OPERATIONAL PROTOCOL FOR A RECORDING PRECIPITATION MONITOR

Manual for Task Group G Site Operators, National Atmospheric Precipitation Assessment Program

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U.S. GEOLOGICAL SURVEY
Open-File Report 86-405-B

Arvada, Colorado
1986

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By Michael M. Reddy, Randolph B. See and Timothy D. Liebermann

ABSTRACT

This report documents the protocol for installation, maintenance and calibration of a recording precipitation monitor. The precipitation monitor measures the depth, temperature, pH, and specific conductance of precipitation continuously during a storm event and stores the data on magnetic tape. These instruments are being utilized at four sites in the eastern United States--Washington, D.C.; Chester, New Jersey; Newcomb, New York; and Research Triangle Park, North Carolina (see cover). At each site, precipitation is collected in a wet-only precipitation collector modified for continuous monitoring of precipitation chemistry during storm.

INTRODUCTION

As part of the investigation of materials corrosion by wet precipitation, the U.S. Geological Survey has modified several wet/dry precipitation collectors to enable continuous measurement and recording of precipitation characteristics during storms. These instruments are being utilized at four sites in the eastern United States--Washington, D.C.; Chester, New Jersey; Newcomb, New York; and Research Triangle Park, North Carolina (see cover). At each site, precipitation is collected in a wet-only precipitation collector modified for continuous monitoring of precipitation chemistry during storms. The sites are National Atmospheric Deposition Program (NADP) Task Group G field sites and integrated with the NADP Acid Rain Site Management Plan and the U.S. Geological Protocol for Collecting, Processing and Shipping Precipitation Samples. This report, which is chapter B of our operations manual for site operators, documents the protocol for installing, maintaining, and calibrating the recording precipitation monitors.

In addition to this report, a manual prepared by the U.S. Geological Survey for the prototype precipitation monitor will be provided. Please refer to it for specific information not presented herein. Information in this report supersedes any differing information presented in the manual.

DESCRIPTION OF PRECIPITATION MONITOR

The recording precipitation monitor was built by the U.S. Geological Survey using a Geotech[1] model 0650 wet/dry precipitation collector that was modified to operate as follows. Water droplets make electrical contact on a precipitation sensor and trigger a motor to uncover the wet-collection bucket. Precipitation falling into the bucket drains into a shelter under the collection buckets and flows through a flow cell containing an instrument-probe package. The flow cell is constructed from a lucite block and precipitation flows through a narrow chamber containing three temperature sensors, a pH electrode, and a conductivity electrode. A Rosemont RMT 78-55-3 platinum resistance thermometer is used to measure the temperature of precipitation in the flow-cell, and two YSI 400 series thermistors are used for temperature conpensation of pH and specific-conductance measurements. An Orion, Ross combination pH electrode, model

8103 is used to measure pH. Precipitation then flows out of the shelter and is collected in a polyethylene sample bottle. All connections are made from Tygon tubing.

Electrical current from the sensors passes through specially designed signal conditioners and into a modified U.S. Geological Survey minimonitor, which contains zero- and slope-adjustment controls. Signals are linearized, corrected for temperature, adjusted to the correct output voltage, and then transmitted to a Campbell Scientific CR21 Micrologger (CR21 micrologger). Precipitation temperature, pH, and specific conductance are monitored as follows: they are measured by the probe package, conditioned through the minimonitor, and recorded by the CR21 micrologger.

The CR21 micrologger controls the operation of the precipitation monitor and the recording of all data. When the precipitation monitor senses precipitation, the CR21 micrologger is activited; the micrologger controls the minimonitor and transmits data to a Campbell CR56 thermal printer and a cassette recorder. The CR21 micrologger operates on the U.S. Geological Survey PROM 253, Water Sampler Program.

Precipitation depth is measured in 0.254-mm increments with a Weather Measure tipping-bucket raingage, model P501-I. External temperature is measured by a Campbell Scientific model 101 thermometer.

For cold-weather operation, the shelter is shielded with foil-clad insulation and heated with a thermostatically controlled heater. The raingage and collection bucket are heated with self-regulating, semiconductive-core heating cables.

A battery is provided to operate the precipitation monitor. However, fewer problems occur, especially during winter, if the precipitation monitor is operated using an alternating-current (AC) power source.

INSTALLATION OF EQUIPMENT

The recording precipitation monitor should arrive complete with all required equipment and pre-labeled connections. If you cannot find something, contact Michael M. Reddy at (303) 236-5355 or 236-3617.

Initial Tasks

1. Set the recording precipitation monitor in an open area, away from obstructions. Position the door to the south or east.
2. Level the monitor and weight it down with sandbags or secure it with guy wires.
3. Bolt on the raingage bracket to the monitor. Level the raingage and bolt it to the bracket. See Attachment I-A.
4. Attach the precipitation sensor; extend the wire attached to the sensor into the shelter. Make sure that the sensor won't be bumped or obstructed by the bucket cover.
5. Extend the AC power cord to the precipitation monitor, but don't

[1] The use of brand names in this report is for identification purposes only, and does not constitute endorsement by the U.S. Geological Survey. The brand name of your field instruments may be different than listed here, but they should be completely interchangeable.

plug it in yet.

6. Ground the base of the monitor to a nearby grounded object.

Set up Equipment Inside the Shelter

1. Place the minimonitor in the left, rear corner, with the writing facing forward. See Attachment I-A.
2. Bolt down the flow cell and instrument-probe package (see attachment II-B), in the front left corner.
3. Carefully connect the signal conditioners into the minimonitor.
4. Attach the pH electrode to the pH cable extending from the minimonitor. Insulate the connection with electrical tape.
5. Position the pH electrode into its holding cell so that it is not touching the sides; the bottom of the electrode is to be 5 mm above the bottom of the holding cell.
6. If the pH electrode is shipped dry, fill it with the appropriate filling solution (probably 3 M KCl). Soak the filled electrode at least 1 day in a beaker of pH 7 buffer before calibration.
7. Move the wires and signal conditioners so they are out of the way, making sure they won't obstruct the motion of the bucket cover.
8. Connect the precipitation sensor and the motor to the wet/dry control box. Plug the wet/dry control box into the power plug panel. See Attachment II-A.
9. Place the battery in the center rear of the shelter, with the regulator in front of it, and connect them. Place the CR21 micrologger in front of the regulator.
10. Connect the power cord from the minimonitor to the regulator.

