and the chlorinator hose, as shown in figure 19, above items are pulled through and far enough beyond the end of the 4-inch PVC pipe to ensure connections can be made to the pump. The chlorinator hose is brought out of the pipe through a 0.75-inch hole drilled in the downstream side of the pipe about 1 foot from the end. The hole should be drilled before the pipe is installed in the stream. The pump hose and electric cable are connected to the pump, and the pump is then inserted about 4 inches into the pipe, clamped to the steel fence post and driven into the streambed to hold it in place. The chlorinator hose is connected to the pump-intake screen as shown in figures 20 and 22. Sufficient hose and electric cable must be left in the shelter to allow for pulling them out when the pump must be replaced. The chlorinator hose can be disconnected at the pump-intake screen.

The type of installation shown in figure 22 should be limited to streams that can usually be waded. A backup pumping system should be installed to use when the submersible pump fails during high flow and is inaccessible for replacement. A distinct disadvantage of this type of installation is that the pump may be damaged by debris or ice or may be torn loose and washed away. The advantages are that the water lines are underground and protected from freezing and vandalism.

At some installations of flow-through water-quality monitors, intermittent rather than continuous operation of the pump may be desirable. Streams that carry a large amount of sediment may cause excessive wear of the pump. A special timer will be required to turn the pump on and off at the proper time before and after the scan and record cycle of the monitor.

Mini-monitor

The installation of the mini-monitor and the sensors should be a very simple procedure if the shelter and the pipe to house the sensors have been installed properly. All that should be necessary is to place the electronic package, digital recorder, and batteries in the shelter in a convenient arrangement and slide the sensors down the pipe into the stream water inside the perforated section of the pipe. A convenient method of mounting the electronics package of the mini-monitor in a shelter is shown in figure 23. Two 10-inch shelf brackets are fastened to the wall of the shelter at a 70° angle to hold the electronics package at about eye level when cradled in them. An elastic cord is fastened around the electronics package and the shelf brackets to secure the unit in place. This mounting may be used for either a look-in shelter or above the shelf of a walk-in shelter.

A very important part of the installation of the mini-monitor is the connection of the cables to the electronics package. Great care must be taken to ensure that all components are connected properly. The sensor cables, the waterproof connectors, and the connectors at the electronic package are identical for all parameters, therefore it is imperative that the sensors and extension sensor cables be matched properly. To facilitate proper matching, both ends of the extension sensor cable and the sensor cable should be labeled with the number of the channel of the electronics package to which it is to be connected. A set of self-adhesive numbered labels can be obtained from electronics supply companies for this purpose. Improper connection of a sensor to the electronics package may damage the sensor and (or) the signal conditioner. The waterproof connectors have alignment marks on the outside of each part as shown in figure 24. When making connections, align these marks and push the connectors together completely. Forcing the connectors together without aligning the marks may damage the connectors and possibly damage the signal conditioner and the sensor. The locking sleeves can be screwed together to prevent the connector from pulling apart after they have been connected. Note: A thin film of silicone grease (electrically nonconductive) spread on the connector bodies will make the connectors slide together more easily, but avoid getting the silicone grease on the connector prongs.

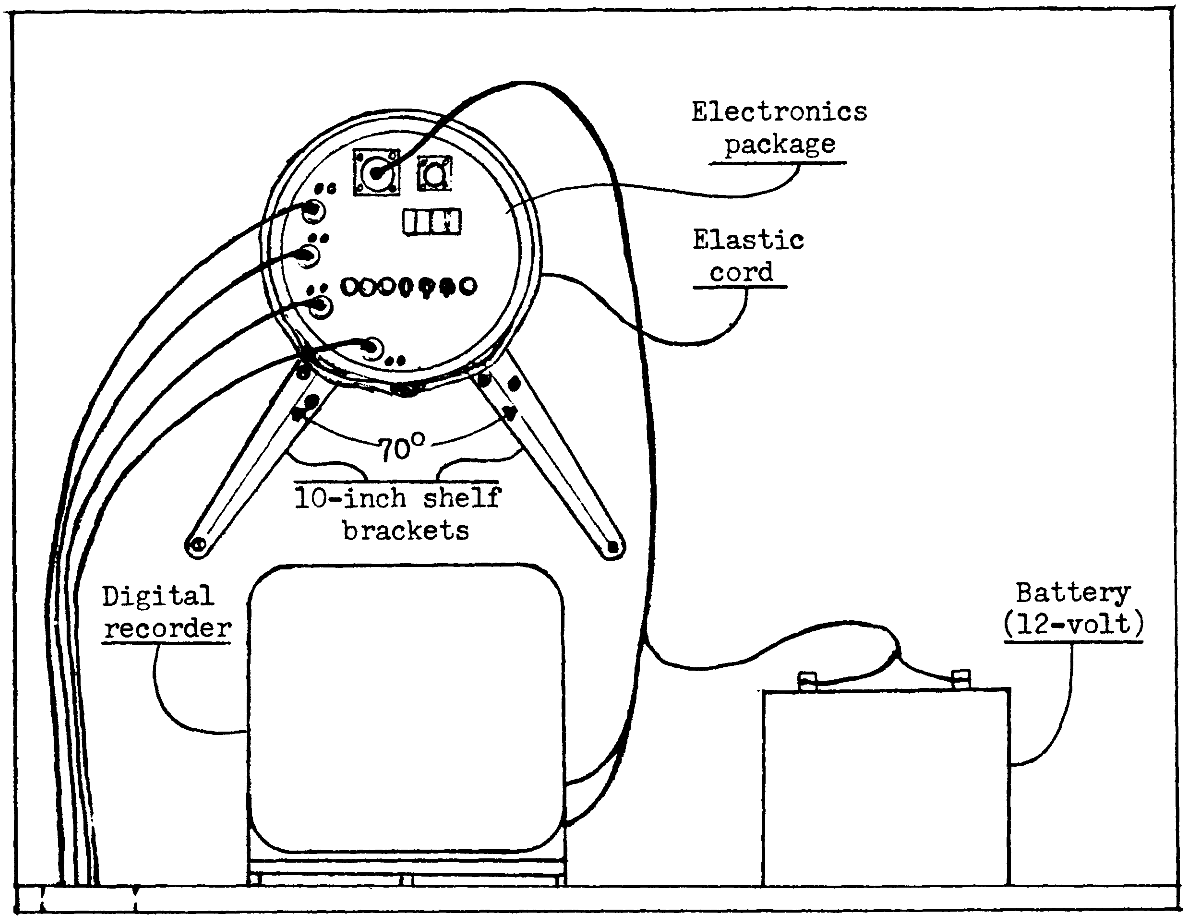

Figure 23.--Mini-monitor electronics package mounted on the shelter wall.

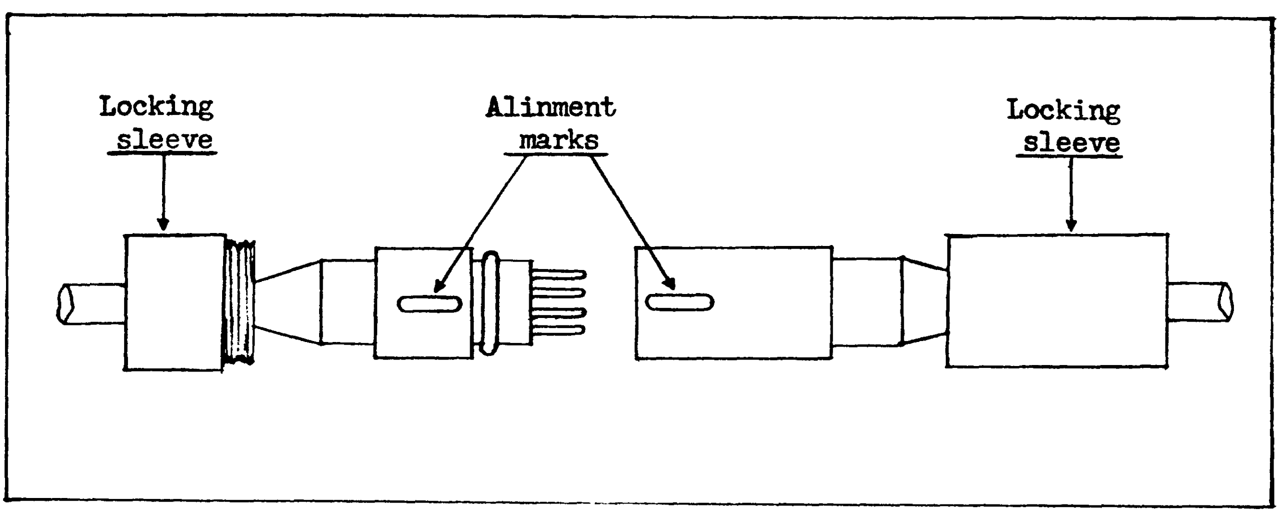

Figure 24.--Waterproof sensor connector.

After the sensors have been connected to their respective extension sensor cables, the final connections of the mini-monitor are made in the order indicated.

(1) Connect the sensor cables to the matching channel connectors on the electronics package.

(2) Connect the package and recorder cable assembly shown in figure 25 to the electronics package.

(3) Connect the recorder part of the power and recorder assembly to the digital recorder.

(4) Connect the power leads of the power and recorder assembly to the 12-volt dc power source, with the power switch turned to "Off". Be sure to observe proper polarity.

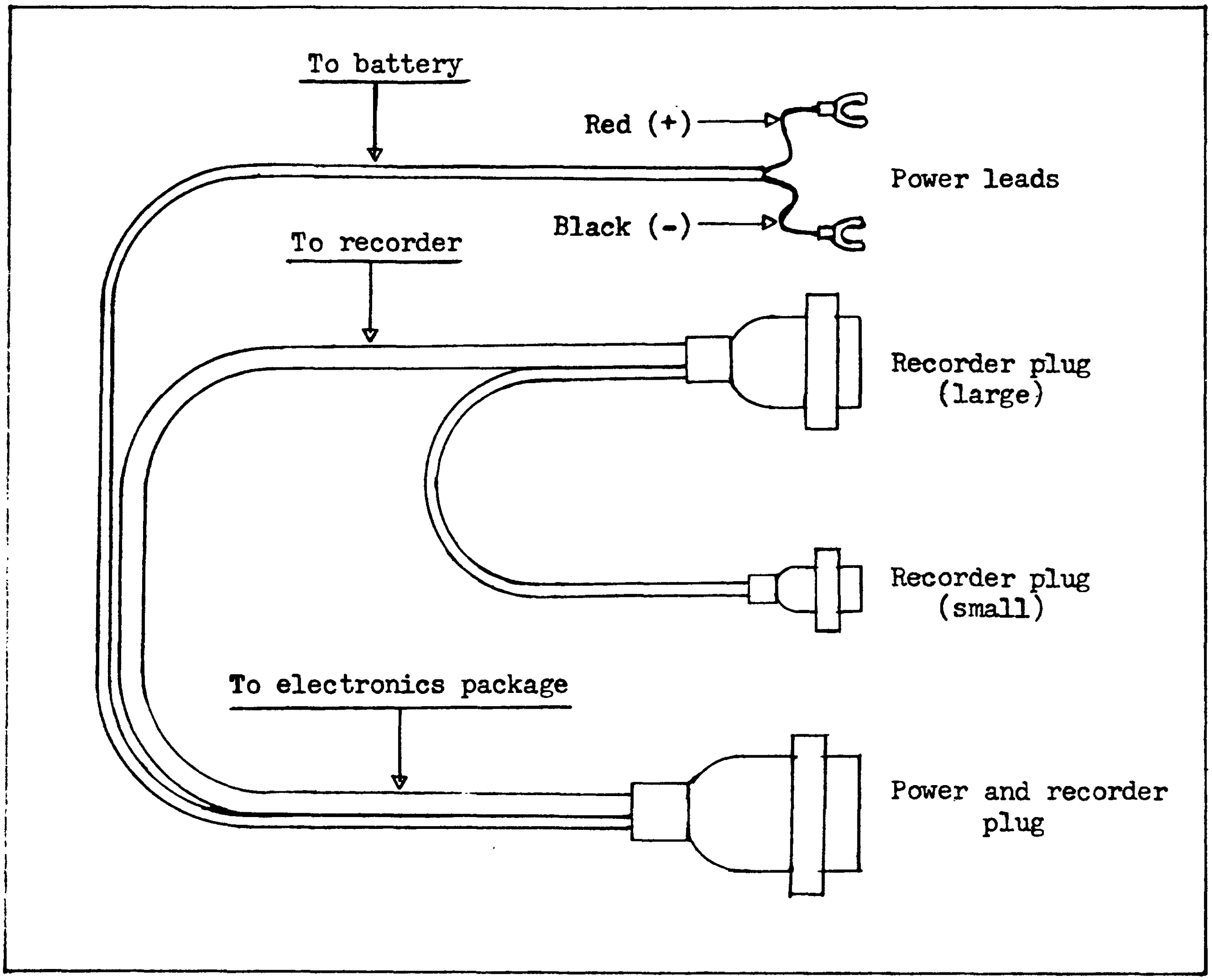

Figure 25.--Power and recorder cable assembly.

CALIBRATION

Monitor inspection forms

Some type of inspection form should be used to record all information pertinent to the calibration and inspection of the monitors. An example of a monitor inspection form is shown in figure 26. The inspection form provides a check list of the various activities to be performed in a complete inspection of a monitor. This information is an absolute necessity in the substantiation of the validity and accuracy of the collected data. The basic data and information that should be recorded when a monitor is inspected are:

1. Station number and location, and inspecting personnel (initials)
2. Data and time: WT (watch time), CT (clock time), TT (tape time)
3. Parameter values and flow rate of water into the sensor tank before cleaning
4. Parameter values and flow rate of water into the sensor tank after cleaning
5. Calibration checks by use of standard procedures
6. Parameter values and test-plug values after calibration
7. Gage height
8. Comparison checks of parameter values between stream and sensor tank
9. Digital tape numbers (beginning and ending, to determine number of days recorded)
10. Remarks (information concerning calibration checks and general conditions)

Flow-through monitor

The maximum value that can be displayed on the panel meter and correctly recorded on the digital tape is 999. Any value greater than 999 displayed on the panel meter will be recorded as a low value. The maximum value of the selected range of a parameter, therefore, must be greater than the anticipated maximum value that will be measured. The maximum panel-meter value listed in the range specifications is 1,000 because this value can be displayed as a panel-meter value and is used to calculate the equivalent-value factor for the selected range of the parameter.

The equivalent-value factor (F) is calculated by the equation,

$$F = (Rm - Ro)/ Pm$$

MONITOR INSPECTION FORM

STATION NO. ______________________ DATE ______________________

LOCATION ____

TAPE REMOVED______________ INSPECTED BY ______________ GAGE HEIGHT ______________

TIME OF BEFORE CLEANING READINGS: WT.______________ CT.______________ TT.______________

READINGS	BEFORE CLEANING			AFTER CLEANING			
PARAMETER	PANEL METER	CONVERTED VALUE	FIELD METER	PANEL METER	CONVERTED VALUE	FIELD METER	TEST PLUG VALUE
SP. COND.							
D.O.							
TEMP.							
pH							

ATMOSPHERIC PRESSURE:______________________ MM HG. AT ______________ °C

CALIBRATION CHECKS:

READINGS		BEFORE CALIBRATION		AFTER CALIBRATION		REMARKS:
PARAMETER	STANDARDS VALUE	PANEL METER	CONVERTED VALUE	PANEL METER	CONVERTED VALUE	
SP. COND.						
D.O.						
TEMP.						
pH						

COMPARISON CHECK	STREAM AT INTAKE	WATCH TIME	SENSOR TANK	WATCH TIME	DIGITAL TAPE NUMBERS
					TAPE ON
D.O.					TAPE INSPEC.
TEMP.					TAPE OFF

AFTER CALIBRATION READINGS: TIME: WT.______________ CT.______________ TT.______________

PARAMETER	PANEL METER	CONVERTED VALUE	FIELD METER	TEST PLUG VALUE	FLOW RATE IN SENSOR TANK
SP.COND.					BEFORE CLEANING
D.O.					FILL TIME:__________ GPM:______
TEMP.					AFTER CLEANING
pH					FILL TIME:__________ GPM:______

REMARKS:

Figure 26.--Water-quality monitor inspection form.

where

Rm = maximum value of the selected parameter range,

Ro = minimum value of the selected parameter range,

Pm = maximum value of the listed panel-meter values (1,000).

The equivalent value (E) in reporting units of a meter display is calculated by the equation,

$$E = M \times F$$

where

M = the value displayed on the panel meter,

F = the equivalent-value factor.

