Standard Operating Procedure
EAP011, Version 2.1

Instantaneous Measurements of Temperature in Water

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Purpose of this Document

The Washington State Department of Ecology develops Standard Operating Procedures (SOPs) to document agency practices related to sampling, field and laboratory analysis, and other aspects of the agency's technical operations.

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DEPARTMENT OF ECOLOGY
State of Washington

Environmental Assessment Program
Standard Operating Procedure EAP011
Version 2.1

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The Washington State Department of Ecology's (Ecology's) Standard Operating Procedures (SOPs) are adapted from published methods, or developed by in-house technical and administrative experts. Their primary purpose is for internal Ecology use, although sampling and administrative SOPs may have a wider utility. Our SOPs do not supplant official published methods. Distribution of these SOPs does not constitute an endorsement of a particular procedure or method.

Any reference to specific equipment, manufacturer, or supplies is for descriptive purposes only and does not constitute an endorsement of a particular product or service by the author or by Ecology.

Although Ecology follows the SOP in most instances, there may be instances in which Ecology uses an alternative methodology, procedure, or process.

SOP Revision History

Revision Date	Revision History	Summary of Changes	Sections	Reviser(s)
3/26/2015	1.1	• Rewrote throughout for generic meter usage and updated the equipment list. • Minor edits and updates to definitions, supplies, and sampling procedures. • Inserted additional methods and requirements for temperature calibration checks. Minor formatting edits throughout the document.	Introduction, 3.13, 5.14, 5.15, 5.2.7, 5.2.8, 6.2, 6.6, and 8.1.1 to 8.1.13.	Dan Dugger
7/30/2015	1.2	Made minor updates to all sections to make document similar to current versions. Revised and inserted new definitions. Added more detail on long-line thermistors, QC checks, and correction factor determinations.	All	Bill Ward
1/4/2019	2.0	• Minor edits to section order, formatting, passive voice, and general Ecology usage throughout. • Updated instruments and procedures. • Added and updated definitions. • Added procedures for creating calibration baths. • Updated field-sampling procedures .Formatting and accessibility updates	All	Dan Dugger Bill Ward, Ruth Froese
2/8/2022	2.1	• Updated references. • Minor edits for clarity. • Corrected typographical errors. • Reduced minimum number of constant temperature test-baths to two (instead of three). • Generalized language regarding wait times for thermometer stabilization. • Updated equipment list. • Added quality control steps as part of the main procedure.	All	Dan Dugger, Evan Newell

1.0 Purpose and Scope

1.1 This Standard Operating Procedure (SOP) details the methods used by the Dept. of Ecology's Environmental Assessment Program (EAP) for instantaneous measurements of water temperature. It may also contain methods that other entities would find useful for their monitoring work.

1.2 Surface water temperature fluctuates greatly with daily, seasonal, geographical, and environmental influences. Human influences, via point source discharge, non-point sources, stormwater, streamside vegetative alterations, and stream morphology changes, may affect water temperatures.

1.3 The Environmental Assessment Program (EAP) determines our range of interest for surface-water temperatures from project needs and state and federal criteria (Payne, 2011, Ecology, 2019).

1.4 In the past, the EAP has used many types of thermometers to measure surface-water temperatures. EAP staff now only use thermistors and alcohol thermometers for field measurements. These instruments are safe and sensitive within the common range of interest (0°-30°C). Due to potential environmental and health hazards, EAP staff no longer use mercury thermometers in the field. However, staff at the Headquarters EAP Operations Center still use a NIST-certified mercury thermometer to verify the accuracy of the lab thermistors used at Ecology offices to confirm field thermometers.

1.5 Some available thermometers may lack measurement sensitivity for the range of interest. Always check a thermometer's manufacturer specifications before choosing them for the project.

1.6 Several other water-quality measurement instruments with built-in thermistors may be used to measure temperature. These include pH, dissolved oxygen, conductivity electrodes, and multi-probe sondes. However, always verify that instrument specifications meet the project sensitivity needs before using them.