Connect all Wiring

1. Follow the wiring diagrams in Attachments II-A amd II-B.
2. Connect the wet/dry control box to input channel 1 and 5V excitation on the CR21 micrologger.
3. Connect the minimonitor output wires to input channels 2, 3, and 4; 5V and ground; and Control Out 1 on the CR21 micrologger. As currently programmed, Control Out 1 is inactive, but connect anyway.
4. Extend the raingage wire into the shelter through the hole in the floor, and connect it to input channel 8 on the CR21 micrologger. Polarity does not matter.
5. Extend the temperature-probe wire into the shelter and connect it to input channel 5, DC excitation, and ground on the CR21 micrologger. Set the sensor in a secure, shaded location, for example, taped under the bottom of the shelter.
6. Connect the regulator to 12V and ground on the CR21 micrologger. Connect the regulator the power plug panel using a DC adaptor.
7. Place the CR56 thermal printer in a convenient location, such as to the left of the CR21 micrologger. Connect the CR56 thermal printer to the power plug panel using a DC adaptor. Connect the CR56 thermal printer to the CR21 micrologger with the SC12 ribbon cable.
8. Connect the cassette recorder to the power plug panel using a DC adaptor. Connect the cassette recorder to the SC12 ribbon cable using the SC235 adaptor cable. The SC235 adaptor cable converts the 9-pin SC12 ribbon cable into a 2-pin remote and microphone jack.

9. Thoroughly check all connections for correctness and contact.

Check Operation of Collection-Bucket Cover

1. Connect the AC power source to the power plug panel, switch on the power plug panel, and switch on the wet/dry control box.
2. Set the toggle switch on the wet/dry control box to Dry. The collection-bucket cover should move until the dry collection bucket is covered. Set the switch to Wet; the collection-bucket cover should cycle to close the wet bucket.
3. Set the switch to AUTO. Whenever the precipitation sensor is wet, the wet collection bucket should be uncovered. Use a wet cloth on the precipitation sensor to test it. Remove the cloth. A heater in the precipitation sensor should evaporate the water. When water droplets no longer connect the precipitation sensor plate and grid, the cover should cycle to close the wet collection bucket.

Check Operation of Minimonitor

1. Set switches to HOLD, ON, and MANUAL. Leave the minimonitor in MANUAL position for normal operation.
2. Flush the flow cell with a solution of known pH and specific conductance, for example 0.0001 N H_2SO_4. Don't try to calibrate yet, this is just a preliminary test of components.
3. Check the voltage of the power source by pressing the channel-advance button until 3 is displayed, then press and hold. Add 7 to the right 3 digits and divide by 10 to determine the voltage. For example, 0 111 indicates 11.8 V (volts). Voltage should always be greater than 10.0 V.
4. Advance to channel 1, temperature. Divide the right 3 digits by 20 to determine temperature, in degrees Celsius. Read 1 468 as 23.4 ^{o}C.
5. Advance to channel 2, specific conductance. The right 3 digits are the value of specific conductance. For example, 2 043 indicates 43 µS/cm. Off-scale readings are displayed as 2 024.
6. Advance to channel 3, pH. The right 3 digits are the value of pH. For example, 3 401 indicates a pH of 4.01.

Program the CR21 micrologger

This is the programming procedure. A complete description of programming logic may be found in the Campbell Scientific CR21 Micrologger manual. An abbreviatiated version of the programming language is shown in Attachment III. Please call Michael M. Reddy at (303) 236-3617 before making changes to the program.

The main controlling program is based on Campbell Scientific Output Program #70, PROM 253. It originally was designed for the U.S. Geological Survey to control the recording of data and the collection of water samples, based on stream gage height. As currently programmed, the CR21 micrologger is activited when the input signal from the wet/dry control box (input channel 1) exceeds 0.5 V. When that occurs, data are recorded at a preset time interval, for example, every 1 minute. Each increment (0.254 mm) of precipitation always is recorded at the end of the 1-minute period in which it occurs. Program #70 also records data at preset baseline intervals, whether the CR21 micrologger is activated or not. Finally, a separate output program records a daily summary of total precipitation and temperature ranges.

To program the Campbell Scientific CR21 Micrologger:

1. Switch on the CR21 micrologger. It should display 99:0000. The index field is 99, the data field is 0000. Before proceeding further, notice the flashing colon in the center of the data field. When the colon is displayed, the CR21 micrologger is scanning the sensors and will not respond to any keyboard entries, this can cause errors when entering commands. Wait for the colon to disappear and then enter your commands. Mistakes can be corrected by typing #, then retyping the entry, or by cycling back to where you began and then retyping the entry. The Campbell Scientific CR21 Micrologger manual contains more details on this procedure.

2. Typing *5A puts the CR21 micrologger into its clock-setting mode. Typing the A processes what you have entered and prepares the CR21 micrologger for the next entry. When it displays the index 91, enter the Julian day, then type A. For example, if it is December 31, type 365 A. Then when index 92 is displayed, enter the hour, then type A. If it is 2 P.M., type 14A. For index 93, enter the minutes, for example 45A, Then type * 0. The display should read 99: HR MIN. To summarize the commands:

Index Prompt	Type	Remarks
99	*5A	Enter "set clock" mode
91	Julian day A	
92	Hour A	
93	Minute A	
05	*0	Return to normal display
99		

3. The input table (Attachment III-A), directs the CR21 micrologger to process the information it receives from the sensors. Three separate entries are required for each input channel. Briefly, the first entry tells the CR21 micrologger how to identify the input. A "6" means to count pulses, a "1" means to measure DC voltage, and so forth. The second and third entries represent A and B respectively in the equation: Stored value = A (measured value) + B. Where: A is the Slope, and B is the Intercept.

Follow this procedure:

Index Prompt	Type	Comments
99	* 4 A	Begin to program the input table
11	1 A	Channel 1, wet/dry control box
12	1 A	Multiplier
13	0 A	Offset
21	1 A	Channel 2, flow-cell temperature
22	25 A	Multiplier
23	0 A	Offset
31	1 A	Channel 3, DC voltage
32	75 A	Limits maximum specific-conductance reading to about 210 µS/cm
33	0 A	Offset
41	1 A	Channel 4 = DC voltage
42	5 A	Multiplier

43	0 A	Offset
51	7 A	Channel 5, exterior temperature
52	1 A	Multiplier
53	0 A	Offset

Type A until the index prompt 91 is displayed.