The equivalent panel-meter value (Me) of a calibration standard is calculated to determine the required meter setting by the equation,

$$Me = S/F$$

where

S = the value of the calibration standard,

F = the equivalent-value factor.

Specific conductance

1. Check to be sure that the specific conductance sensor has been connected to the sensor connector on the side panel with the same number as the position of the specific conductance signal in the front panel.

2. Turn the range switch on the specific conductance signal conditioner panel to the position of the selected specific conductance range:

Range position	Approximate range µmhos/cm	Panel-meter value
1	0 to 100	000 to 1,000
2	0 to 1,000	000 to 1,000
3	0 to 10,000	000 to 1,000
4	0 to 100,000	000 to 1,000

Note: All range positions are provided with enough adjustment to overlap. For example: A required range of 0 to 500 µmhos/cm can probably be used on either range position 1 or 2. In addition, some offset adjustment is provided to allow for offsetting of ranges as in the following example:

Range position	Required range µmhos/cm	Panel-meter value
2	1,000 to 2,000	000 to 1,000

3. Place the auto-manual switch on the front panel in the manual position.

4. Toggle the start-stop switch on the front panel to start position and release.

5. Toggle the advance switch on the front panel to sequence the programmer until the light on the specific conductance signal conditioner panel is lit. The panel meter now indicates the output of the specific conductance signal conditioner.

6. Place the specific conductance sensor in a plastic or glass container of standard solution of potassium chloride (KCl) with a specific conductance of approximately 15 percent of full range and wait until the temperature of the sensor and the solution equalize and the panel-meter value is constant. Adjust the zero coarse pot (potentiometer) and then the zero fine pot on the signal conditioner with a small screwdriver until the panel-meter value is 000.

7. Place the sensor in a container of standard solution of approximately 100 percent of full range. (Note: The sensors must be rinsed with the new standard solution before using that standard.) Adjust the span coarse pot and then the span fine pot on the signal conditioner until the panel-meter value is the equivalent value of the difference between the low standard solution and the high standard solution. For example: If the selected range is 0 to 500 µmhos/cm and the panel-meter values are 000 to 1,000, the equivant-value factor is 0.5 (500 / 1,000 = 0.5). If the low is 15 percent of full range or 75 µmhos/cm (0.15 x 500 = 75) and the high standard is 90 percent of full range or 450 µmhos/cm

(0.90 x 500 = 450), the difference between them is 375 μmhos/cm (450 - 75 = 375). The panel-meter value should be adjusted to 750 (375 / 0.5 = 750).

8. Adjust the zero coarse pot and then the zero fine pot while the sensor is still in the high standard solution until the panel-meter value is the equivalent value of the high standard solution. In the above example, the value should be 900 (450 / 0.5 = 900).

9. Rinse the sensor with the low standard solution, return it to the low standard and discard the low standard rinse. The panel-meter value should be the equivalent value for the low standard solution. In the above example, the value should be 150 (75 / 0.5 = 150).

10. Place the sensor in a standard solution of approximately midrange value. The panel-meter value should be the equivalent value for this standard solution. In the above example, a standard solution with a value of 50 percent of full range, 250μmhos/cm (0.50 x 500 = 250), the panel-meter value should be 500 (250 / 0.5 = 500).

11. Place the sensor in the sensor tank. With the water flowing through the sensor tank, observe the panel-meter value. After sufficient time has been allowed for the temperature of the sensor to equalize to that of the water, the panel-meter value should be the equivalent value for the specific conductance of the water. If the parameter is calibrated as in the example and the panel-meter value is 740, the specific conductance value of the water is 370 μmhos/cm (740 x 0.5 = 370). The specific conductance of the water may be determined by use of a specific conductance field meter to verify that the parameter has been properly calibrated and that the field meter was in agreement with the value determined by the monitor at the time of calibration.

12. Record all pertinent information for future reference.

Summary of specific conductance calibration procedure:

Selected range: 0 to 500 umhos/cm = 000 to 1,000 panel-meter values.		
Equivalent-value factor = 0.5 (500 / 1,000 = 0.5).		
Specific conductance standard solutions: 75, 250, and 450 umhos/cm.		
With sensor in	Adjust	Until panel-meter value is
75 µmhos/cm standard	Zero coarse pot and then fine pot	000.
450 µmhos/cm standard	Span coarse pot and then fine pot	750 (450 - 75 = 375 diff.) (375 / 0.5 = 750).
450 µmhos/cm standard	Zero coarse pot and then fine pot	900 (450 / 0.5 = 900).
75 µmhos/cm standard	Nothing	150 (75 / 0.5 = 150).
250 µmhos/cm standard	Nothing	500 (250 / 0.5 = 500).
Sensor tank water	Nothing	740 (740 x 0.5 - 370 µmho).
Verification by specific conductance field meter = 370 umhos/cm		

Dissolved oxygen

The dissolved-oxygen sensor is delivered dry and will not operate until it is activated by installing a Teflon membrane, as shown in figure 27, and filling the electrolyte chamber with electrolyte. The Teflon membrane must be installed before the electrolyte is added. An efficient method for the installation of the Teflon membrane is shown in three steps in figure 27 and described below. If other methods are used they must provide a waterproof installation and the Teflon membrane must be held firmly in place over the silver electrode.

1. Remove the protective cover cap (not shown in fig. 27) and the second O-ring from the tip of the sensor. With the first O-ring in place, spread a thin film of silicone grease around the sides of the tip. Do not allow any silicone grease to get on the silver electrode or in the small holes around the silver electrode. Center a piece of Teflon membrane over the silver electrode and smooth it snuggly down over the sides of the tip. Do not allow any wrinkles to form over the end of the tip.

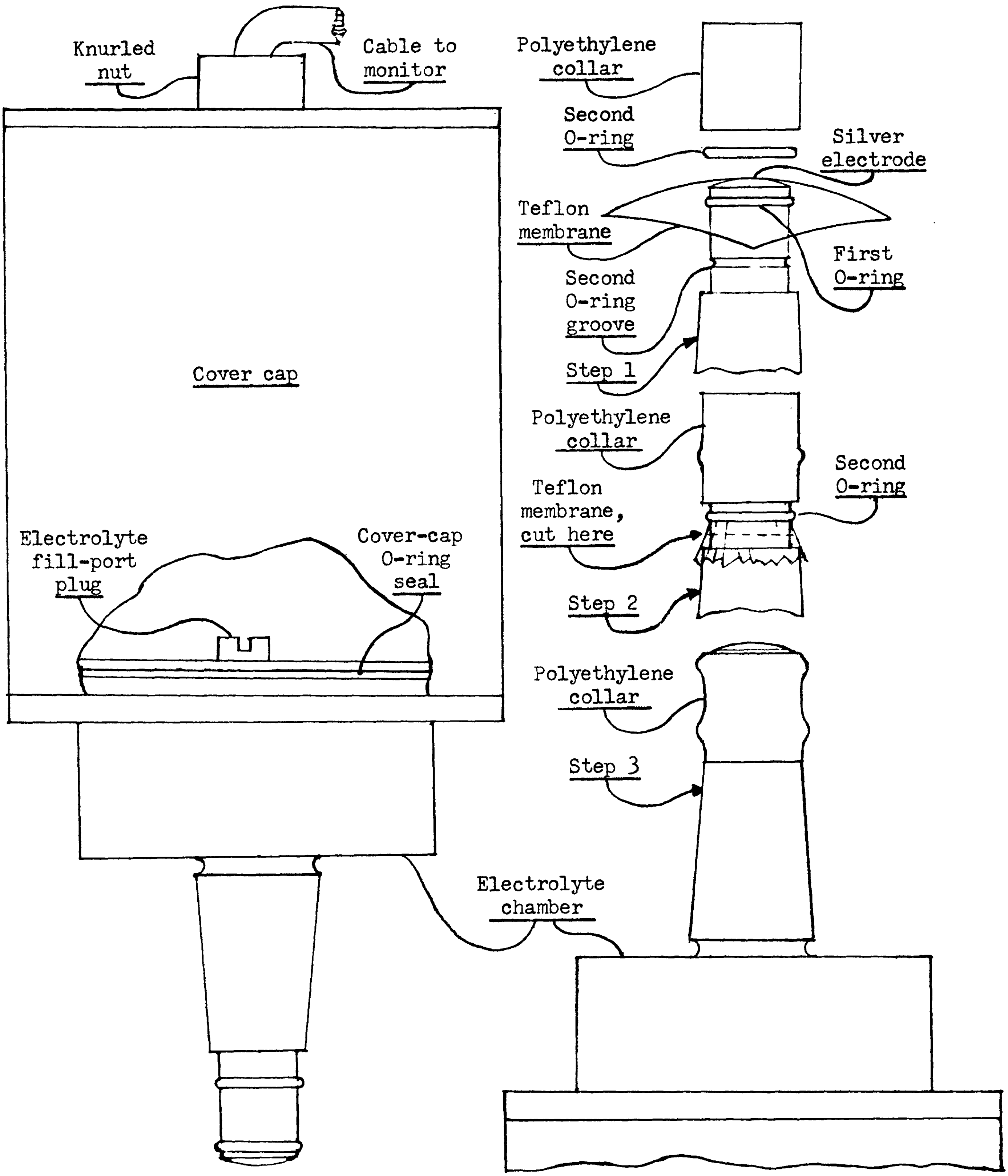

Figure 27.--Dissolved-oxygen sensor.

2. While holding the membrane firmly in place, hook one side of the second O-ring under the first O-ring, stretch it across the tip and down over the first O-ring, then slide it down into the second O-ring groove. Center the polyethylene collar over the tip and press it down over the first O-ring as shown. Do not twist or move the collar back toward the upper end of the tip because it may loosen or damage the membrane. A loose or damaged membrane must be replaced. Cut off the excess membrane at the point shown in figure 27.

3. Apply a small amount of silicone grease to the second O-ring and the exposed part of the tip shaft beyond the collar, then press the collar down over the second O-ring to the shoulder of the tip to expose the Teflon covered silver electrode. Both O-rings must remain in the grooves.

After the Teflon membrane has been installed the sensor should be activated by filling the electrolyte chamber with a 1-normal solution of potassium hydroxide (KOH) electrolyte. KOH is caustic and care should be taken not to spill it on the wiring or on the hands while filling the electrolyte chamber. If electrolyte should get on the hands or wiring, rinse hands with water immediately and rinse the wiring with distilled water and dry completely with a paper towel.

1. Remove the sensor cover cap by unscrewing the knurled nut at the top (see fig. 27) and sliding the knurled nut, flat washer, and washer seal up the the cable. The cover cap is held rather firmly by a rubber O-ring seal at the bottom of the cap, so it may need to be forced off by holding the cap and pushing on the edge of the threaded tubing that protrudes through the top of the cap. Care must be taken to prevent cutting the cable or damaging the threads. If the knurled nut is not removed completely before loosening the cover cap, a better surface is provided

2. After the cover cap is removed, unscrew the electrolyte fill-port plug (fig. 27). Fill the electrolyte chamber with the electrolyte to the bottom of the fill port and replace the fill-port plug. Do not overfill by allowing electrolyte to stand in the fill-port. The capacity of the electrolyte chamber is about 30 milliliters. The sensor may be held at a slight angle with the fill-port on the high side to allow all of the air to escape. Shake the sensor vigorously to dislodge any air bubbles that may be trapped in the small holes around the silver electrode.

3. A newly activated sensor may need to operate overnight before stable operation is achieved. The output of the sensor must be tested and should be about 3 millivolts per milligram of dissolved oxygen concentration at 25°C. The output may be measured by the use of a multimeter with a 0- to 100-millivolt capability connected to terminals 4 (minus) and 9 (plus) on the strip inside the cover cap or in the sensor connector.

4. Stabilization can be achieved more quickly by use of a solution with a dissolved-oxygen concentration of 0.0 milligrams per liter. Such a solution may be prepared by dissolving 1 gram of sodium sulfite (Na_2SO_3) in 1 liter of distilled water and adding a small crystal of cobaltous chloride ($CoCl_2$) to hasten the reduction of the dissolved oxygen in the distilled water. Place

the tip of the sensor in an appropriate container of the solution and connect the multimeter as described above. The output of the sensor should be reduced to 0.00 millivolts within a few minutes. Remove the sensor from the solution, rinse the tip with distilled water, and allow the output to increase to about the maximum value as indicated by the multimeter value. Repeat the procedure until the output value is reduced to 0.00 mullivolts. This should require about 1 minute.

5. Replace the cover cap, the washer seal, the flat washer, and the knurled nut. Be sure that the cover cap goes all the way down over the O-ring seal at the bottom, then tighten the knurled nut finger-tight. The dissolved-oxygen sensor is now activated. When the sensor is not in use, the tip should be inserted into a plastic test tube, 3 inches long by 0.75 inch inside diameter, containing enough distilled water to cover the polyethylene collar, and sealed with plastic electricians tape. Storing the sensor this way will greatly extend the life of the sensor.

The dissolved-oxygen calibration may be done by use of an air-calibration chamber shown figure 28. This method is very reliable but the Teflon membrane must be in good condition. A damaged membrane must be replaced before calibration.

1. Check to be sure that the dissolved-oxygen sensor has been attached to the sensor connector on the side panel with the same numbered position as the dissolved-oxygen signal conditioner in the front panel.

2. Select the dissolved-oxygen concentration range required. The panel-meter volume for all concentration ranges between 0 and 20 mg/L will be 000 to 1,000.

3. Place the auto-manual switch on front panel in manual position.

4. Toggle the start-stop switch on front panel to start position and release.

5. Toggle the advance switch on front panel to sequence programmer until the light on the dissolved-oxygen signal conditioner panel is lit. Panel meter now indicates the output of the dissolved-oxygen signal conditioner.

6. Place the sensor in a container of Na_2SO_3 solution (1g/L) with a dissolved-oxygen concentration of 0.0 milligrams per liter. The panel-meter value will move down scale rapidly if the sensor is operating properly and stabilize at some low panel-meter value.

7. Adjust the zero coarse pot and then the fine pot until the panel-meter value is 000. To determine that the sensor output has reached true zero, the cover cap of the sensor may be removed and connections 4 and 9 on the top of the terminal strip shorted momentarily. There should be no change in the panel-meter value when the connections are shorted if the output of the sensor is 0.00 millivolts.

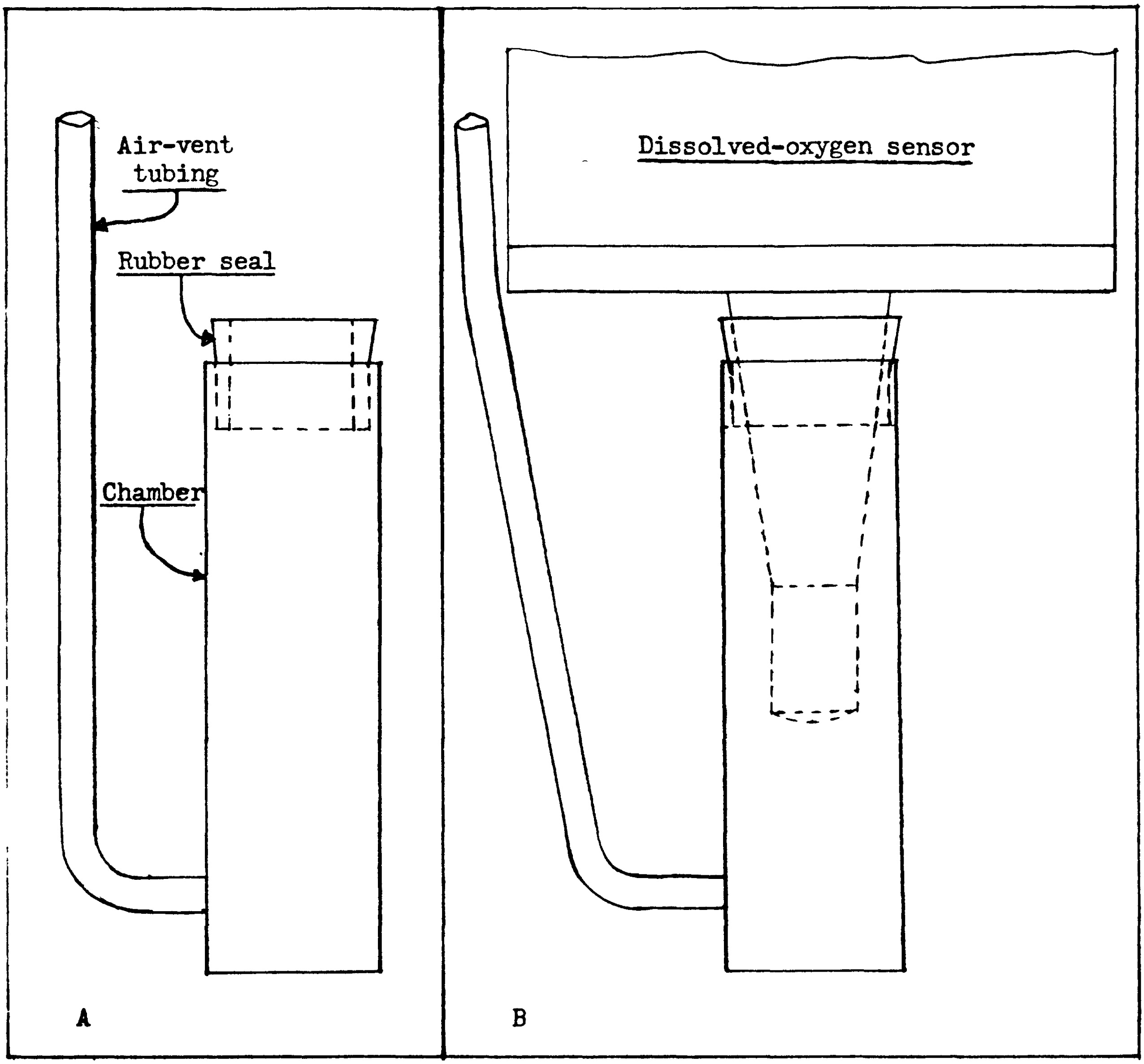

Figure 28.--Air calibration chamber for dissolved oxygen. A. Air-calibration chamber. B. Dissolved-oxygen sensor inserted in air-calibration chamber.