1.7 Devices used to collect continuous temperature measurements, including the TidbiT v2 Water Temperature Data Loggers®, are covered in the Continuous Temperature SOP (Ward, 2018) and the Continuous Temperature Monitoring of Freshwater Rivers and Streams Conducted in a Total Maximum Daily Load SOP (Bilhimer and Stohr, 2019).

2.0 Applicability

2.1 This SOP applies to EAP staff conducting surface-water temperature measurements using thermistors and alcohol thermometers.

2.2 Follow this SOP when making an instantaneous (discrete) measurement of temperature in surface waters. For continuous measurements of temperature, refer to the SOPs EAP044 (Bilhimer and Stohr, 2019) and EAP080 (Ward, 2018).

3.0 Definitions

3.1 Digital Thermometers (including thermistors and others) provide a display for reading temperature and may record temperature values over time. Please see Table 1 and reference the Hydrolab and Continuous Temperature SOPs for more information (Anderson, 2020 and Ward, 2018).

3.1.1 *Resistance thermometer* or *Resistive Temperature Detector (RTD)* – determine temperature from resistance of a glass or ceramic rod wound with metallic (platinum, copper, or nickel) wire or filament. RTDs are more accurate than thermocouples up to 600 ºC, but less accurate than thermistors at surface water temperatures. RTDs are more expensive and fragile than thermistors or thermocouples.

3.1.2 *Thermistor* – (thermal resistor) is a type of semiconductor that varies in resistance in a predictable way as temperature changes. Thermistor semiconductor materials vary. Thermistor software converts resistance values non-linearly to a linear temperature scale. Thermistors are durable, inexpensive, and precise at surface water temperatures.

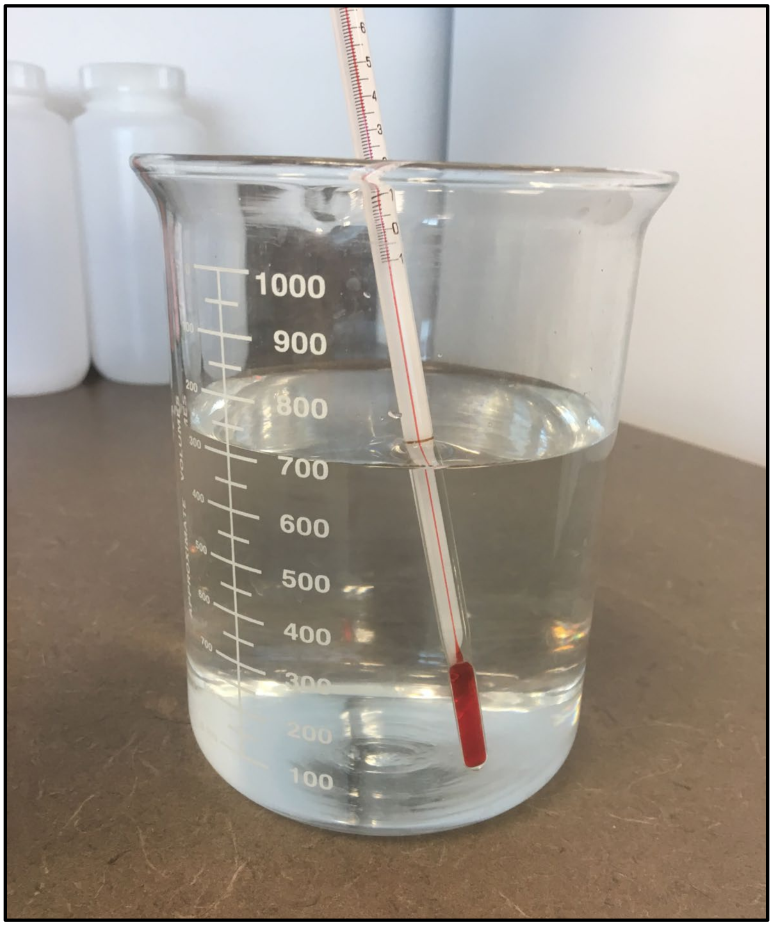
3.1.3 *Thermocouple* – consists of two dissimilar and connected conductors that determine temperature based on the circuit voltage change from a reference temperature. Thermocouples operate well at high temperatures above 600 ºC, but are less accurate at surface water temperatures.