91	6 A	Channel 9, raingage
92	1 A	Multiplier
93	0 A	Offset

Typing B returns you to your first entry in the table. Now type A and check and see what entry you have entered. If entry is correct, type another A. If entry is incorrect, type the correct value, then A and proceed. When satisfied that all entries are correct, type * 0 to return to the normal operation mode.

4. Now program output table #1 (Attachment III-B) to run the Water Sampler Control Program #70. This program records data at baseline intervals, during the active state, and records precipitation tips from the raingage whenever they occur. Use a 1-minute interval for rain (index prompt 12). For snow, index 12 can be reset to a 2- or 5-minute interval, to decrease the data generated and to conserve paper and tape.

Index Prompt	Type	Remarks
99	* 1 A	Enter output table #1
03	180 A	Baseline interval = 180 minutes
11	70 A	Enter program #70
12	1 A	For active state, use a 1 minute recording interval
13	0101	
21	1 A	Set controls to input channel 1
22	0050A	Threshold = 0.5 V
23	0050A	
31	2 A	
32	0900A	Port disabled
33	1000A	
41	0 A	
42	0900A	Port disabled
43	1000A	
51	0 A	Set in order which the
52	2345A	input channels will be displayed
53	0 A	during active state
61	B	Verify entries and then type *0 to return to normal operation.

5. Program the output table #2 (Attachment III-C), the daily summary. Total precipitation is required; the other outputs are optional, but recommended. Here are some examples of output control codes:

52 = total the number of pulses
53 = print maximum value
54 = print minimum value

Follow this procedure to give total precipitation and the maximum and minimum interior and exterior temperatures and the times they occurred. By typing 1 as the third entry, the time at which the maximum or minimum occurred also is printed.

Index Prompt	Type	Remarks
99	* 2 A	Enter output table #2
03	1440 A	Recording interval = 1440 minutes
11	52 A	Record precipitation pulses
12	9 A	from input channel 9
13	0 A	
21	53 A	Record maximum flow cell temperature
22	2 A	from channel 2
23	1 A	
31	54 A	Record minimum flow cell temperature
32	2 A	from channel 2
33	1 A	
41	53 A	Record maximum exterior temperature
42	5 A	from channel 5
43	1 A	
51	54 A	Record minimum exterior temperature
52	5 A	from channel 5
53	1 A	
61	B	Verify your entries and then type *0 to return to normal operation

If the CR21 micrologger is turned off or loses power, all programming and stored data will be lost, and you will need to re-program. Normally, batteries inside the CR21 micrologger safegaurd against power loss. Some useful commands for operating the CR21 micrologger are:

*0	Return to normal operating mode
*1A	Program output table #1
*2A	Program output table #2
*4	Program the input table
*61A	Display input channel 1, wet/dry control box voltage
*62A	Display input channel 2, flow-cell temperature
*63A	Display input channel 3, specific conductance
*64A	Display input channel 4, pH
*65A	Display input channel 5, exterior temperature
*8	Transfer memory buffer to cassette tape
*7	Transfer memory buffer to CR56 thermal printer
#	Cancel current entry
*DOA	Record current readings

Interpreting Output from the CR21 Micrologger

The CR21 produces five types of output as currently programmed, three from output table #1, one from output table #2, and the data scan of current sensor readings produced by entering "*DOA". Although each output table has a different format, certain features are the same for all. Each data field contains 10 characters. The first two characters are reserved for a sequential index number, the next six characters are a numeric value, and the last two characters are blanks. After eight data fields (80 characters) a carriage return is generated automatically. The data field associated with index number 1 always represent one of the five types of output. These codes are:

0001. = Baseline summary (see Attachment III-B and IV)
0041. = Active state
0249. = Precipitation tip
0002. = Daily summary (output table #2, Attachment III-C)
0000. = Current sensor readings from CR21 micrologger, using "*DOA"

A sample of output from the CR21 micrologger is shown in Attachment IV. The formats for output are:

Format for code 0001, baseline summary (see attachment IV):
01 0001. 02 JULIAN DAY 03 TIME 04 WET/DRY CONTROL BOX VOLTAGE 05 FLOW-CELL TEMPERATURE 06 CONDUCTIVITY 07 pH 08 EXTERIOR TEMPERATURE

Format for code 0041, active state and code 0000, current sensor readings:
01 0041. 02 TIME 03 WET/DRY CONTROL BOX VOLTAGE 04 FLOW-CELL TEMPERATURE 05 CONDUCTIVITY 06 pH 07 EXTERIOR TEMPERATURE

Format for code 0249, precipitation tip:
01 0249. 02 TIME 03 X.000
where X = the number of precipitation tips recorded during that minute and each tip is equal to 0.254 mm of precipitation. If no tips occurred, code 0249 will not be printed.

Format for code 0002, daily summary:
01 0002. 02 TOTAL PRECIPITATION 03 MAXIMUM FLOW-CELL TEMPERATURE 04 TIME OF MAXIMUM 05 MINIMUM FLOW-CELL TEMPERATURE 06 TIME OF MINIMUM 07 MAXIMUM EXTERIOR TEMPERATURE 08 TIME OF MAXIMUM 09 MINIMUM EXTERIOR TEMPERATURE 10 TIME OF MINIMUM

MAINTENANCE OF EQUIPMENT

Collecting Samples

If any precipitation has been collected, remove the sample bottle and cap it. Label the bottle with the date, time and any important notes. After calibration and flushing are complete, replace the old sample bottle with a new bottle, using the procedure described in Reddy and others (1986). Make onsite measurements of volume, pH, and specific conductance as soon as possible after collection. After making the measurements, process the samples as follows: (1) Pass 250 mL of sample through a 0.45 μm filter into a 250-mL shipping bottle; (2) pour 250 mL of unfiltered sample into a 250-mL shipping bottle; and (3) ship both bottles to the U.S. Geological Survey laboratory in Denver, Colorado. Use the Site Observer's Record Sheet (Attachment V) to record data measurements. Chapter A of this manual (Reddy and others, 1986) provides detailed instructions for processing water samples.