8. Place the air-calibration chamber (fig. 28A) and the sensor in the sensor tank and allow sufficient time for both to reach the temperature of the water. This may require 5 to 10 minutes depending upon the initial temperature difference.

9. Remove the sensor from the sensor tank and dry the tip by dabbing with a soft paper tissue. Invert the chamber so that the water will drain out of it and the air-vent tubing as the chamber is removed from the sensor tank. Insert the tip of the sensor into the chamber (fig. 28B) and return the combination to the sensor tank. Allow about 10 minutes for the temperature of the air in the chamber to stabilize.

10. Measure the temperature of the water and the atmospheric pressure to determine the dissolved-oxygen concentration by use of table 1.

11. Adjust the span coarse pot and then the fine pot until the panel-meter value is the equivalent value for the dissolved-oxygen concentration at the prevailing atmospheric pressure and the temperature of the water as determined above. For example: If the atmospheric pressure is 710 mm Hg and the water temperature is 20°C, the dissolved-oxygen concentration is 8.5 mg/L. If the selected dissolved-oxygen concentration range is 0 to 20 mg/L and the panel-meter value is 000 to 1,000, the equivalent-value factor is 0.02 (20 / 1,000 = 0.02). For a dissolved-oxygen concentration of 8.5 mg/L, the panel-meter value is 425 (8.5 / 0.02 = 425).

12. Remove the sensor from the calibration chamber and return the sensor to its proper location in the sensor-tank. The panel-meter value should be the equivalent value for the dissolved-oxygen concentration in the water. A panel-meter value of 350 in the example above indicates a dissolved-oxygen concentration of 7.0 mg/L. (350 x 0.02 = 7.0). The dissolved-oxygen concentration in the water may be determined when future inspections are made by use of the dissolved oxygen field meter to verify that the dissolved oxygen is properly calibrated and that the field meter is in agreement with the value determined by the monitor at the time of calibration.

13. Record all pertinent information for future reference.

Summary of dissolved oxygen calibration using the air-calibration chamber procedure:

Selected range: 0 to 20 mg/L = 000 to 1,000 panel-meter values		
Equivalent-value factor = 0.02 (20 / 1,000 = 0.02).		
Standards: Solution of Na_2SO_3 (0.0 mg/L DO) and air-calibration chamber with table 1 (DO concentrations at various temperatures and atmospheric pressures).		
With sensor in	Adjust	Until panel-meter value is
0.0 mg/L DO standard	Zero coarse pot and then fine pot	000.
Air-calibration chamber 710 mm Hg at 20°C = 8.5 mg/L DO (table 1)	Span coarse pot and then fine pot	425 (8.5 / 0.02 = 425).
Water in sensor tank	Nothing	350 (350 x 0.02 = 7.0 mg/L.)
Verification by dissolved-oxygen field meter = 7.0 mg/L.		

Other methods for calibrating oxygen are available. For example, nitrogen gas can be bubbled through water to produce zero dissolved oxygen, or nitrogen gas can be used in the air calibration chamber to produce a zero dissolved oxygen. Nitrogen and oxygen gases can be mixed in varying percentages with accurate flow meters to produce any desired concentration in water (Henry's Law) or in an air calibration chamber. The advantage of mixed gases is that any concentration of dissolved oxygen can be obtained.

Temperature

1. Check to be sure that the temperature sensor has been connected to the sensor connector on the side panel with the same numbered position as the temperature signal conditioner in the front panel.

2. Select the temperature range required. All ranges between -40°C and 60°C will have a panel-meter value of 000 to 1,000.

3. Place the auto-manual switch on front panel in manual position.

4. Toggle the start-stop switch on front panel to start position and release.

5. Toggle the advance switch on front panel to sequence programmer until the light on the temperature signal conditioner panel is lit. Panel meter now indicates the output of the temperature signal conditioner.

6. Place the sensor in a container of cold water and maintain constant mixing. Measure the temperature of the water by use of a thermometer. The water may be a mixture of ice and water to provide a temperature value near 0°C if constant mixing is maintained.

7. When the panel-meter value stabilizes, adjust the zero coarse pot and then the fine pot until the panel-meter value is 000.

8. Place the sensor in a container of water at a temperature near the high end of the selected range and maintain constant mixing. Allow the panel-meter value to stabilize. Adjust the span coarse pot and then the fine pot until the panel-meter value is the equivalent value for the difference between the low-temperature water and the high-temperature water in the selected range. For example: If the selected range is 0° to 50°C and the panel-meter value is 000 to 1,000, the equivalent-value factor is 0.05 (50 / 1,000 = 0.05). If the temperature of the low-temperature water and the high-temperature water are 1.0° and 46.0°C, the difference is 45.0°C. The panel-meter value should be adjusted to 900 (45.0 /0.05 = 900).

9. Leave the sensor in the high-temperature 46°C water. Adjust the zero coarse pot and then the fine pot until the panel-meter is the equivalent value for the high-temperature water. In the above example, the equivalent value is 920 (46.0 / 0.05 = 920).

10. Return the sensor to the low-temperature water. After stabilization, the panel-meter value should be the equivalent value for the low-temperature water. In the above example, if the temperature of the water is still 1.0°C, the panel-meter value should be 020 (1.0 / 0.05 = 20).

11. Place the sensor in a container of water at about midrange temperature to verify the calibration. After stabilization, the panel-meter value should be the equivalent value for the temperature of the water. In the above example, a temperature of 24°C should have an equivalent panel-meter value of 480 (24.0 / 0.05 = 480).

12. Place the sensor in its proper location in the sensor-tank. After stabilization, the panel-meter value should be the equivalent value for the water in the sensor tank. In the above example, if the panel-meter value is 300, the temperature of the water should be 15.0°C (300 x 0.05 = 15). Measure the temperature of the water by use of the thermometer to verify that the temperature is properly calibrated and that the thermometer is in agreement with the monitor at the time of calibration.

13. Record all pertinent information for future reference.

Summary of temperature calibration procedure:

Selected range: 0° to 50°C = 000 to 1,000 panel-meter values.

Equivalent-value factor = 0.05 (50 / 1,000 = 0.05).

Standards: Water samples at temperatures near low end, midrange, and high end of the selected range (1.0°C, 24.0°C, and 46.0°C

With sensor in	Adjust	Until panel-meter value is
1.0°C standard	Zero coarse pot and then fine pot	000.
46.0°C	Span coarse pot and then fine pot	900 (46.0 - 1.0 = 45.0 diff.) (45.0 / 0.05 = 900).
46.0°C	Zero coarse pot and then fine pot	920 (46.0 / 0.05 = 920).
1.0°C	Nothing	020 (1.0 / 0.05 = 20).
24.0°C	Nothing	480 (24.0 / 0.05 = 480).
Water in sensor tank	Nothing	300 (300 x 0.05 = 15.0°C).

Verification by thermometer = 15.0°C

pH

The pH sensor consists of a reference electrode, glass electrode, and temperature compensator. Systems for the measurement of pH respond more slowly at low temperatures, so more time is required for calibration when the water temperature is near 0°C. The temperature of the pH buffers should be at the same temperature as the water in the sensor tank during calibration. Some pH buffers are sensitive to temperature, therefore, the pH-temperature equivalents listed on the container label must be used as the value of the buffer in the calibration procedure.

The Leeds & Northrup plastic reference electrode, furnished with the sensor, has a rubber storage cap over the end. This cap must be removed to expose the porous, ceramic junction that is threaded into the end of the electrode. Check the interior of the plastic tube to make sure that the gel-electrolyte has not become dry. If the electrolyte is dry, replace the electrode. When the electrode is kept out of water for short periods, the end must be covered by the rubber cap to prevent the gel-electrolyte from becoming dry.

The glass pH electrode should be immersed in water and occasionally cycled in high and low pH buffers for a day to stabilize it. This is done by removing the protective rubber cap and placing the sensor in a beaker containing water and occasionally placing it alternately in beakers containing buffers of pH 4 and pH 10. The glass pH electrode is fragile and may be easily broken or scratched, rendering it useless. The pH sensor should be stored in a beaker of distilled water. If it is stored dry, the rubber caps must be placed over the end of the electrodes.

The calibration of the pH sensing system uses three standard buffer solutions to include the low, mid, and high portions of the instrumental range. The following calibration procedure is used.

1. Check to be sure that the pH sensor has been connected to the sensor terminal on the side panel with the same numered position as the pH signal conditioner in the front panel.

2. Select the required pH range. The panel-meter value is 000-1,000 for the range selected.

3. Place the auto-manual switch on the front panel in the manual position.

4. Toggle the start-stop switch on the front panel to the start position and release.

5. Toggle the advance switch on the front panel to the sequence programmer until the light on the pH signal conditioner is lit. The panel meter now indicates the output of the pH signal conditioner.

6. Place the sensor in a container of buffer at a low value. Stir until the panel-meter value is stabilized. Buffers of various pH values may be obtained from scientific supply companies.

7. Adjust the zero coarse pot and then the fine pot until the panel-meter value is 000.

8. Place the sensor in container of buffer at a high value. Stir until the panel-meter value is stabilized.

9. Adjust the span coarse pot and then the fine pot until the panel-meter value is the equivalent value for the difference between the value of the low buffer and the high buffer. For example: If the selected pH range is 0 to 14 and the panel-meter value is 000 to 1,000, the equivalent-value factor is 0.014. If the low buffer value is 4.0 and the high buffer value is 10.0, the difference is 6.0, and the equivalent panel-meter value is 429 (6.0 / 0.015 = 429). Be sure to use the correct pH value for the temperature of the buffer.

10. Leave the sensor in the container of buffer at a high value. Adjust the zero coarse pot and then fine pot until the panel-meter value is the equivalent value for the high-value buffer. In the above example, the equivalent panel-meter value for 10.0 is 714 (10.0 / 0.014 = 714).

11. Return the sensor to the container of buffer at a low value. The panel-meter value should be the equivalent value for the low-value buffer. In the above example, the equivalent value for 4.0 is 286 (4.0 / 0.014 = 286).

12. Place the sensor in the container of buffer at about midrange value as a check. The panel-meter value should be the equivalent value for the midrange-value buffer. In the above example, the equivalent panel-meter value for a buffer at 7.0 is 500 (7.0 / 0.014 = 500). The sensor should be rinsed with distilled water and dried by dabbing with a soft paper tissue between transfers from one buffer to another.

13. Place the sensor in its proper location in the sensor-tank. After stabilization, the panel-meter value should be the equivalent value for the pH value of the water. In the above example, if the equivalent panel-meter value is 571, the pH value is 8.0 (571 x 0.014 = 8.0). Measure the value of the water in the sensor tank by use of the pH field meter to verify that the parameter is properly calibrated and that the field meter is in agreement with the monitor at the time of calibration.

14. Record all pertinent information for future reference.

Summary of pH calibration procedure:

Selected range: 0 to 14 = 000 to 1,000 panel-meter values.		
Equivalent-value factor = 0.014 (14.0 / 1,000 = 0.014).		
Standards: pH buffers at 4.0, 7.0, and 10.0.		
With sensor in	Adjust	Until panel-meter value is
4.0 buffer	Zero coarse pot and then fine pot	000.
10.0 buffer	Span coarse pot and then fine pot	429 (10.0 - 4.0 = 6.0 diff.) (6.0 / 0.014 = 429).
10.0 buffer	Zero coarse pot and then fine pot	714 (10.0 / 0.014 = 714).
4.0 buffer	Nothing	286 (4.0 / 0.014 = 286).
7.0 buffer	Nothing	500 (7.0 / 0.014 = 500).
Water in sensor tank	Nothing	571 (571 x 0.014 = 8.0)
Verification by pH field meter = 8.0		

The procedures outlined in the previous sections for calibration are designed to verify that the sensors and connecting circuitry are functioning properly and are providing accurate results. When accurate results are not obtained, test plugs may be used in place of the sensors to determine the performance of the measuring circuits. Should any of the measuring circuits not perform accurately, replacement is suggested.

Test plugs provide fixed values that will not changes unless the zero or span adjustments are changed or there is electronic drift in the circuits in the monitor cabinet. The values are used to isolate malfunctions in the system.

1. After the parameters are calibrated, substitute the test plugs for the sensors in their respective sensor connectors on the side panel of the monitor cabinet. Check to be sure that the test plug is connected to the terminal with the same numbered position as the matching signal conditioner in the front panel. Damage to components may result if the test plugs and signal conditioners are mismatched. The electric power should be turned off as a precaution before any component changes are made.

2. After the test plugs have been substituted for the sensors, turn on the monitor and place the auto-manual switch in the manual position.

3. Toggle the start-stop switch to the start position and release.

4. Toggle the advance switch to manually scan each parameter. Record the panel-meter values for each parameter on the MIF for future reference when inspections of the monitor are made. A copy of the MIF should be left in the shelter.

5. The auto-manual switch must always be returned to the auto position after manual scanning is completed so that the monitor will automatically turn on to record the data.