3.2 Liquid-In-Glass Thermometers – A thermometer made from a graduated glass stem with an internal hollow column and bulb containing a liquid that expands and contracts with temperature (McGee, 1988). They should be in a protective case for fieldwork, to help prevent breakage (Figures 1 and 2).

3.2.1 *Alcohol Thermometer* - These thermometers use colored alcohol as a safe alternative to mercury. They may be slightly less accurate, but they release no hazardous substance if they break. A downside to alcohol thermometers is that air gaps can form in the liquid. You can prevent air gap formation by storing the thermometer bulb end down in a cool location[1].

3.2.2 *Mercury Thermometer* – Mercury thermometers are liquid-in-glass thermometers, which can be very accurate, but should only be used in the lab. They are not for field use, because they can easily break and release mercury, a hazardous substance, to the environment. See also Section 9: Safety.

[1] Before use, check a liquid-filled thermometer for air gaps to ensure it reads accurately. If it has gaps, then chill or gently heat it to help purge the air at the bulb or the top end. You can give the thermometer to the Operations Center technician for possible repair. If these remedies fail, do not use the thermometer.



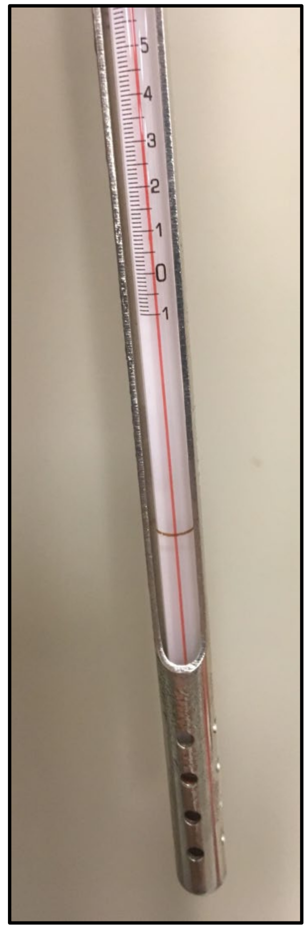


Figure 1. Left: A partial immersion alcohol (liquid in glass) thermometer immersed in water to the immersion line, below the incremental temperature marks on the stem and above the alcohol filled bulb. Photo by Dan Dugger.

Figure 2. Right: A partial immersion alcohol (liquid in glass) thermometer in a protective metal sheath, with an open window for reading the temperature marks, and bulb holes to allow exposure to water. The horizontal line is the immersion line (see 3.2.3). Photo by Dan Dugger.

3.2.3 *Partial-Immersion Thermometer* – These thermometers have an immersion line around it below the lowest value increment. It measures correctly with the bulb and the liquid column immersed in the sample to that line (Figure 1).

3.2.4 *Total Immersion Thermometer* – These thermometers measure temperature correctly when you expose the bulb and the entire liquid column to the sample temperature (except for a minimal emergent length for handling).

3.3 NIST Certified Thermometer - A thermometer certified according to procedures outlined by the National Institute of Science and Technology (NIST). Calibration services should send a calibration certificate with any newly certified NIST thermometer. EAP prefers a NIST certified calibration range of 0 to 50 °C, with six check intervals in 10 °C increments, and ≤0.1 °C resolution for water temperature measurement. Recertify NIST Certified Thermometers at least once per year. If the NIST certified thermometer diverges from the NIST reference temperature by more than +/-0.1 °C at any of the 0, 10, 20, or 30 °C check intervals, replace the thermometer. Refer to section 8: Quality Control and Quality Assurance for details.