Check Calibration (Weekly)

With the sample bottle removed, flush the flow cell with distilled water. Using the Calibration Record Sheet (Attachment VI) as a guide, flush the flow cell with standard check solutions and write the readings for each solution on the calibration record, after typing *DOA. Be sure to rinse the flow cell thoroughly with distilled water after each flushing. Record all information on the Calibration Record Sheet. To minimize potential compensation errors, the temperature of all solutions should be about 25° C. Calibration is required if:

1. pH buffers deviate more than ± 0.05 unit from the expected values; or
2. Specific-conductance standards (0.001 N or 0.0001 N KCL) deviate more than ± 1 μS/cm from the expected value.

If calibration is required proceed to the section entitled "Calibration of Instruments".

Servicing the CR56 Thermal Printer

1. Keep the printer dry, and keep it from freezing. Put the printer in a plastic bag with dessicant, if necessary.
2. Follow the instructions in the Campbell Scientific CR56 Thermal Printer manual.
3. Eventually the print chip deteriorates and begins to leave gaps on the output paper because a column is not printing. When the output begins to become illegible, return the CR56 thermal printer to Michael M. Reddy for replacement of the chip. Keeping the CR56 thermal printer dry helps to prevent this problem.
4. If the red charging light is not on, a power problem is indicated.

Servicing the Cassette Recorder

1. Label all cassette tapes with the site name, date, and time that the cassette tapes are put on and removed. Number each tape sequentially. Change the cassette tape each week.
2. To change a tape, Type *8A on the CR21 micrologger and wait for it to transfer any information still in the memory buffer onto the tape. After the transfer ends, the index code 08 will be displayed, and it is safe to remove tapes, rewind tapes, and so forth. No data will be lost. Leave the recording volume set at 6, turn on to RECORD, and then type *0 to return to normal mode.
3. If your tape ran out while you were away, you can retrieve the last 640 data points recorded, but any earlier information will be lost. Bypass step 2, put on a new tape, turn on to RECORD, type *8, and wait for the memory buffer to clear. The CR21 micrologger then will display 08: OXXX. Type in YYY A, where YYY = XXX +1. The CR21 micrologger will then transfer its entire memory to the cassette, beginning with the oldest data point still in memory. When the transfer is finished, type *0, and make a note of what happened.

Data collection (weekly)

Remove the paper-tape record from the CR56 thermal printer, date it, and re-spool the paper tape. Make lots of notes on the paper tape. Read the Campbell Scientific CR56 Thermal Printer manual if necessary. Check the cassette recorder and change tapes if necessary. Leave the recorder in RECORD mode. Each week send shipping bottles, any paper or cassette tapes, and any completed calibration forms to:

Randolph B. See
U.S. Geological Survey
5293 Ward Road, MS 407
Arvada, CO 80002

Miscellaneous Maintenance

Inspect the pH electrode and refill, if necessary, with the proper filling solution. Check the placement of the pH electrode. If you have been getting strange recordings, or are otherwise suspicious of the equipment, track down the problem and solve it. Don't let the problem continue. If you are unable to resolve the probelm, call Michael M. Reddy or Randolph B. See (303) 236-3617.

Condensation inside the shelter during damp or snowy conditions may cause problems, especially with the CR21 micrologger and the CR56 thermal printer. Enclose them in large plastic bags, put in a beaker of dessicant, and seal the bags with tape around the wires.

Check the inside of the tipping bucket and collection bucket, and remove any debris. If the collection bucket contains debris, remove the input line from the probe package and rinse the bucket with distilled water.

Flip the toggle switch on the wet/dry control box to DRY, then to AUTO. The collection-bucket cover should cycle. Drip a little water onto the sensor and see what happens. Adjust the heater thermostat, if necessary. Flush the flow-cell with distilled water before attaching a new sample bottle.

Before leaving, follow procedures outlined in the checklist given in Attachment VII. Make a copy of the checklist, and post it inside the shelter.

CALIBRATION OF INSTRUMENTS

Disconnect the sample bottle from the probe-package outlet. When calibrating, record your measurements on the paper tape by typing *DOA. Make penciled notations on the paper tape, so that your procedure can be reconstructed later. Use distilled water from a squirt bottle to flush the flow-cell between measurements. The pH and specific-conductance values are automatically compensated to 25°C.

Calibrations are made using the zero and span (slope) screws on the minimonitor. Use the readings from the CR21 micrologger when calibrating, rather than the readings from the minimonitor. To increase a reading, turn the appropriate adjusting screw clockwise. The exception is for pH span; in this instance, the adjusting screw should be turned counterclockwise to increase the reading.

Ideally, the temperature probe should be calibrated every 3 months. Ideally, the pH and specific-conductance electrodes should be calibrated every week, or more often if substantial drift occurs. If a pH electrode will not maintain its calibration, call Michael M. Reddy (303) 236-3617.

Resistance Thermistor

The temperature measured by the Rosemont resistance thermistor and recorded on input channel 2 is that of precipitation in the flow cell. It may not be the actual temperature of the incident precipitation, but is our best estimate of the temperature of the precipitation as pH and specific conductance are being measured.

1. Carefully remove the resistance thermistor from the flow cell. Use padded pliers, do not use vice grips, as the thermistor will be crushed.
2. Insert the resistance thermistor into a beaker of iced water, with a mercury thermometer accurate to $\pm$ 0.1 °C.
3. Type *62A to display temperature, and turn the zero screw on the minimonitor until the display on the CR21 micrologger is the same as the mercury-thermometer reading.
4. Place thermometer and the thermistor into a beaker of warm water (30 to 40 °C) and adjust the span screw.
5. Repeat steps 3 and 4 until the calibration is within 0.2 °C.

pH Electrode

1. Check the filling-solution level and add solution, if necessary. Ensure that the electrode is not touching the sides of its containment cell and is 6.35 mm from the bottom.
2. Flush the cell with distilled water, then with pH 7 buffer. Type *64A, let the reading stabilize, record the reading using *DOA, and make a note on the paper tape.
3. Repeat step 2, but use pH 4 buffer instead.
4. Flush thoroughly with distilled water. You can check the thoroughness of flushing by typing *63A and measuring the specific conductance. For most purposes, when the reading remains at less than 3.0, the cell is flushed. Type *64A, let the distilled-water pH reading stabilize, record the reading, and make a note.
5. Check the calibration again using dilute, standard acid solutions, preferably 0.0001 N H_2SO_4 followed by 0.001 N H_2SO_4. This may seem like a lot of checking before the actual calibration begins, but it is a necessary quality-control procedure.
6. Flush thoroughly with distilled water and then with pH 7 buffer. Adjust the pH zero adjustment screw to give the correct reading. Read the label on the buffer bottle to see how the true pH changes with temperature. For example, if *62A reads 20 °C and the buffer bottle indicates the solution is pH 7.02 at 20 °C, adjust the reading to 7.02 instead of 7.00.
7. Flush thoroughly with distilled water, then with pH 4 buffer. Adjust the span (counter clockwise to give a larger reading) until the proper setting is obtained.
8. Repeat steps 6 and 7 until both readings are within 0.02 units of the expected (true) pH. Keep recording and making notes.
9. Flush thoroughly with distilled water twice, let the reading stabilize, and record.
10. Check with dilute, standard acid solutions or other solutions of known pH.
11. Always flush thoroughly with distilled water when finished.