Mini-monitor

To calibrate the mini-monitor, an understanding of the operation of the panel meter (fig. 29) is required. The panel meter displays four individual digits. The left-most digit indicates the number of the channel being scanned, and the other three digits to the right indicate the panel-meter value for the channel being scanned. When channel 0 is displayed on the panel meter (0 in the left-most digit), the number of minutes since the last scan and record cycle is represented by the other three digits to the right. When channels 1 through 4 are displayed in the panel meter, it indicates the respective parameters as they are being scanned and recorded and the panel meter value is represented in the three digits to the right. For example: A panel-meter value of 0035 indicates that channel 0 is being displayed and that 35 minutes have elapsed since the last scan and record cycle occurred. Panel-meter values of 1,035, 2,035, 3,035, and 4,035 indicate that a value of 35 will be recorded for the respective parameter connected to the channel indicated by the left-most-digit. The range selected for any parameter must

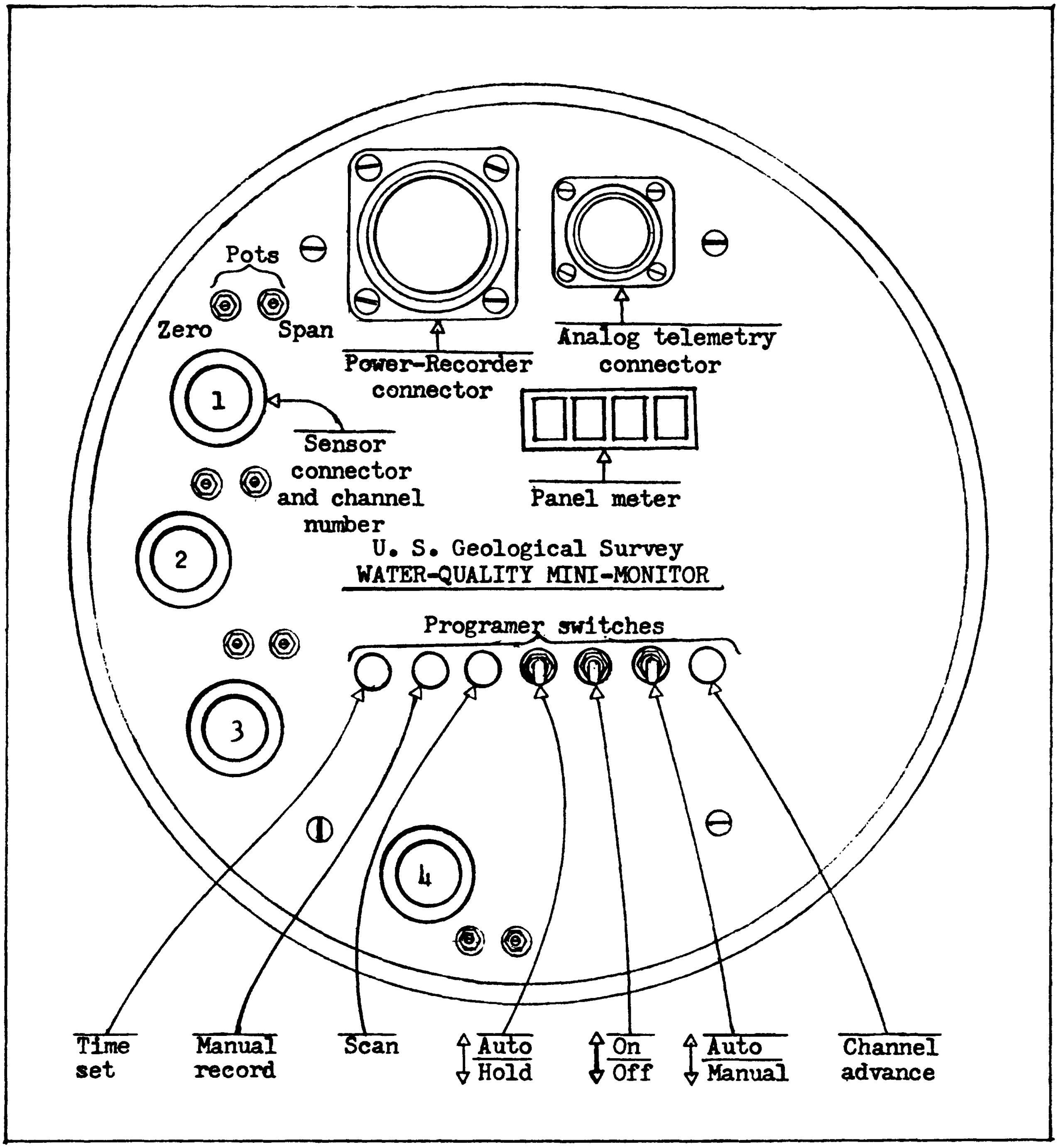

Figure 29.--Front panel of mini-monitor showing location and function of switches, pots, and connectors.

have an equivalent-value measurement that will not exceed 999 because greatest panel-meter value that can be correctly recorded is 999, preceded by the channel number. To simplify calculation of the equivalent-value factor, the panel-meter values for a selected range are listed as 000 to 1,000. A panel-meter value of 024, preceded by the parameter channel number, will be displayed if the upper limit is exceded, however, this should not be confused with a true value of 024. A check of preceding and subsequent recorded values should verify the value.

Temperature

The temperature parameter is usually placed in channel 1 because it requires less warm-up time than the other parameters. Check to be sure that the temperature sensor has been connected to the sensor terminal of channel 1.

1. Select the range required. The standard range is 0-50°C and is the only range available except by special request.

2. Place the auto-hold switch in hold position and the auto-manual switch in the manual position.

3. Place the power (ON-OFF) switch in the ON position.

4. Depress and release the channel advance switch until the panel meter displays channel 1 in the left-most-digit which, in this case, is chosen as the temperature channel.

5. Place the sensor in a container of cold water at a temperature of near 0°C and maintain constant mixing. A mixture of water and ice will provide the required temperature value. Measure the temperature of the water with the temperature of the water with the thermometer described in section 1.0.

6. After the panel-meter value has stabilized, adjust the zero pot located above the sensor connector until the panel-meter value is between 000 and 001. An occasional 001 must be displayed to ensure that the setting is not less than zero because negative values will be displayed as 000 also. Record the temperature of the water.

7. Place the sensor and the thermometer in a container of warm water at a temperature near the high end of the temperature range and maintain constant mixing.

8. After the panel-meter value and the thermometer reading stabilize, record the temperature and adjust the span pot, located above the sensor connector, until the panel-meter value is the equivalent value for the difference between the high-temperature water and the low-temperature water. For example: If the selected temperature range is 0° to 50°C and the panel-meter value is 000 to 1,000, the equivalent-value factor is 0.05. If the temperature of the high-temperature water is 36.0°C and

the temperature of the low-temperature water is 0.3°C, the difference is 35.7°C (36.0 - 0.3 = 35.7). The panel-meter value should be adjusted to 714 (35.7 / 0.05 = 714).

9. Leave the sensor in the high-temperature water. Adjust the zero pot until the panel-meter value is the equivalent value for the high-temperature water. In the above example, the equivalent value for 36.0°C is 720 (36.0 / 0.05 = 720).

10. Return the sensor to the container of constantly mixed low-temperature water. After stabilization, the panel-meter value should be the equivalent value for the low-temperature water. In the above example, if the thermometer still reads 0.3°C, the equivalent value if 006 (0.3 / 0.05 = 6).

11. Place the sensor and the thermometer in a container of constantly mixed water at a midrange temperature to check the calibration. The panel-meter value should be the equivalent value of the temperature of the water. If the water temperature is 21.0°C, the equivalent panel-meter value is 420 (21.0 / 0.05 = 420).

12. Place the sensor in the stream. The panel-meter value should be the equivalent value for the temperature of the stream. In the above example, if the equivalent panel-meter value if 300, the temperature of the stream should be 15.0°C. Verify the temperature by use of the thermometer, and record the value for future reference.

Summary of temperature calibration

Selected range: 0.° to 50°C = 000 to 1,000 panel-meter values.		
Equivalent-value factor = 0.05 (50 / 1,000 = 0.05).		
Standards: Water at 0.3°C, 21.0°C, and 36.0°C.		
With sensor in	Adjust	Until panel-meter value is
0.3°C standard	Zero pot	000 to 001 (occasional 001).
36.0°C standard	Span pot	714 (36.0 - 0.3 = 35.7 diff.), (35.7 / 0.05 = 714).
36.0°C standard	Zero pot	720 (36.0 / 0.05 = 720).
0.3°C standard	Nothing	006 (0.3 / 0.05 = 6).
21.0°C standard	Nothing	420 (21.0 / 0.05 = 420).
Water in stream	Nothing	300 (300 x 0.05 = 15.0°C).
Verification by thermometer = 15.0°C.		

Specific conductance

1. Check to be sure that the specific-conductance sensor has been connected to the correct channel sensor terminal.

2. Select the specific-conductance range required, as prescribed in the operations manual. The panel-meter value will be 000 to 1,000 for all specific conductance ranges between 0 and 100,000 µmhos.

3. Unscrew and remove the shield from the lower end of the sensor and wipe the sensor dry.

4. Fasten two leads, that have small alligator clips on each end, to the electrodes. Clip one of the leads to the center electrode and an adjacent electrode and the other lead to the two electrodes near the end as shown in figure 30.

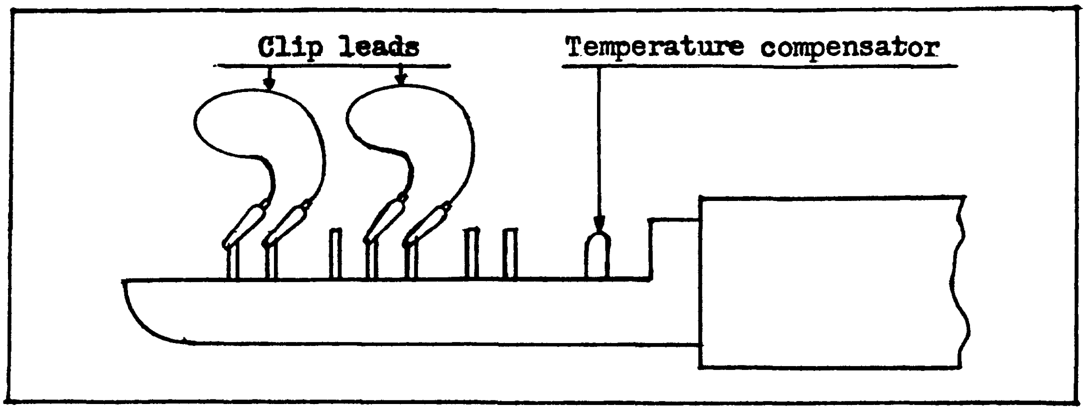

Figure 30.--Specific conductance sensor with the shield removed and clip leads connected for zero calibration.

5. Place the auto-hold switch in the hold position and the auto-manual switch in the manual position.

6. Place the power (ON-OFF) switch in ON position.

7. Depress and release the channel advance switch. Repeat this process until the panel meter displays the number of the specific-conductance channel in the left-most-digit.

8. Adjust the zero pot for the channel until the panel-meter value is between 000 and 001. An occasional 001 must be displayed to ensure that the adjustment is not below zero because a negative value will be displayed as 000 also.

9. Remove the clip leads and replace the shield on the sensor.

pH

The electrode furnished with the pH sensor shown in figure 31 is a combination pH-reference electrode, and must be prepared for operation. Remove the protective rubber storage cap, not shown in figure 31, to expose the tip of the electrode. The glass bulb is extremely fragile and the sensor must be handled with care. If the glass bulb is scratched or broken, the sensor is useless and the electrode must be replaced. The electrode should extend between 0.75 to 1.5 inches below the black plastic packing gland that secures the electrode in the sensor, and if necessary, the electrode should be adjusted. Carefully remove the nut closest to the electrode without turning the packing gland or the electrode. If the electrode is turned excessively, the wiring inside the sensor may be damaged. Carefully adjust the electrode until it extends the proper length below the packing gland. A slight back-and-forth twisting movement will assist the adjustment of the electrode. Do not use excessive force to move the electrode and do not push the electrode into the sensor with less than 0.75 inch extending below the packing gland. After the electrode is adjusted, replace the nut on the sensor with caution being careful not to cross-thread it and tighten it finger-tight. Soak the sensor for a minimum of 24 hours in a pH buffer at 4.0, 6.0, or 7.0 (preferred) before calibration.

The calibration of the pH sensing system uses three standard buffer solutions to include the low, mid, and high portions of the instrumental range. The following calibration procedure is used:

1. Check to be sure that the pH sensor has been connected to the correct channel sensor terminal.

2. Select the required pH range. The panel-meter range will be 000 to 1,000 for all pH values between 0 and 12.

3. Place the auto-hold switch in the hold position and the auto-manual switch in the manual position.

4. Place the power (ON-OFF) switch in the ON position.

5. Depress and release the channel advance switch. Repeat this process until the panel meter displays the pH channel number in the left-most-digit.

6. Rinse the sensor with distilled water and place it in a container of pH buffer at a value near the low end of the pH range. Be sure that the ground pin and temperature compensator shown in figure 31 are immersed in the buffer. Gently stir the buffer until the panel-meter value stabilizes.

7. Adjust the zero pot until the panel-meter value is the equivalent value for the value of the buffer. For example: If the selected range is 2.0 to 12.0 and the panel-meter value is 000 to 1,000, the equivalent-value factor and equivalent panel-meter value of a sample or standard are calculated using the equations previously explained in the "Calibration" section.

10. Place the sensor in a container of standard solution at a value near the maximum value of the selected range.

11. After the panel-meter value has stabilized, adjust the span pot for the channel until the panel-meter value is the equivalent value for the standard solution. For example: If the selected specific-conductance range is 0 to 1,000 µmho/cm and the panel-meter value is 000 to 1,000, the equivalentvalue factor is 1. If the standard solution has a value of 890 µmho/cm, the panel-meter value should be adjusted to 890 (890 / 1.0 = 890). In this specific-conductance range the equivalent value and the panel-meter value are the same and can be read directly on the panel meter. In other ranges other 0-1,000 µmhos/cm the equivalent-value factor must be used.

12. Place the sensor in a container of standard solution at about the midrange value of the selected specific-conductance range for a check. The panel-meter value should be the equivalent value for the standard solution. In the above example, a standard solution at a value of 450 µmho/cm should have a panel-meter value of 450 (450 / 1.0 = 450). The sensor must be rinsed with a small portion of the receiving standard when transferring it from one standard to another. When transferring the sensor from a high to a low standard, the sensor should be rinsed with distilled water before rinsing with the low standard.

13. When the sensor is placed in the stream, the panel-meter value should be the equivalent value for the specific conductance of the stream. In the above example, if the panel-meter value is 743, the specific conductance of the stream should be 743 µmho/cm (743 / 1.0 = 743). This value should be verified by use of a specific conductance field meter, and all pertinent information recorded for future reference.

Summary of specific conductance calibration procedure:

Selected range: 0 to 1,000 µmho = 000 to 1,000 panel-meter values.		
Equivalent-value factor = 1.0 (1,000 / 1,000 = 1.0).		
Standards: 2 clip leads (0 µmho/cm), 450 µmho/cm, and 890 µmho/cm KCl solutions.		
With sensor in	Adjust	Until panel-meter value is
Shorted mode by use of 2 clip leads (0 µmho/cm)	Zero pot	000 to 001 (Occasional 001).
890 µmho/cm standard	Span pot	890 (890 / 1.0 = 890)
450 µmho/cm standard	Nothing	450 (450 / 1.0 = 450)
Water in stream	Nothing	743 (743 x 1.0 = 743 µmho)
Verification by specific conductance field meter = 743 µmho/cm.		

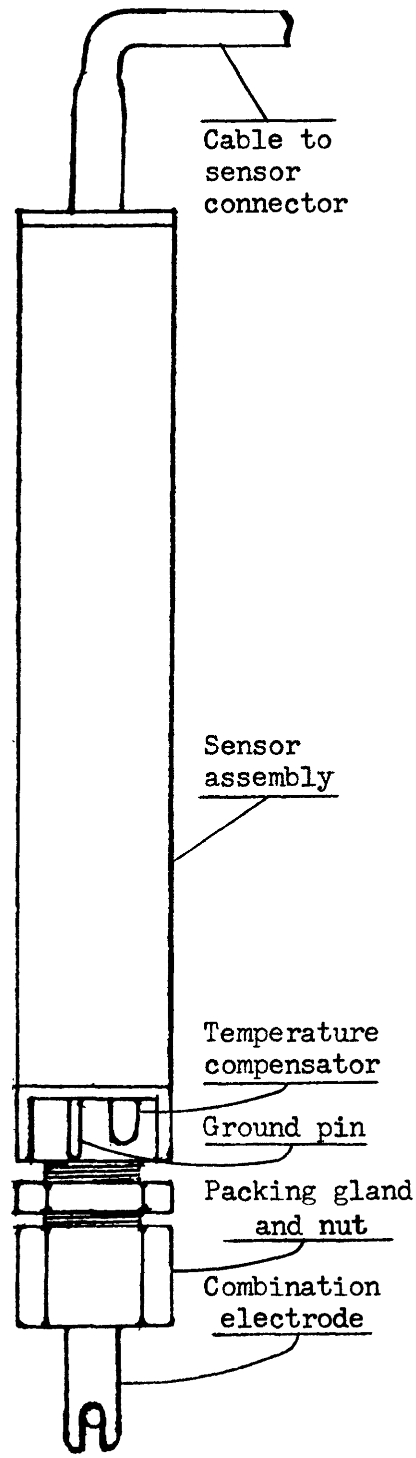

Figure 31.--pH sensor assembly for the mini-monitor.

In the example, the equivalent-value factor is 0.01 (12.0 - 2.0) / 1,000 = 0.01. If the low-value pH buffer is 4.2, the equivalent panel-meter value is 220, (4.2 / 0.01) - 2.0 / 0.01) = 220. The above equations are used to calculate the equivalent-value factor and equivalent panel-meter value for any selected parameter range that has a minimum value of zero or greater and panel-meter value of 000 to 1,000.

8. Remove the sensor from the low-value buffer and rinse it with a portion of the high-value buffer. Place the sensor in a container of buffer at a value near the high end of the pH range and discard the rinse. Be sure that the ground pin and the temperature compensator are immersed in the buffer. Gently stir the buffer until the panel-meter value is stabilized.