Specific-Conductance Cell

As currently (1985) configured, the CR21 micrologger will not record a specific-conductance value larger than about 210 µS/cm. Although larger values will be displayed, they will be recorded as about 210 µS/cm. Because of KCl leakage from the pH electrode, the specific-conductance of water in the specific-conductance cell gradually will increase to more than

210 μS/cm. Although this water is flushed out rapidly, usually within the first 0.5 mm of precipitation, the water may cause an increased specific-conductance in the sample bottle. The specific-conductance of buffer solutions is very large, and always will be displayed as about 210 μS/cm.

1. Type *63A. Flush the cell with distilled water until a minimum reading is obtained. Record it.
2. Flush the cell with standard KCl solutions and record the readings. The readings stabilize rather quickly. Start recording the weakest solutions, progressing the strongest. Flushing with distilled water between these measurements is not necessary.
3. Note the specific-conductance readings recorded when you were checking the pH calibration with the dilute, H_2SO_4 solutions. Those numbers are useful as an additional check of specific conductance.
4. Flush thoroughly with distilled water, until a minimum reading is obtained. Then turn the zero screw until the reading is the same as the specific-conductance value of the distilled water when measured in the laboratory (normally 1.0 to 2.0 μS/cm). Record the specific-conductance value.
5. Flush with 0.001 N KCl. Adjust the span screw to obtain a reading of 147 and record it.
6. Repeat steps 4 and 5 until the readings are within 0.25 μS/cm for distilled water and are within 1 percent for the KCl standard solution.
7. Measure and record specific-conductance values of your standard KCl solutions, and any standard-acid solutions that have a pH greater than 3.
8. Flush thoroughly with distilled water and flush again.
9. Reconnect the sample bottle to the outlet from the probe package.

Hints for Calibration

1. Try turning the span screw (after you have adjusted the zero for whatever parameter you are calibrating) all the way down (decrease); turn conterclockwise (except for pH span, which you turn clockwise to decrease) until the reading on the CR21 micrologger for the parameter stays at a constant number.
2. Adjust the zero screw as previously instructed.
3. Turn span screw to increase toward the number expected to be the correct reading. If you turn the span screw to increase and you eventually get a constant reading on the CR21 micrologger that is larger than the reading in step 1, but it is not the correct reading, turn the span screw all the way back down (decrease) as in step 1.
4. Repeat the above steps and you should obtain an accurate calibration.

SUMMARY

Using the protocol outlined in this report, a site operator should be able to install, maintain, and calibrate the recording precipitation monitor. The data collected, including continuous measurements of precipitation volume, temperature, pH, and specific conductance will be utilized in the investigation of materials corrosion by wet precipitation.

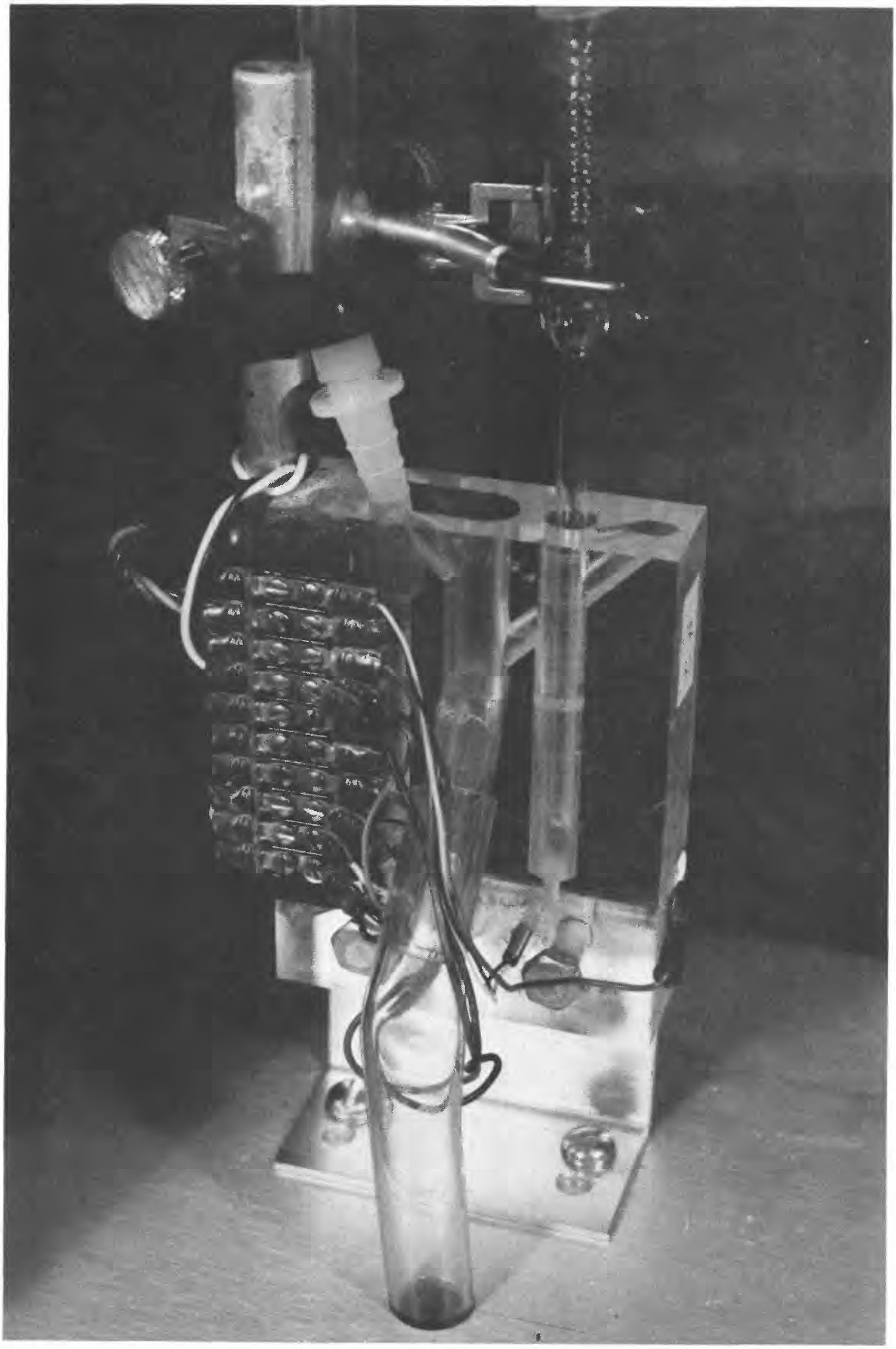
REFERENCES

Reddy, M.M., See, R.B., Liebermann, T.D., 1986, Water-sample protocol for precipitation collection: U.S. Geological Survey Open-File Report 86-405, 18 p.

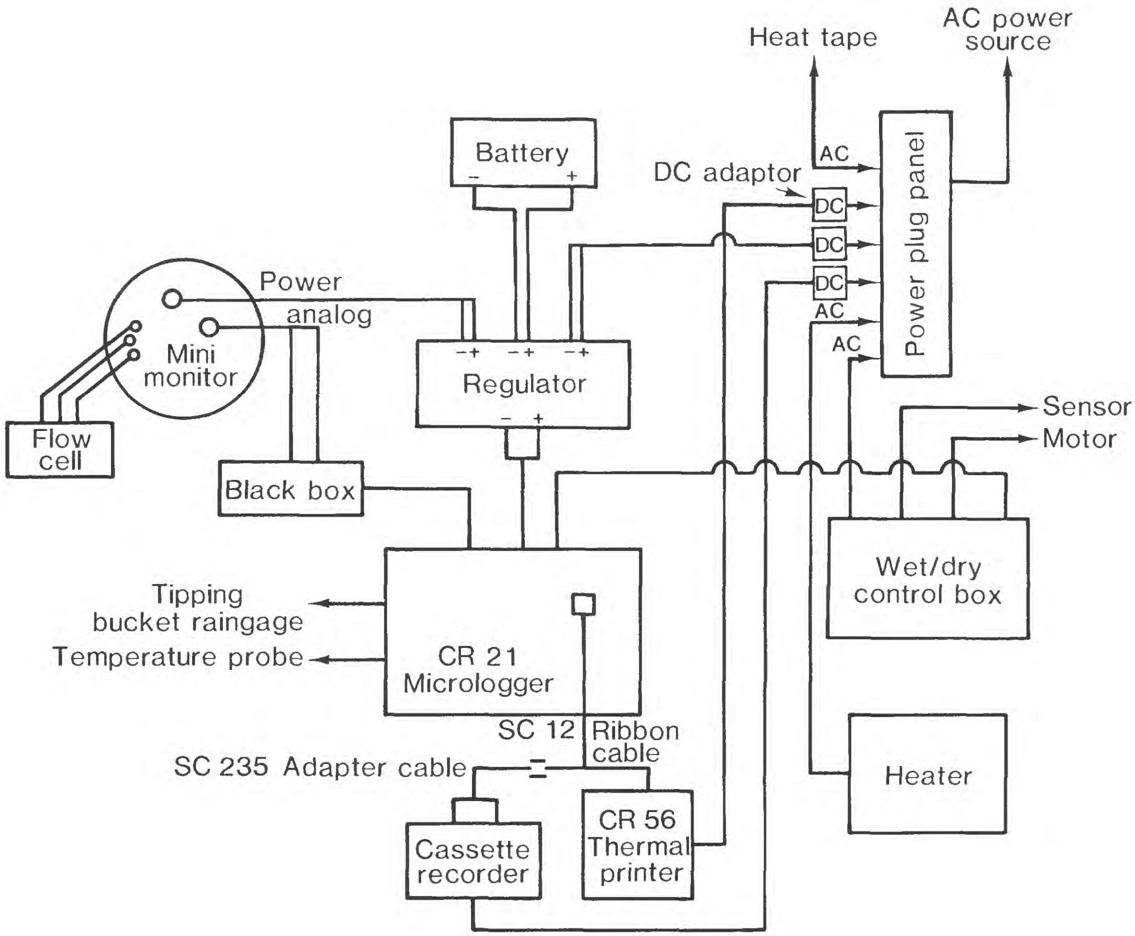
National Park Service, 1984, Acid rain site management plan for dimension stone: Washington, D.C., 34 p.

Attachment I-A.--Components of recording precipitation monitor, clockwise from upper left to lower left: tipping-bucket raingage wet collection bucket, dry collection bucket and cover, CR56 thermal printer (top), wet/dry collection control box (bottom), CR21 micrologger, U.S. Geological Survey minimonitor, and flow cell and instrument-probe package.