9. Adjust the span pot until the panel-meter value is the equivalent value for the high-value buffer. In the example, if the high-value buffer is at 9.8, the panel-meter value should be adjusted to 780, (9.8 / 0.01) - (2.0 / 0.01) = 780.

10. Due to the characteristics of the electronic circuits of the pH signal conditioners, calibration steps 6 through 9 may need to be repeated several times to obtain the correct panel-meter values for the buffers without adjustment of the respective pots. All buffers should be at the same temperature, and the pH-temperature values shown on the buffer label must be used.

11. After proper adjustments are made, rinse the sensor with a portion of the receiving buffer. Place the sensor in a container of buffer at a value near the anticipated pH value of the water in the stream and discard the rinse. The equivalent panel-meter value of the buffer should be displayed after stabilization occurs. The zero pot may be adjusted to correct any slight variation from the correct equivalent panel-meter value. Do not adjust the span pot or the entire calibration procedure will have to be repeated. In the example, a buffer at a value of 7.0 should display an equivalent panel-meter value of 500, (7.0 / 0.01) - 200 = 500.

12. Place the sensor in the stream. CAUTION: Great care must be taken when placing the pH sensor in the stream. The exposed electrode is very fragile and must be protected from breakage caused by rubbing against the side of the sensor housing or by debris in the stream. The equivalent panel-meter value for the pH value of the stream should be displayed after stabilization occurs. The pH for the equivalent panel-meter value displayed is calculated by the equation,

    S = (F x Me) + Ro.

All abbreviations are covered in the "Calibration" section of this manual. In the example, if the equivalent panel-meter value is 560, the pH value of the water in the stream is 7.6 [0.01 x 560] + 2.0 = 7.6. This value should be verified by the pH field meter and all pertinent information recorded for future reference.

NOTE: Values of pH that exceed the selected range are displayed and recorded as 024, and values of pH that are less than the minimum value of the selected range are displayed and recorded as 000.

Summary of pH calibration procedure:

Selected range: 2.0 to 12.0 = 000 to 1,000 panel-meter values.		
Equivalent-value factor = 0.01, (12.0 - 2.0) / 1,000 = 0.01.		
Standards: pH buffers at 4.2, 7.0, and 9.8		
With sensor in	Adjust	Until panel-meter value is
4.2 buffer	Zero pot	220, (4.2 / 0.01) - (2.0 / 0.01) = 220
9.8 buffer	Span pot	780, (9.8 / 0.01) (2.0 / 0.01) = 780
Repeat above buffers until	Nothing	220 and 780 for the respective buffers.
7.0	Nothing (Zero pot only, if required)	500, (7.0 / 0.01) - (2.0 / 0.01) = 500.
Water in stream	Nothing	560, [560 + (2.0 / 0.01)] x 0.01 = 7.6
Verification by pH field meter = 7.6		

Dissolved oxygen

The dissolved oxygen measuring system for the mini-monitor uses a dissolved-oxygen sensor and stirrer assembly that is shown is figure 32 and is manufactured by YSI (Yellow Springs Instrument Company). The signal conditioner developed by the Geological Survey has a two-range capability by use of a low-high toggle switch located on the signal-conditioner board. The switch is placed in the selected range when the monitor is prepared for operation as described in the operations manual that is furnished with the monitor. A 1-mil (0.001-inch) thick Teflon membrane (standard) is used on the sensor. Extra membranes are furnished with the monitor and replacement kits may by obtained from YSI.

The dissolved oxygen sensor is delivered dry and must be prepared for operation according to the following procedure:

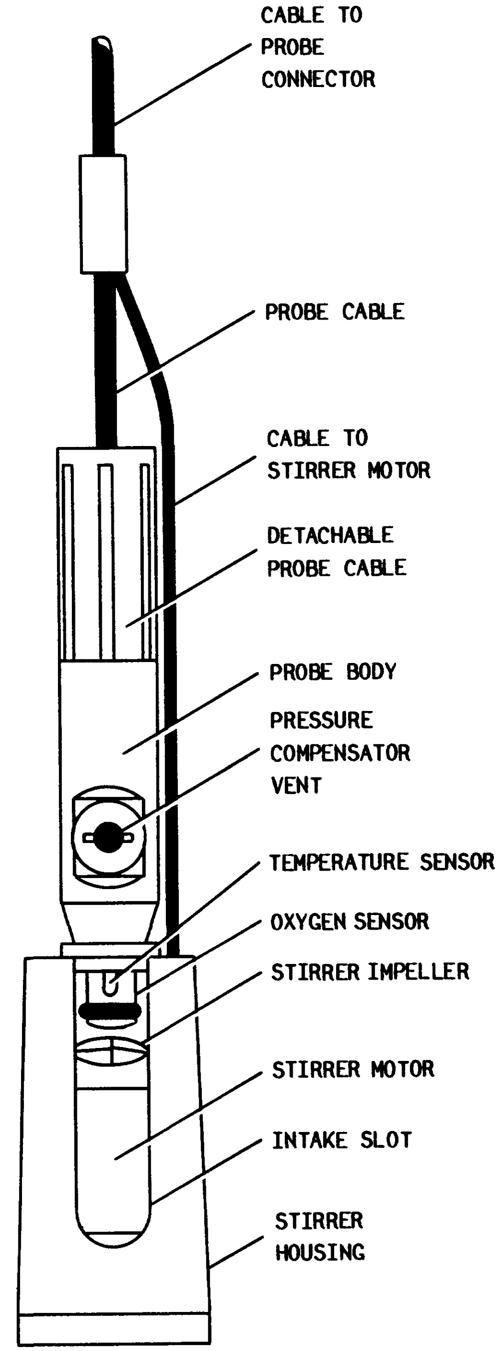

Figure 32.--Dissolved-oxygen sensor and stirrer assembly for the mini-monitor. (Reproduced with the permission of the Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio.)

1. Prepare the electrolyte by dissolving the potassium chloride (KCl) crystals in distilled water and store in a dropper bottle.

2. Unscrew the stirrer assembly from the sensor and remove the O-ring and membrane. After the air bubbles have dissipated from the KCl electrolyte, thoroughly rinse the electrolyte chamber of the sensor with the KCl electrolyte solution.

3. Fill the sensor with electrolyte and install the membrane as shown in figure 33.

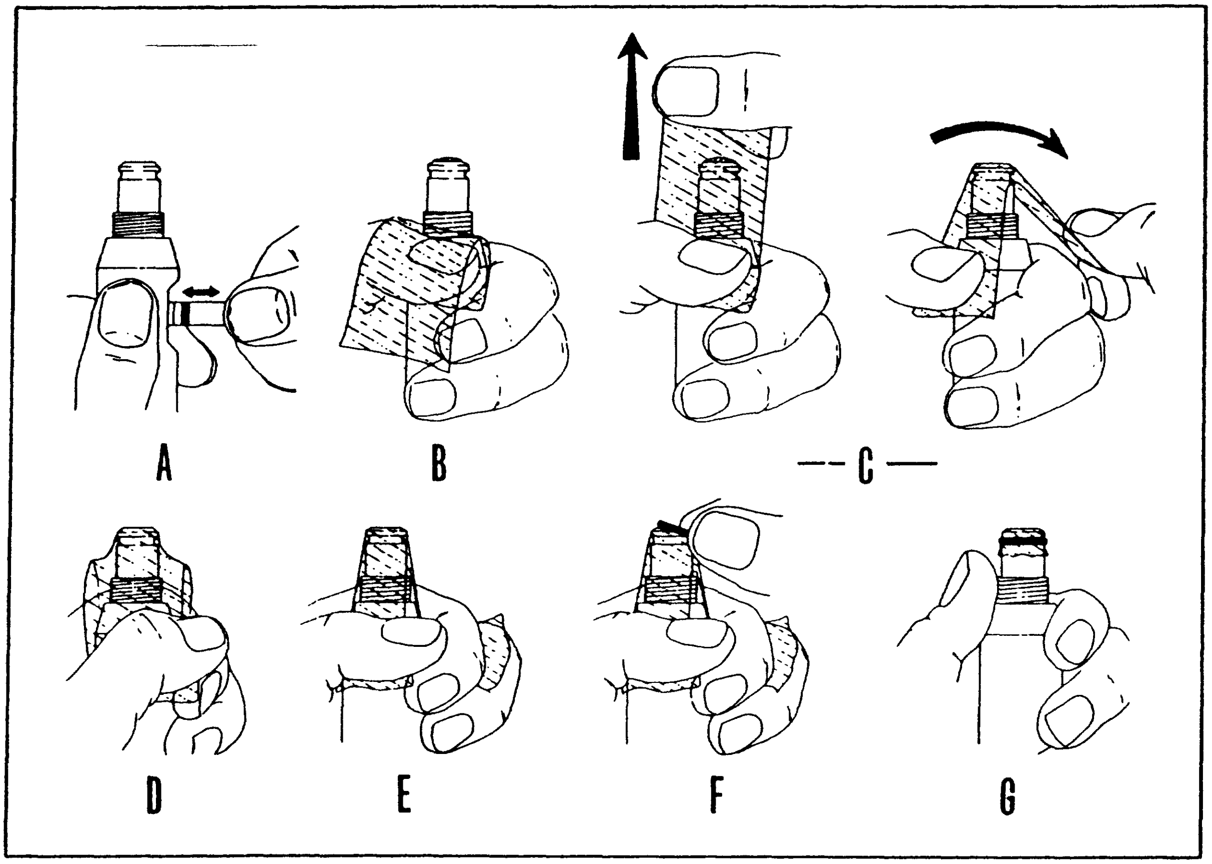

Figure 33.--Electrolyte addition and membrane installation for the mini-monitor dissolved-oxygen sensor. (Reproduced with the permission of the Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio.)

A. Grasp the inverted sensor in the left hand with the pressure compensator vent turned to the right. Fill the electrolyte chamber with electrolyte through the tip, then pump the pressure-compensator diaphram with a pencil eraser or other soft, blunt tool of similar size. Continue filling and pumping alternately until the air bubbles disappear from the top of the sensor.

B. Secure a membrane under the left thumb. Add more electrolyte until a large raised drop of electrolyte completely covers the gold cathode.

NOTE: Handle the membrane with care; keep it clean and dust free, and touch it only at the ends.

C. Grasp the free end of the membrane by the thumb and forefinger of the left hand.

D. Stretch the membrane up, over, and down the other side of the sensor tip in a continuous motion.

E. Secure the membrane under the forefinger of the left hand.

F. Hook the O-ring in the side of the O-ring groove and roll it over the end and into the O-ring groove on the opposite side using the thumb and forefinger of the right hand. There should be no wrinkles in the membrane or trapped air bubbles under the membrane. Some wrinkles may be removed by gently tugging on the membrane beyond the O-ring.

G. Trim off the excess membrane below the O-ring with scissors or a sharp knife, being careful not to cut the rubber O-ring. Check to be sure that the stainless-steel temperature sensor is not covered by the membrane.

4. Remove excess KCl solution and reinstall the stirrer assembly.

When the mini-monitor is turned on, an 0.8-volt polarizing current is transmitted to the dissolved-oxygen sensor. The stirrer on the dissolved-oxygen sensor turns on first at the beginning of the scan and record cycle. The signal conditioners are turned on and the scan and record cycle continues until all the parameters are scanned and recorded. The time lapse before the signal conditioners are turned on and the scan and record cycle continues are preselected and depend on the thickness of the membrane and the water velocity.

The following calibration procedure for the dissolved oxygen system is used:

1. Check to be sure that the dissolved-oxygen sensor is connected to the sensor terminal of the dissolved-oxygen channel.

2. Select the required dissolved-oxygen range as prescribed in the operations manual. The 1-mil membrane may be used for the low range (1-10 mg/L) and the high range (0-20 mg/L) dissolved oxygen. The panel-meter value will be 000 to 1,000 for both low and high range.

3. Place the auto-hold switch in the hold position and the auto-manual switch in the manual position.

4. Place the power (ON-OFF) switch in the ON position.

5. Depress and release the channel advance switch. Repeat this process until the panel meter displays the number of the dissolved-oxygen channel in the left-most-digit.

6. Place the sensor and stirrer in a container of standard solution with a dissolved-oxygen concentration of 0.0 milligrams per liter. The panel-meter value will decrease rapidly if the sensor is operating properly and will stabilize at some low value.

7. After the panel-meter value stabilizes, adjust the zero pot for the channel until the panel-meter value is between 000 and 001. An occasional 001 should be displayed to ensure that the 000 is not the result of a negative output from the signal conditioner, because all negative values are displayed as 000.

8. Obtain a sample of water from the stream by use of the dissolved-oxygen sampler. Determine the dissolved-oxygen concentration of the water by the U.S. Geological Survey method I-1576-78, Procedure A.

9. Remove the sensor and stirrer from the low-value standard and rinse thoroughly with distilled water to remove all traces of the sodium sulfite solution and place the sensor assembly in the steam. When the panel-meter value has stabilized, adjust the span pot for the channel until the equivalent panel-meter value for the dissolved-oxygen concentration determined is displayed. For example: If the selected dissolved-oxygen range is 0 to 20 mg/L and the panel-meter value is 000 to 1,000, the equivalent-value factor is 0.02, (20 / 1,000 = 0.02). If the dissolved-oxygen concentration is 8.5 mg/L, the equivalent panel-meter value is 425, (8.5 / 0.02 = 425).

10. After completion of the calibration procedure, record the equivalent panel-meter value and immediately analyze the stream water by the polarographic probe method again to ensure that no significant change in the dissolved-oxygen concentration has occurred during the calibration procedure. In the example, if the equivalent panel-meter value is 450 when the second sample is taken, the dissolved-oxygen concentration of the sample should be 9.0 mg/L, (450 x 0.02 = 9.0 mg/L). If the equivalent panel-meter value of the second dissolved-oxygen concentration determination does not agree with the value recorded when the sample was taken, a judicious adjustment of the span pot may be made to correct the error.

11. Record all pertinent information for use when future inspections are made.

Summary of dissolved-oxygen calibration procedure:

Selected range: 0.0 to 20.0 mg/L = 000 to 1,000 panel-meter values.		
Equivalent-value factor = 0.02, (20.0 / 1,000 = 0.02).		
Standards: Solution of Na_2SO_3 (0.0 mg/L DO) and standard value determined by USGS Method I-1576-78(A).		
With Sensor in	Adjust	Until panel-meter value is
0.0 mg/L DO standard	Zero pot	Between 000 and 001 (occasional 001).
Water in stream 8.5 mg/L DO by I-1576-78(A)	Span pot	425, (8.5 / 0.02 = 425).
Water in stream 9.0 mg/L DO by I-1576-78(A)	Nothing	450, (450 x 0.02 = 9.0 mg/L DO).

Internal clock

The internal clock of the mini-monitor operates continuously except when the power (ON-OFF) switch is placed in OFF position. After calibration is completed, the clock must be set to the correct watch time.

1. Place the auto-hold switch in the hold position and the auto-manual switch in the manual position.

2. Place the power (ON-OFF) switch in ON position. The panel meter should display the exact minute of the hour as indicated by the correct watch time.

3. Depress and release the time set switch to obtain the correct panel-meter value. Continue this process until the panel-meter value displays the number of minutes of the hour indicated by the correct watch time.

4. If analog telemetry is used with the mini-monitor, the clock must be set to the exact second of the minute by depressing and releasing the time set switch. The process must be repeated until the panel-meter value is advanced to one minute ahead of the actual watch time that is correct to the exact second. Depress the time set switch and release it when the watch time reaches the zero second of the minute displayed on the panel meter. The clock will start when the time set switch is released and should be correct to the exact second if the switch is released on the exact second.

Battery check

The battery voltage can be displayed on the panel meter to check the condition of the battery.

1. Place the auto-hold switch in the hold position and the auto manual switch in the manual position.

2. Place the power (ON-OFF) switch in ON position.

3. Depress and release the channel advance switch. Continue this process until the last channel in use is displayed on the panel meter.

4. Depress the channel advance switch and hold it down. The panel-meter value displayed indicates the voltage of the battery, however, 007 must be added to the value to obtain the exact voltage of the battery. For example: If the panel-meter value is 113, the battery voltage is 12.0 volts, (113 + 007 = 120). A panel-meter value of less than 093 indicates that the battery voltage is very low and the battery must be replaced to prevent erroneous data from being recorded. The battery voltage must not fall below 10.0 volts.

NOTE: After any check procedures have been performed, be sure to return all switches to operation mode before leaving the station.

OPERATION

After the water-quality monitor has been installed and calibrated it is ready for continuous operation. The monitor will require thorough testing and timely maintenance and service to ensure the collection of valid data.

Test instruments and equipment

The following items will be needed to test the monitor system periodically:

1. Digital VOM (volt-ohm-meter), capable of measuring to ± 0.01 millivolt.

2. Monitor inspection form for field notes (fig. 26).

3. Fresh standard solutions and pH buffers.

4. Test plugs for each parameter measured.

5. Spare sensors, especially for dissolved oxygen and pH.

6. Assortment of hand tools (screwdrivers, pliers, soldering gun, etc.).

General maintenance

Standby batteries:

1. Replace standby batteries at least once a year and after periods of power failure.

2. Frequent battery checks should be made to detect weak or leaking batteries. Batteries found to be weak or leaking should be replaced.

Timers:

1. Most timers used by the Geological Survey will operate the flow-through monitor. The following timers can be used and are listed in order of preference:

    A. USGS solid-state digital timer.

    B. Chelsea tuning-fork timer.

    C. USGS crystal CT-1 timer.

    D. Chelsea clockwind timer.

2. At least one spare timer should always be carried on field trips because failure of a timer will render a monitor inoperative.

Flow-through monitor

Routine maintenance

The following procedure is to be used as a guide for the orderly performance of routine maintenance and service of the monitor system:

1. Make a preliminary visual inspection of the site to discover any unusual or abnormal conditions, such as signs of water leaks, flood damage, wind damage, damage from debris or ice, and vandalism. Any abnormalities should be recorded.

2. Check the digital tape time and record the information.

3. Check the timer-clock time and watch time and record both times.

4. Visually check the flow of water in the sensor tank, but do not disturb the sensors or the sensor tank at this time.

5. Scan back a few days of the punched tape to see if there are any punching problems that would indicate other than a routine maintenance and servicing procedure.

6. If the digital tape is not due for removal, place the auto-manual switch in the manual position and advance the programmer through the scan cycle, dwelling on each channel. Record the panel-meter values before cleaning.

7. If the digital tape is due for removal, move the tape ahead 1 hour, place the auto-manual switch in the auto position, press the start switch, and allow the monitor to scan and record each parameter on the digital tape. Record the values as the parameter values before cleaning. Remove the punched tape from the recorder, empty the chad tray, and reconnect the tape to the takeup spool of the recorder. Prepare a tape leader, wrap it around the punched tape, and secure it with a rubber band. Take the punched tape back to the office for processing the data.

8. Measure the values of all parameters on the water flowing in the sensor tank and at the sample intake in the stream to determine if differences exist. Record all values and compare with the before-cleaning values.

9. Drain the water out of the sensor tank, replace the drain plug, and check the time required to refill the tank. Record the information as the fill time before cleaning. Perform the cleaning chores: Backflush the pump and screen and the intake lines; clean the sensor tank; wipe off and clean the sensors and return to the proper place in the sensor-tank; drain the tank and replace the drain plug. Turn on the pump and check the refill time. Record the time as the refill time after cleaning. If the refill time indicates a significant reduction in flow (less than 10 gallons per minute), check for the cause and make necessary repairs or changes. The effect of the rate of flow in gallons per minute and the resultant velocity in feet per second of water across the dissolved-oxygen sensor membrane, versus dissolved oxygen concentration in mg/L is shown in figure 34. The velocity is of prime importance when the dissolved-oxygen parameter is calibrated by use of the air-calibration chamber.

   Velocity tubes such as shown in figure 35 should be installed in all flow-through monitor sensor tanks to assure optimium flow across the tip of the dissolved-oxygen sensor.

10. When the sensors in the tank have stabilized, place the auto-manual switch in the manual position, advance the monitor through the scan cycle and record the panel-meter values for each parameter as the values after cleaning. Return the auto-manual switch to auto position.

11. Make calibration checks on all parameters. If the parameters cannot be calibrated the problem may be in the electronics of the monitor.

    A. Specific conductance

    Check the specific conductance parameter by use of a standard solution at a value near the specific conductance value of the water. If the difference between the equivalent panel-meter value and the standard solution is more than $\pm$ 5 percent or $\pm$ 5 µmho, whichever is greater, recalibrate the parameter.

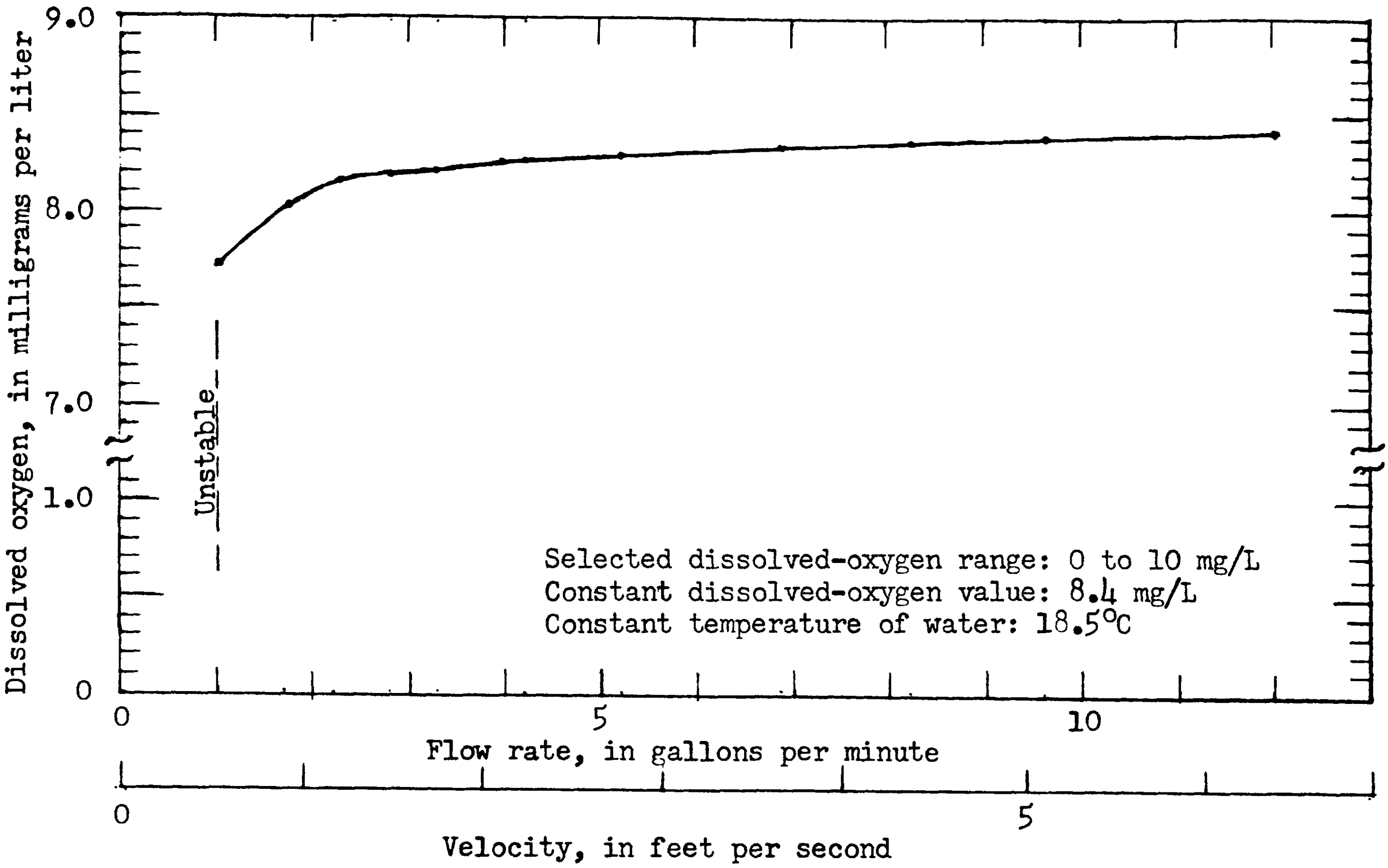

Figure 34.--Dissolved-oxygen readings versus flow rate and velocity at constant dissolved-oxygen concentration in the water.

B. Dissolved oxygen:

Check the Teflon membrane of the dissolved-oxygen sensor to be sure that it is in good condition before making calibration checks. The most frequent problem is a damaged membrane and it must be replaced. Check the dissolved-oxygen parameter by use of the air-calibration-chamber-in-water method. If the difference between the equivalent panel-meter value and the value determined is more than ± 5 percent of full range or ± 0.3 mg/L, whichever is greater, recalibrate the parameter.

C. Temperature

Check the temperature parameter by use of a precision thermometer. If the difference between the temperature of the water and the equivalent panel-meter value is more than ± 0.3°C, recalibrate the parameter.

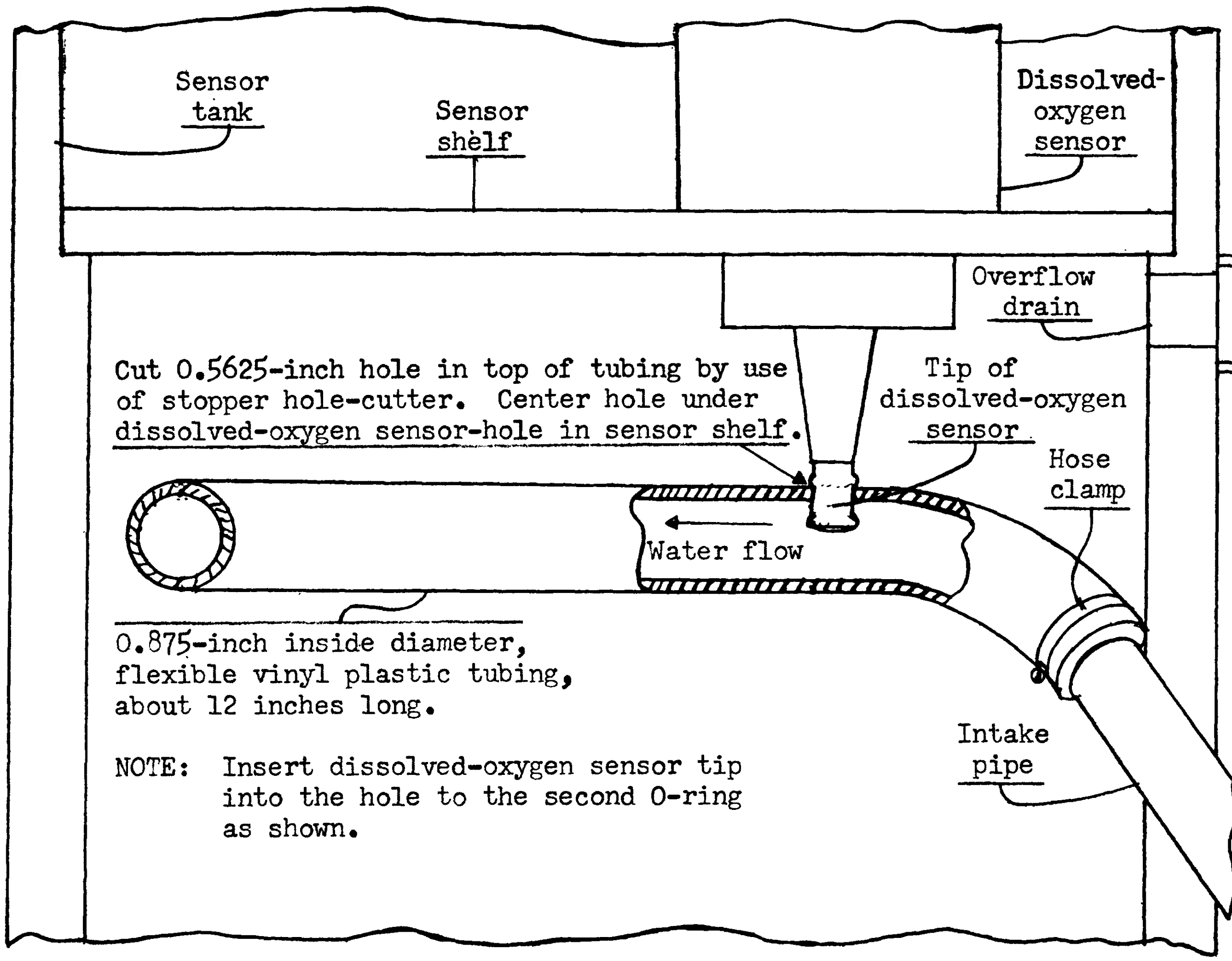

Figure 35.--Cross-sectional view of installation of velocity tube for dissolved-oxygen sensor in tank of flow-through monitor.

D. pH:

Check the pH calibration by use of a pH buffer at a value near that of the water. If the difference between the value of the pH buffer and the equivalent panel-meter value for the water is more than ± 0.2, recalibrate the parameter.

12. After the calibration checks have been made and the information for each parameter is recorded, place the auto-manual switch in auto position, press the start switch, and allow the monitor to scan and punch the parameter values. Check to be sure that the values punched are the same as those displayed on the panel meter. Record the values as values after calibration if recalibration was required. The test plug values of the recalibrated parameters will need to be checked and recorded.

13. Check to be sure that all switches are in operation mode before leaving the station, and leave a copy of the monitor inspection form in the shelter.

Nonroutine maintenance

1. Trouble shooting electronic circuits:

Trouble shooting usually consists of isolating malfunctions to a specific electronic circuit or sensor assembly and replacing the malfunctioning component with a spare unit. The problem of differentiating between sensor problems and signal-conditioner problem is simplified usually by use of the test plugs.

A. If an apparent drift is noted during calibration and is not corrected by cleaning the sensor, substitute the appropriate test plug for the sensor assembly. If the panel-meter value is not the same as recorded at the time of calibration, the problem is in the signal conditioner of the parameter or other internal electronic circuits that are common to all parameters. Substitution of the respective test plugs in the other parameters will determine whether the problem is in the signal conditioner or the common electronic circuits.

B. Problems in scanning, sequencing, and punching usually can be corrected by replacement of the programer.

C. Problems of punching incorrect values in the digital tape can usually be traced to the digital buffer, panel meter, or the programer. Methods of isolating the three most common problems are shown in figure 36.

2. Trouble shooting sensors:

If the cause of the malfunction is traced to the sensor, a few simple checks will usually reveal the defect and the required action can be taken to remedy the problem.

A. Specific conductance sensor:

(1) Remove the cover cap and check for broken wires or loose solder connections.

(2) Check to be sure that all terminals are covered completely by silicone rubber sealer as a waterproof coating. If moisture collects on the uncoated connections, the calibration may drift.

(3) Check the resistance of the temperature compensator by use of the digital volt-ohm meter connected across pin 5 and pin 6 of the sensor connector. The resistance should be within the range of 2,253 ohms at 25°C to 7,355 ohms at 0°C. If the temperature compensator is defective, the sensor must be replaced.