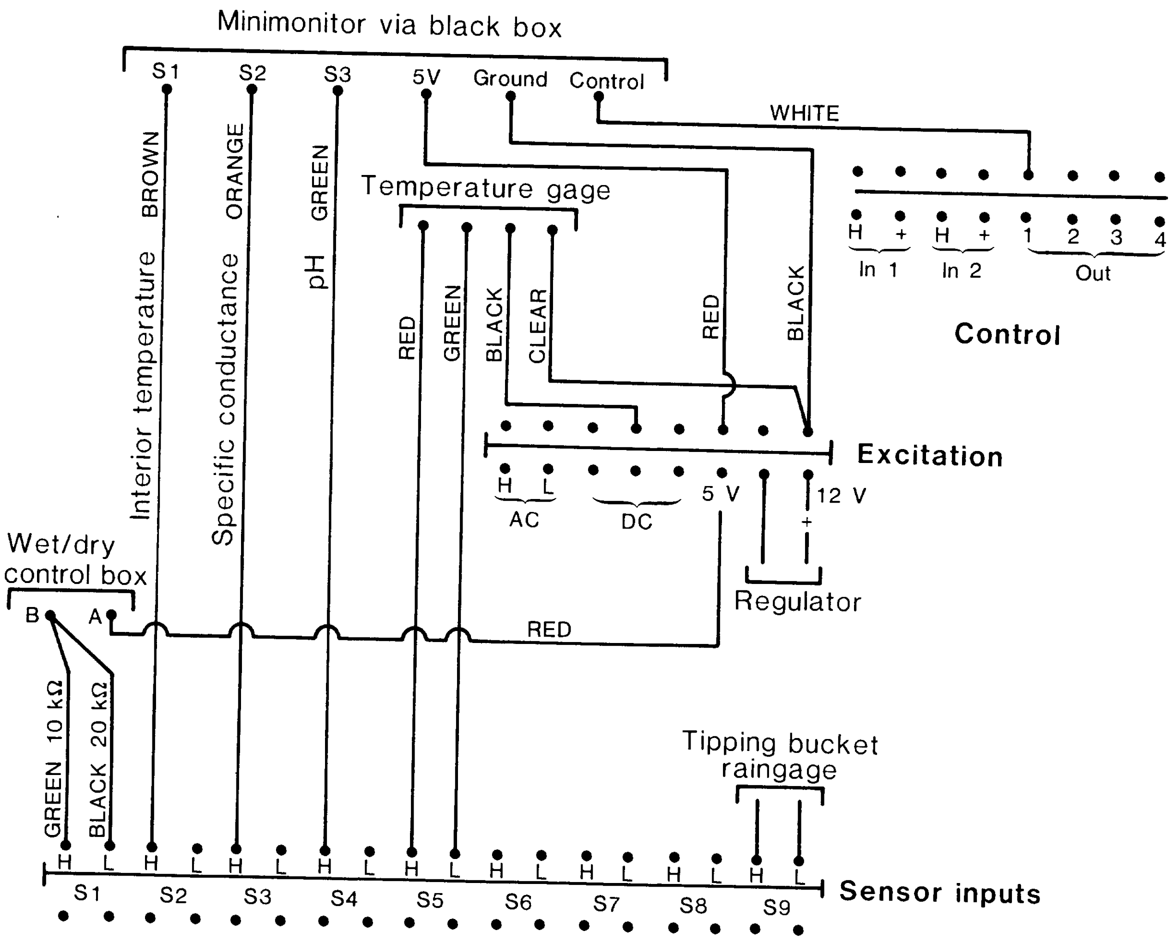
Attachment I-B.--Flow cell and instrument-probe package.



Attachment II-A.--General wiring diagram.



Attachment II-B.--Wiring diagram for CR21 micrologger.



Attachment III-A.--CR21 Input Table Coding Form

CR21 ID 3448 FMT II   Start Date Julian Day & Date   Start Time Military Time

NOTE: Select input program numbers from appendix A of the CR21 Operator's Manual. Specify a multiplier (a) and offset (b) for each sensor using the equation EU = aX + b to convert the sensor output (X) to engineering units. EU = Final Output Engineering Units. IU = Input Units e.g. volts (V), millivolts (MV), and counts.

Sensor Number		Sensor Description and Calibration	Range (EU)	Input Program	Program No.	Multiplier (EU/IU)	Final Output (EU) Offset (EU)
1	(V, MV, DC Resistance)	Wet/Dry Control Box	Dc, Volts		11: 1	12: 1	13: 0
2	(V, MV, DC Resistance)	Flow-Cell Temperature	DC, Volts	°C	21: 1	22: 25	23: 0
3	(V, MV, DC Resistance)	Specific Conductance	Dc, Volts	µS/cm	31: 1	32: 75	33: 0
4	(V, MV, DC Resistance)	pH	DC, Volts	Standard Units	41: 1	42: 5	43: 0
5	(V, MV, DC & AC Resistance)	Exterior Temperature	101 Temperature	Sensor °C	51: 7	52: 1	53: 0
6	(V, MV, DC & AC Resistance)				61:	62:	63:
7	(V, MV, DC & AC Resistance)				71:	72:	73:
8	Pulse counter (4095 counts per scan maximum)				81:	82:	83:
9	Pulse counter (15 counts per scan maximum)	Precipitation	Total Pulses		91: 6	92: 1	93: 0

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Attachment III-B.-- **CR21 Output Table Coding Form**

CR21 ID 3448, FMT II Start Date JD 57, 2-27-84 Start Time 1003

NOTE: Select output program number and parameters from appendix B of the CR21 Operator's Manual. Output ID numbers 1, 2 and 3 identify table number, day and time. ID numbers 4 and greater identify data generated by ouput programs. Only positive integers are used to program the output table.

Output Table Number (1, 2 or 3) 1 Output Time Interval (minutes) 03: 180 = baseline interval

Table Entry Number	Output Program and Data Description				Output ID No.
	Param 1 descrip.	Param 2 descrip.	Program No.	Parameter 1	Parameter 2
1	Water Sample Control Program #70				4
	12: Active State	Recording Interval	11: 70	12: 1	13: 0101
2	Active State Threshold (wet/dry relay)				
	0.5 Volt		21: 1	22: 0050	23: 0050
3	Disable Sediment-Sampler Control Port				
			31: 2	32: 0900	33: 1000
4	Disable Minimonitor Control Port				
			41: 0	42: 0900	43: 1000
5	Set the order of output				
			51: 0	52: 2345	53: 0
6	Precipitation tips				
			61: 69	62: 8	63: 1
7					
			71:	72:	73:
8					
			81:	82:	83:
9					
			91:	92:	93:

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Attachment III-C.-- CR21 Output Table Coding Form

CR21 ID 3448, FMT II Start Date JD 58, 2-27-84 Start Time 0946

NOTE: Select output program number and parameters from appendix B of the CR21 Operator's Manual. Output ID numbers 1, 2 and 3 identify table number, day and time. ID numbers 4 and greater identify data generated by ouput programs. Only positive integers are used to program the output table.

Output Table Number (1, 2 or 3) 2 Output Time Interval (minutes) 03: 1440

Table Entry Number	Output Program and Data Description					Output ID No.
	Param 1 descrip.	Param 2 descrip.	Program No.	Parameter 1	Parameter 2	
1	Total precipitation pulses from input channel 8					4
			11: 52	12: 9	13: 0	
2	53 = maximum value					
	2 = input channel 2		21: 53	22: 2	23: 1 - print tim of max. or mi	
3	54 = minimum value					
	2 = input channel	2	31: 54	32: 2	33: 1	
4	53 = maximum value					
	5 = input channel	5	41: 53	42: 5	43: 1	
5	54 = minimum value					
	5 = input channel	5	51: 54	52: 5	53: 1	
6						
			61:	62:	63:	
7						
			71:	72:	73:	
8						
			81:	82:	83:	
9						
			91:	92:	93:	

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Attachment IV.--Partial record of output from CR21 micrologger beginning at 0300 hours on julian day 203, 1985.