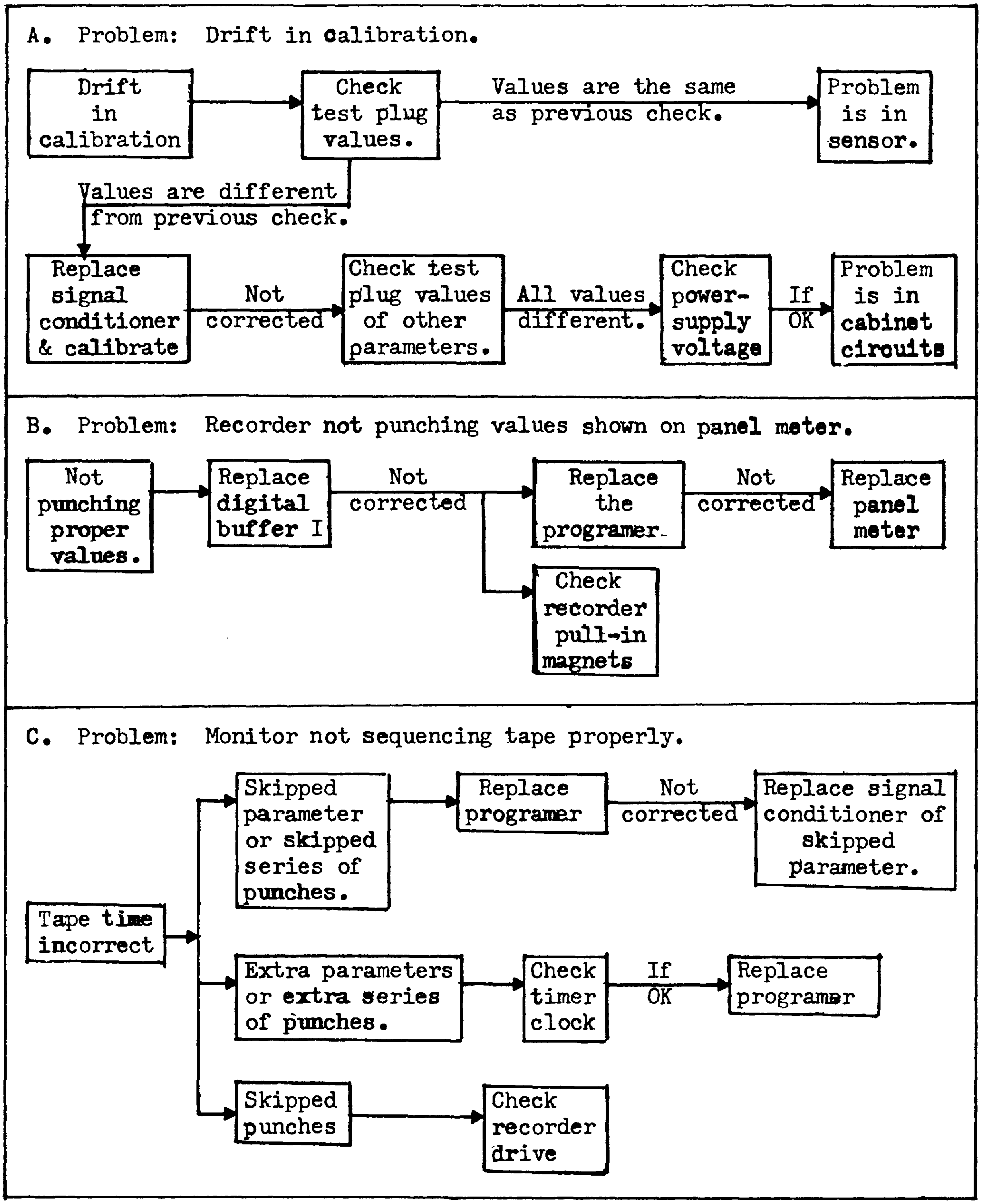

Figure 36.--Trouble shooting flow charts for isolation of some of the problems encountered in servicing the flow-through monitor.

(4) After repair or replacement of the sensor, calibrate the parameter.

(5) After calibration, substitute the test plug for the sensor and record the test plug values.

B. Dissolved-oxygen sensor:

(1) The most efficient method of trouble shooting the dissolved-oxygen sensor is by replacement with a spare sensor that is known to be in good condition.

(2) If a spare sensor is not available, install a new membrane on the sensor. The membrane should be checked before it is removed to be sure that it has not been damaged. The electrolyte should be replaced also if the membrane has been damaged and the electrolyte has swept out of the electrolyte chamber. Note--electrolyte should be replaced about every 4 months and the level checked monthly when the sensor is in use. A new membrane will usually solve the problem.

(3) Check the output voltage of the sensor by use of the digital volt-ohm meter connected across pin 4 (-) and pin 9(+) of the sensor connector after the membrane has been replaced. The output voltage per milligram per liter of dissolved-oxygen concentration should be approximately 3 millivolts at 25°C to 1 millivolt at 0°C. Normal life expectancy of the sensor is about 18 to 24 months, after which the output decreases due to oxidation of the lead electrode. If the output voltage of the sensor is not within the 1 to 3 millivolt range then removal and repair is the only recourse.

(4) Check the resistance of the two temperature compensators by use of the digital volt-ohm meter connected across pin 5 and pin 6 for one and pin 7 and pin 8 for the other. The resistance of each should be about 2,235s ohms at 25°C to 7,355 ohms at 0°C. The sensor must be removed and repaired if either one or both of the temperature compensators are defective.

(5) Check for broken wires and loose solder connections. Check to be sure that the small resistor is connected across connections 4 and 9 from the top of the terminal strip and that all connections are covered completely with silicons-rubber sealer as a waterproof coating. Make necessary repairs and recheck.

(6) After repair or replacement of the sensor, calibrate the parameter.

(7) After calibration, substitute the test plug for the sensor and record the test plug values.

C. Temperature sensor:

1. Check the resistance of the sensor by use of the digital volt-ohm meter connected across pin 6 and pin 7 of the sensor connector. The resistance should be 110 ohms at 25°C to 100 ohms at 0°C.

2. Remove the sensor cover cap and check for broken wires and loose solder connections. Check to be sure that all terminals are covered completely with silicone-rubber sealer as a waterproof coating. Make necessary repairs and recheck the resistance. Replacement of the sensor is necessary if the resistance is not within the 100 to 110 ohms range.

3. After calibration, sustitute the test plug for the sensor and record the test plug value.

D. pH sensor:

Most pH sensors problems are caused by defective electrodes. The only solution is replacement of the defective electrode and temperature compensator.

1. Inspect the reference electrode for air pockets or bubbles and a clogged reference junction. Some reference electrodes are gel filled and others salt filled. The gel-filled electrodes may be converted to salt-filled electrodes by flushing out the gel with hot water and refilling with KCl (potassium chloride solution). A gradual clearing of the salt solution occurs in the salt-filled electrodes over a period of time as diffusion takes place. A clear solution devoid of salt crystals indicates that the solution is not saturated and the electrode should be refilled with KCl electrolyte. Sometimes a salt bridge of a glass constructed reference electrode can be reactivated by rubbing the salt wick area lightly over "o" corborundum paper and applying a light suction. Moisture or droplet should appear at the wick if a free flow of the electrolyte is obtained. If the reference junction cannot be unclogged, it should be replaced.

2. Check the glass electrode if it is broken, cracked, scratched, or otherwise damaged. Glass electrodes may become covered with a coating that cannot be removed by normal cleaning. Some manufacturers suggest the use of hydrochloric acid or, in extreme cases, ammonium biochloride for cleaning; however, this procedure should be reserved for use in the office. Replacement of the electrode is more efficient in the field.

3. Check the resistence of the temperature compensator by use of the digital volt-ohm meter connected across pin 7 and pin 8 of the sensor connector. The resistance should be in the range of 2,253 ohms at 25°C to 7,355 ohms at 0°C.

4. If the resistance is not within the 2,253 to 7,355 ohm range, remove the sensor cover cap and check for broken wires and loose solder

connections. Check to be sure that the wire between the stainless-steel grounding rod and the small metal-cased preamplifier is connected. Make necessary repairs.

5. Check to see that the protective insulation sleeve is covering the metal connector that connects the glass electrode to the pre-amplifier. Check to be sure that all terminals are covered completely with silicone-rubber sealer as a waterproof coating. Application of the sealer around each electrode, around the sensor cover-cap seal, and around the sensor cable at the top of the sensor cover cap may be necessary to prevent moisture from collecting inside the sensor cover cap. Make necessary repairs and recheck the resistence. If the resistence is not within the 2,253 to 7,355 ohms range, the sensor must be replaced.

6. After repair or replacement of the electrodes, temperature compensator, or sensor, calibrate the parameter.

7. After calibration, substitute the test plug for the sensor and record the test-plug value.

Mini-monitor

Routine maintenance

The following procedure is to be used as a guide for the orderly performance of routine maintenance and servicing of the mini-monitor:

1. Make a preliminary visual inspection of the site to check for any unusual or abnormal conditions such as flood damage, wind damage, damage caused by debris or ice, and vandalism. Any abnormalities should be recorded.

2. Open the door of the shelter and observe the digital tape time in the recorder to determine if the tape time is the same as the watch time. Place the auto-hold switch in the hold position and the auto-manual switch in the manual position and check the internal digital clock time. Record these values as the tape time, watch time, and clock time.

3. If the digital tape is not due for removal, before disturbing the sensors, leave the auto-hold switch in the hold position and the auto-manual switch in the hold position. Depress and release the channel advance switch to advance the monitor through the scan cycle, dwelling on each channel monentarily. Record the panel-meter values for each parameter as the values before cleaning. At this time, check the battery voltage and record it.

4. If the digital tape is due for removal, before disturbing the sensors, place the auto-hold switch in the auto position and auto-manual switch in the manual position. Move the tape ahead one hour and depress and release the scan switch and allow the monitor to scan and punch each parameter. Remove the punched tape from the recorder. Record punched

values as values before cleaning. Empty the chad tray and reconnect the tape to the take-up spool of the recorder.

5. Whether the tape is removed or not removed, scan back a few days of the punched tape to determine if there are any problems that indicate the need for a nonroutine procedure.

6. Make the before-cleaning measurements on the water near the location of the sensors in the stream. Record the values as values before cleaning and compare with the monitor values before cleaning.

7. Clean the sensors and return them to their original position in the stream.

8. While the sensors are stabilizing, make after-cleaning measurements on the water near the location of the sensors in the stream to determine if any changes have occurred during the cleaning time and record the values.

9. After the sensors have stabilized, place the auto-hold switch in the hold position and the auto-manual switch in the manual position. Depress and release the channel advance switch to advance the monitor through the scan cycle, dwelling on each channel momentarily. Record the panel-meter values as the values after cleaning.

10. If the difference between the equivalent panel-meter value and the measured value for each parameter is within the allowable limits and no malfunctions are indicated by scanning the punched tape, the inspection is complete. If the difference is not within allowable limits, proceed with the nonroutine maintenance and service.

11. Check to be sure that the auto-hold and auto-manual switches are in auto position and that all pertinent information is recorded before leaving the station. Leave a copy of the monitor inspection form in the shelter.

Nonroutine maintenance

1. Temperature:

   If the difference between the equivalent panel-meter value and the temperature measured by use of the precision thermometer is more than ± 0.3°C, recalibrate the parameter.

2. Specific conductance:

   If the difference between the equivalent panel-meter value and the specific conductance value measured at the stream by the specific conductance field meter is more than ± 5 µmho or ± 5 percent of the measured value, whichever is greater, recalibrate the parameter.

3. pH:

If the difference between the equivalent panel-meter value and the pH value measured at the stream by use of the pH field meter is more than ± 0.2, recalibrate the parameter. Check the combination pH electrode to be sure that is has not been damaged.

4. Dissolved oxygen:

If the difference between the equivalent panel-meter value and the dissolved-oxygen value measured at the stream by use of the dissolved-oxygen field meter is more ± 0.3 mg/L or ± 5 percent of the measured value, whichever is greater, recalibrate the parameter. Check to be sure that the Teflon membrane is not damaged or loose, and that the stirrer is operating properly.

5. Recorder

Check the recorder for bent pins and malfunctioning pull-in magnets and check the spacing of the center guide-holes of the digital tape. Some digital tapes have been found to have improperly spaced guide-holes that cause the tape feeder sprocket to malfunction by climbing out of the holes. A new roll of tape with properly spaced guide-holes is the only solution to the problem. A digital recorder that has bent pins or malfunctioning pull-in magnets should be replaced and taken to the office for repair.

Quality control

Many factors will determine the quality of the data collected by any water-quality monitor whether flow-through or in situ, and must be maintained in control.

Standards and test equipment:

Check to be sure that the specific conductance standard solutions and the pH buffer solutions are fresh and at the value shown on the label. Check all field meters to determine that they are properly calibrated and in good condition.

Recalibration:

Recalibration is indicated if the difference between the measured value and the equivalent panel-meter value of a parameter exceeds the acceptable limits and cannot be traced to other malfunctions of the system and corrected by routine procedures.

Parameter	Acceptable limit
Specific conductance	±5 μmho/cm or ± 5 percent of the measured value, whichever is greater.
Dissolved oxygen	±0.3 mg/L or ±5 percent of the measured value, whichever is greater.
Temperature	±0.3°C
pH	±0.2

Frequency of inspections:

The frequency of inspections for maintenance and servicing of monitors depends upon the characteristics of the water being monitored. Stations where rapid fouling of the sensors and pumping system occurs require the most frequent inspections. If the problem conditions are seasonal, the monitor should be inspected more frequently at those times of the year. The dissolved-oxygen sensor is more sensitive to both fouling and flow rate than the other sensors, therefore, the frequency of inspections will depend primarily upon how long the dissolved oxygen sensor can operate efficiently without cleaning. Experience at any station will eventually determine the frequency of inspections.

A local observer may be hired and trained to inspect the station, provide system cleaning, and report any system malfunctions or other problems. Another method of surveillance of the operation of the monitor is by use of telemetry to provide current data and detect malfunctions more quickly.

Frequency of water-quality cross sections:

A set of sampling instructions for several discharges for the site should be kept in the station shelter or in the field vehicle for use in periodically checking the water-quality characteristics across the width of the stream as a quality control check on the data collected at a single point. The frequency of checks will be determined by the homogeniety of the water-quality cross section. Judicious consideration of factors that may affect poor mixing of water at each site will prove helpful.

Field notes:

The importance of field notes in maintaining good quality control of the data collected by a water-quality monitor can not be overemphasized. The completed monitor inspection form shown in figure 37 is from an inspection of a flow-through monitor that is calibrated as follows.

MONITOR INSPECTION FORM

STATION NO. 03231500 DATE 4-5-78

LOCATION SCIOTO RIVER AT CHILLICOTHE, OHIO

TAPE REMOVED YES INSPECTED BY ABG GAGE HEIGHT 15.4

TIME OF BEFORE CLEANING READINGS: WT. 0940 CT. 40 TT. 0900

READINGS	BEFORE CLEANING			AFTER CLEANING			
PARAMETER	PANEL METER	CONVERTED VALUE	FIELD METER	PANEL METER	CONVERTED VALUE	FIELD METER	TEST PLUG VALUE
SP. COND.	462	462	460	462	462	460	350/700
D.O.	460	9.3	10.0	500	10.0	10.0	001/400
TEMP.	330	16.5	16.0	330	16.5	16.0	001/910
pH	750	7.5	7.5	750	7.5	7.5	001/470/940

ATMOSPHERIC PRESSURE: 750 MM HG. AT 16.0 °C

CALIBRATION CHECKS:

READINGS		BEFORE CALIBRATION		AFTER CALIBRATION	
PARAMETER	STANDARDS VALUE	PANEL METER	CONVERTED VALUE	PANEL METER	CONVERTED VALUE
SP. COND.	495	497	497		
D.O. (AIR-CHAMBER)	9.8	490	9.8		
TEMP.	29.5	600	30.0	590	29.5
	5.0	102	5.1	100	5.0
	16.0			320	16.0
pH	7.0	700	7.0		

REMARKS: TEMPERATURE TEST PLUG VALUE DRIFTED FROM 900 TO 910 SINCE LAST CALIBRATION. 0.5°C HIGH SO RECALIBRATED. D.O. WAS LOW BUT CLEANING SENSOR CORRECTED VALUE.

COMPARISON CHECK	STREAM AT INTAKE	WATCH TIME	SENSOR TANK	WATCH TIME
D.O.	10.1	1030	10.1	1040
TEMP.	16.0	1030	16.0	1040

DIGITAL TAPE NUMBERS

TAPE ON 389652

TAPE INSPEC.

TAPE OFF 389647

AFTER CALIBRATION READINGS: TIME: WT. 1050 CT. 50 TT. 1100

PARAMETER	PANEL METER	CONVERTED VALUE	FIELD METER	TEST PLUG VALUE
SP.COND.	465	465	463	
D.O.	500	10.0	10.1	
TEMP.	320	16.0	16.0	001/900
pH	750	7.5	7.5	

FLOW RATE IN SENSOR TANK

BEFORE CLEANING

FILL TIME: 30 SEC GPM: 10

AFTER CLEANING

FILL TIME: 30 SEC GPM: 10

REMARKS: SET TAPE TO PUNCH 1100 PUNCH CYCLE, NO PUNCHING PROBLEMS OBSERVED BY TAPESCAN.

Figure 37.--Example of completed monitor inspection form.

Parameter	Range	Panel-meter value
Specific Conductance	0 to 1,000 μmho/cm	000 to 1,000
Dissolved oxygen	0 to 20 mg/L	000 to 1,000
Temperature	0 to 50°C	000 to 1,000
pH	0 to 10	000 to 1,000

The before-cleaning and after-cleaning specific conductance and pH values are in agreement, and indicated that the recorded values for the parameters are valid. The 0.7 mg/L difference between the before-cleaning and after-cleaning values for dissolved oxygen indicates that the error was caused by fouling of the sensor membrane. The calibration check shows that the parameter is in calibration, however, the chlorination system should be turned on to reduce the fouling caused by biological growth. The difference between the measured value and the recorded value for temperature exceeded the acceptable limit for the parameter, so the temperature system was recalibrated.

DATA EVALUATION

Water-quality data from monitors that are maintained and serviced properly will usually require very little correction; however, erroneous data may be recorded occasionally. No corrections of data should be made unless the amount of error is known and can be supported by additional data, otherwise, the data should be deleted from the record. Some of the most common causes of erroneous data are:

1. Fouling of the sensors

2. Drift in the calibration or improper calibration of the signal conditioners

3. Failure of other electronic components of the monitor

4. Malfunction of other equipment associated with the monitor, such as pumps.

When the recorded value is within the acceptable limit of the measured value for the parameter), no correction of the data is necessary. When the difference is greater than the acceptable limit, consideration of all the known factors pertinent to the error will determine whether the erroneous data should be corrected or deleted. Erroneous data may be recorded due to uniform error or nonuniform error. A uniform error produces a record in which all values are displaced by the same amount throughout the erroneous part of the record. A nonuniform error produces a record in which the amount of error, usually, increases or decreases gradually throughout the erroneous part of the recorded data.

An example of a uniform error in the recorded data of temperature is shown in figure 38. Comparison of the data punched in the digital tape and the after-calibration information on the monitor inspection form at the beginning of the tape period indicated that the signal conditioner had been improperly calibrated in the amount of 1.0°C, which was the same error determined by checks made during the next inspection of the monitor. A simple correction of the erroneous data in both the minimum and maximum in the amount of 1.0°C for the 14 days of record was considered to be justified. After recalibration, the recorded data was in agreement with the measured value indicated at the end of the tape period.

Application of corrections to erroneous data produced by a nonuniform error is more difficult than for that produced by a uniform error because more information is needed to document the rate of change in the error. An

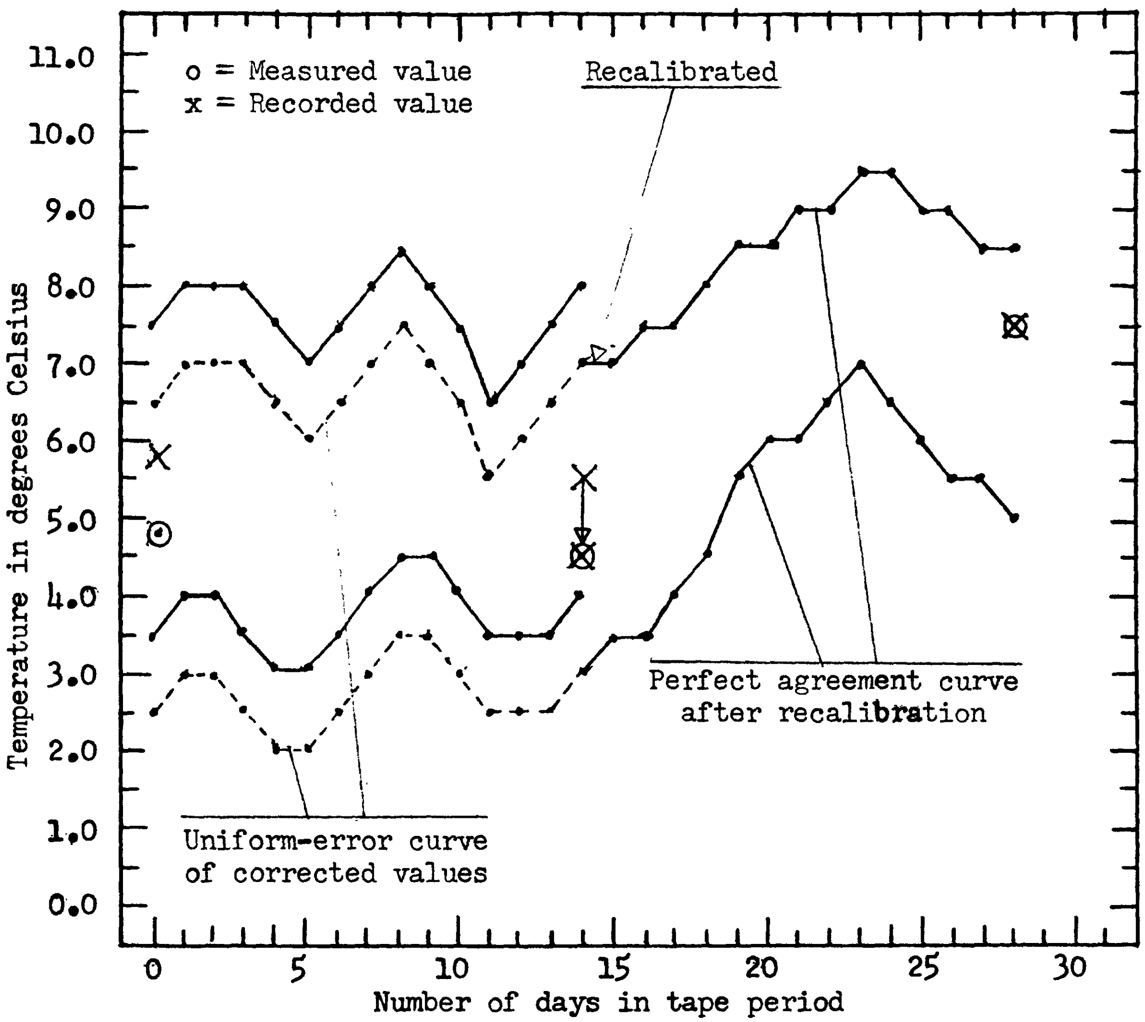

Figure 38.—Daily maximum and minimum recorded values of temperature and corrected uniform error curves.

example of nonuniform error in the recorded data for dissolved oxygen is shown in figure 39. The error was caused by fouling of the dissolved-oxygen sensor, as indicated by the fact that the difference between the measured value and the recorded value was eliminated by cleaning the sensor at both inspections during the tape period. The amount of error was about the same at both inspections, which would indicate that the rate of fouling was about the same between sensor cleanings and probably occured gradually. A prorated correction of 0.0 to 0.9 mg/L for the first part of the tape period (from day 2 to day 14) and 0.0 to 0.7 mg/L for the second part of the tape period (from day 18 to day 28) would be justified.

Another type of nonuniform error, caused by improper calibration of the signal conditioner, is the constant-percentage error as shown in figure 40. A constant-percentage error occurs if the signal conditioner is improperly calibrated so that the amount of error increases or decreases with the magnitude of the parameter value. In the example shown in figure 40, the signal

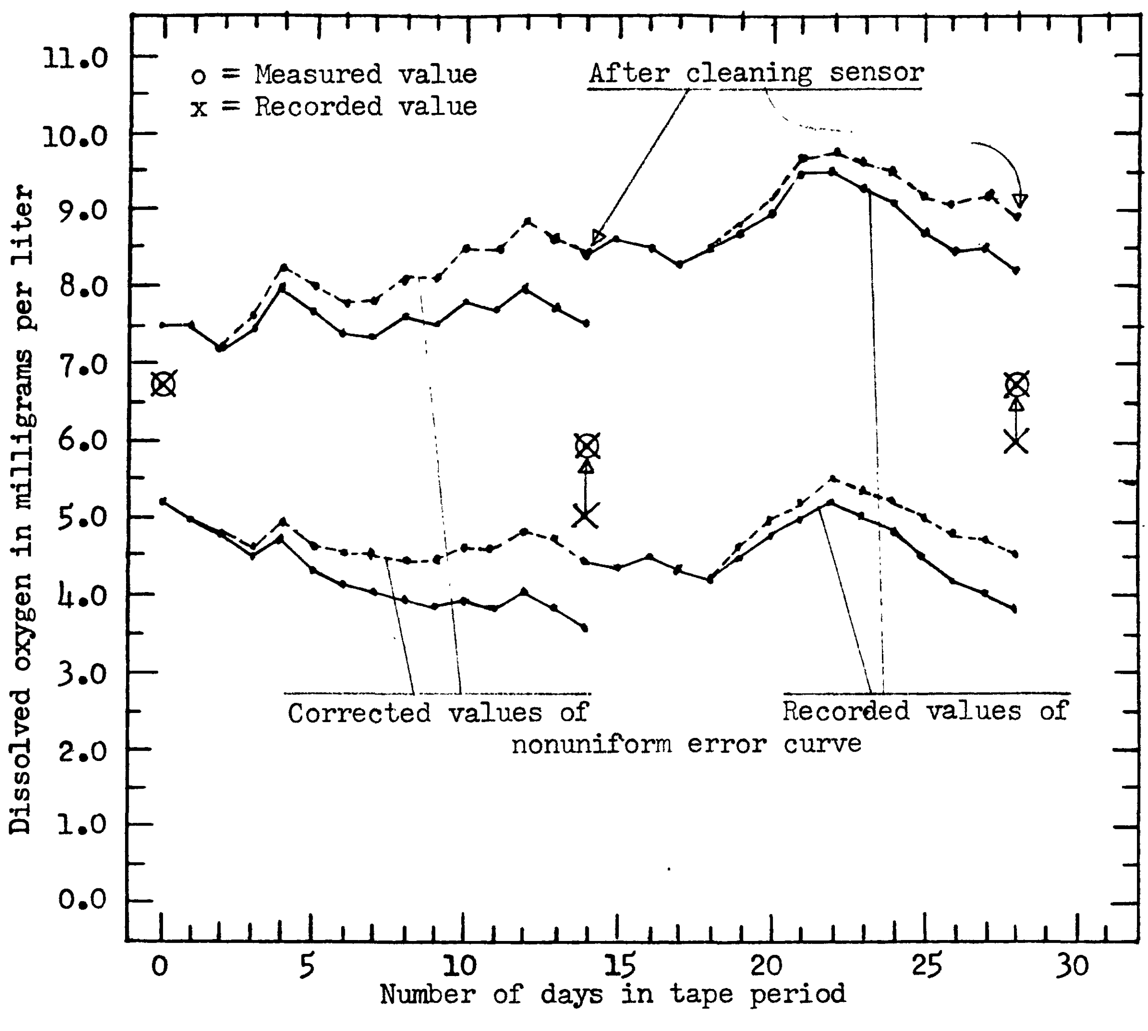

Figure 39.--Daily maximum and minimum recorded values of dissolved oxygen and corrected nonuniform error curves.

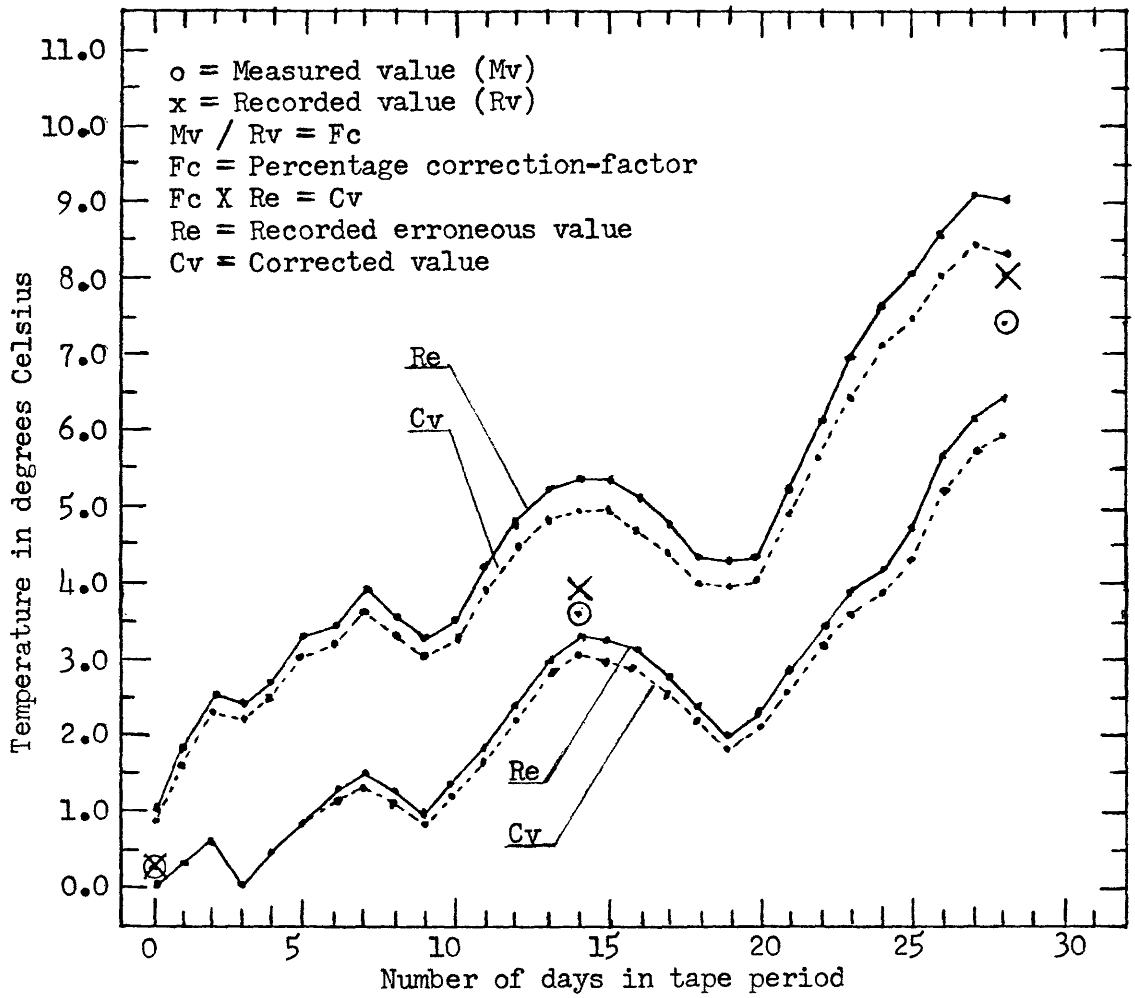

Figure 40.--Daily maximum and minimum recorded values of temperature and corrected constant percentage error curves.

conditioner was apparently in calibration at the beginning of the tape period when the temperatures were near 0.0°C. As the temperatures increased, the amount of error increased. When temperature checks were made on the 14th day of the tape period, the measured temperature was 3.6°C and the recorded temperature was 3.9°C, a difference of + 0.3°C, which indicates that the recorded value was within the acceptable limit and recalibration not needed. When the temperature checks were made at the end of the tape period, the measured value was 7.4°C and the recorded value ws 8.0°C, a difference of ±0.6°C and that difference indicated that recalibration was needed. Temperature checks at the high end and low end of the calibration range determined that the error was greater at the high rather than low end and was a function of the magnitude of the value, a constant percentage error.

A percentage correction-factor (Fc), determined as shown in figure 40, is used to correct this type of erroneous data. In the example, the correction factor is 0.92, (7.4 / 8.0 = 0.92) or (3.6 / 3.9 = 0.92). If proper checks are made to determine the cause of the error, this type of correction would be justified.

The primary computer data printout is used to make an overall evalution of the validity of all of the recorded values for each parameter with special attention given to "flagged" data. If there is a valid change in one parameter, there is usually a corresponding or related change in one or more of the other parameters. Comparison of simultaneously recorded data for each parameter should determine the validity of data that appears to be erroneous. Any change in gage height and the consequential change in discharge should be considered, also, as a factor that may cause data to appear erroneous. Isolated or short-term conditions, such as spills from sewage treatment plants or industrial holding ponds, may cause apparently erroneous data. All the facts must be considered in determining whether the data should be retained or deleted. Do not attempt to fabricate data for missing data, because it will serve only to cast doubt on the valid data.

The data reviewer should have access to maps and information describing basin and land-use characteristics, locations of major point sources of anomalous water-quality locations, operating patterns of upstream reservoirs, and types of chemical processes of major industries and their release schedules and quantities. All these factors and how each impacts on that particular stream and monitor station should be considered.

SUMMARY

The standardized procedures described in this manual are based on many years of experience of Geological Survey scientists, instrument specialists and skilled field personnel. Proper use of the procedures will limit problems encountered in collecting water-quality data at continuously recording water-quality monitor stations, and will ensure the accuracy and precision of the collected data.

The various phases of establishing and operating a water-quality monitor station have been arranged in this manual in a priority sequence, but the importance of each phase can not be overemphasized. Improper attention to any phase will affect the completeness and effectiveness of the other phases and, subsequently, the satisfactory accomplishment of the project objectives. Preliminary preparation must include consideration of all phases of the monitoring system. Some phases have requirements that must be satisfied concurrently with other phases. Installation must take into consideration calibration, maintenance, and service of the monitor system. A poorly-arranged installation will encourage improper maintenance and service and will likely result in lost data. Proper installation of the monitor system and complete and accurate field notes will reduce the time required to process and evaluate the collected data, and will greatly enhance the quality and accuracy of the published data.

The final product from information derived from any water-quality monitor depends upon how completely personnel perform the functions required to operate, maintain, and service the monitor system, regardless of how satisfactory the installation may be.

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