01+0001.	02+0203.	03+0300.	04+0.000	05+17.57	06+074.1	07+4.000	08+15.64
01+0001.	02+0203.	03+0600.	04+0.000	05+17.60	06+69.60	07+4.090	08+15.56
01+0001.	02+0203.	03+0900.	04+0.000	05+19.80	06+69.90	07+4.150	08+18.88
01+0001.	02+0203.	03+1200.	04+0.000	05+27.57	06+094.7	07+4.235	08+22.52
01+0001.	02+0203.	03+1500.	04+0.000	05+29.70	06+084.2	07+4.280	08+22.72
01+0001.	02+0203.	03+1800.	04+0.000	05+25.22	06+132.9	07+4.275	08+17.90
01+0001.	02+0203.	03+2100.	04+0.000	05+17.55	06+179.4	07+4.240	08+12.64
01+0001.	02+0203.	03+2400.	04+0.000	05+12.30	06+178.9	07+4.215	08+08.86
01+0002.	02+0.000	03+29.77	04+1518.	05+12.30	06+2400.	07+24.02	08+1350.
09+08.70	10+2306.						
01+0001.	02+0204.	03+0300.	04+0.000	05+11.60	06+178.8	07+4.220	08+10.53
01+0001.	02+0204.	03+0600.	04+0.000	05+12.25	06+178.9	07+4.235	08+10.94
01+0041.	02+0805.	03+1.979	04+13.35	05+179.0	06+4.245	07+11.79	
01+0041.	02+0806.	03+1.979	04+13.37	05+179.1	06+4.250	07+11.75	
01+0041.	02+0807.	03+1.979	04+13.37	05+179.0	06+4.245	07+11.70	
01+0041.	02+0808.	03+1.979	04+13.40	05+179.1	06+4.250	07+11.62	
01+0041.	02+0809.	03+1.979	04+13.40	05+179.0	06+4.245	07+11.58	
01+0041.	02+0810.	03+1.979	04+13.42	05+179.1	06+4.245	07+11.62	
01+0041.	02+0811.	03+1.979	04+13.42	05+179.1	06+4.245	07+11.66	
01+0249.	02+0811.	03+0001.					
01+0000.	02+0812.	03+0000.	04+13.42	05+179.1	06+4.245	07+11.65	08+0.000
09+0000.							

Key to micrologger tables:

01+0000 - display current sensor readings:
02 time 03 wet/dry control box voltage 04 flow-cell temperature 05 conductivity 06 pH 07 exterior temperature 08 not used 09 not used

01+0001 - baseline interval:
02 julian day 03 time 04 wet/dry control box voltage 05 flow-cell temperature 06 conductivity 07 pH 08 exterior temperature

01+0002 - daily summary:
02 total precipitation 03 maximum flow-cell temperature 04 time of maximum 05 minimum flow-cell temperature 06 time of minimum 07 maximum exterior temperature 08 time of maximum 09 minimum exterior temperature 10 time of minimum

01+0041 - active state:
02 time 03 wet/dry control box voltage 04 flow-cell temperature 05 conductivity 06 pH 07 exterior temperature

01+0249 - precipitation:
02 time 03 tips

Attachment V.--Site Observers Record Sheet

	Year
	Storm
	Sample Type
	Site
	Rack (1-8)
	Duplicate (1 or 2)
	Julian Day On
	Julian Day Off
	Volume Collected (mls)
	Overflow (Y or N)
	Rainfall (inches)
	Precipitation Type
	pH first measurement
	pH second measurement
	Specific Conductance first measurement µ s/cm
	Specific Conductance second measurement µ s/cm
	Filtered Volume (mL)
	Unfiltered Volume (mL)

Attachment VI.--Calibration record sheet

Site Name	Date	Julian Day
Date Of Last Check	Operator	

READINGS AT INITIAL CALIBRATION CHECK:

SOLUTION	TIME(02)	CELL TEMP(04)	CONDUCTIVITY(05)	PH(06)
Distilled water				
0.0001 N H_2SO_4				
0.001 N H_2SO_4				
0.0001 N KCl				
0.001 N KCl				
pH 7 buffer				
pH 4 buffer				

READINGS AFTER CALIBRATION ADJUSTMENTS:

SOLUTION	TIME(02)	CELL TEMP(04)	CONDUCTIVITY(05)	pH(06)
Distilled water				
0.0001 N H_2S04				
0.001 N H_2SO_4				
0.0001 N KCl				
0.001 N KCl				
pH 7 buffer				
pH 4 buffer				

Attachment VII.--Weekly checklist after completion of calibration.

Site____________________

Operator____________________

Date of check____________________

1. Activate the precipitation sensor with water, did the collection-bucket cover open properly?
   Y/N____________________

2. While the sensor is activated:
   slowly pour 50 mL of water into the tipping-bucket raingage. How many tips registered on the paper tape?
   ____

3. Type *8A on the CR21 micrologger and allow 30 seconds for transfer of information from the micrologger to the cassette tape. Remove the cassette tape and label it with date off. Install a new cassette tape labeled with site name, operator, and date on. Did you leave the cassette recorder in the record position?
   Y/N____________________

4. Remove the printed paper from the CR56 thermal printer and label it with date off and site. Label the new end with site name, operator, and date on; connect the new end to the uptake spool. Is there adequate paper for another week of operation?
   Y/N____________________

5. Are all power cords plugged in?
   Y/N____________________

6. Is the heater working properly and is the heater thermostat adjusted to the correct level?
   Y/N____________________

7. Are the minimonitor switches set to Hold, On, and Manual?
   Y/N____________________

8. Is the Goetech wet/dry control box set to On, and Auto?
   Y/N____________________

9. Are there any obstructions to the swinging counter-balance arm?
   Y/N____________________

10. Did you leave the CR21 micrologger in the *0 mode?
    Y/N____________________

11. Please send all samples, tapes, and forms immediately to:

Michael M. Reddy/Randolph B. See
Mail Stop 407
U.S. Geological Survey
5293 Ward Road
Arvada, Colorado 80002

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