3.4 NIST Traceable Thermometer – Any thermometer with a calibration check record kept in reference to a NIST Certified Thermometer. Check NIST Traceable Thermometers against a NIST Certified Thermometer at least annually, or any time you suspect the thermometer is drifting. Calibration checks at both near freezing and room temperatures (or higher) should be done to bracket the expected stream water temperatures to be measured. Refer to section 8: Quality Control and Quality Assurance for details.

3.5 Thermometer – A temperature-measuring instrument. Types include Liquid-In-Glass Thermometers, Thermistors, and many others. Thermometer ranges and sensitivity depend on their materials, construction, and calibration. See sections 3.1 to 3.4 for descriptions.

3.6 Water Temperature - The amount of heat present in water (°C). This is a key parameter that can greatly affect aquatic ecosystems. It will influence the physiological and behavioral processes of most aquatic organisms and is associated with dissolved oxygen saturation, conductivity, pH, alkalinity, and other water parameters.

4.0 Personnel Qualifications/Responsibilities

4.1 Field operations require training specified in EAP's Field Safety Manual (EAP, 2019) such as First Aid, CPR, and Defensive Driving.

4.2 Typical Job Class performing SOP: Natural Resource Scientist 1/2/3, Environmental Engineer 1/2/3/4/5, Environmental Specialist 1/2/3/4/5, Administrative Intern 1/2/3, Hydrogeologist 1/2/3/4 and Hydrologist 1/2/3/4.

5.0 Equipment, Reagents, and Supplies

5.1 NIST certified thermometer or NIST-traceable thermistor for quality control checks (with a 0.1 °C readable scale).

5.2 Field Thermometer - Use a digital thermometer with a thermistor, an alcohol thermometer, or a water quality meter with a thermistor (See Table 1 below for accuracy examples). Note: The investigator should make sure that the instrument accuracy meets their project requirements. For measurements in lakes, use a sonde with a depth sensor.

Table 1. Example Temperature specifications for select field meters.

Model	Manufacturer Specifications	
	Accuracy (°C)	**Range (°C)**
Oakton® Acorn Temp 4 / 5 Meter with long line probe	±0.2	-40 to 125
Hach Hydrolab DataSonde™ or MiniSonde™	±0.1	-5 to 50
Hach HQ40d with IntelliCAL™ LDO101 dissolved oxygen probe	±0.3	0 to 50
Hach HQ40d with IntelliCAL™ CDC401 conductivity probe	±0.3	-10 to 110
Orion Star™ A329 Portable Multiparameter Meter	±0.1	-5 to 105
YSI ProDSS™	±0.2	-5 to 70
Digi-Sense™ Temp-14 Single-Input Thermistor Thermometer	±0.2	-40 to 125

5.3 Field notebook (preferably with waterproof paper) or an electronic field notebook (smartphone, tablet, etc.)

5.4 Writing utensil (pen/pencil) if using paper

5.5 Batteries for thermistor

5.6 GPS unit if location measurements (latitude/longitude) are required, such as for temperature measurements in lakes.

6.0 Summary of Procedure

6.1 Perform quality control on the field thermometer, using a NIST-certified or NIST-traceable thermometer, at intervals determined for your specific project (see section 8 below).

6.2 Select a safe representative area of the water body to measure the temperature directly with the field thermometer.

6.2.1 In moving water measure the sample in well-mixed main flow away from the influence of tributaries, eddies, and backwaters.

6.2.2 Lake depth temperature measurements require a thermistor on a sonde with an attached depth sensor. Record the:

6.2.2.1 Sensor depth to the nearest 0.1 meter.

6.2.2.2 Latitude and longitude with projection.

6.3 Allow the immersed field thermometer to equilibrate to a stable temperature reading. The amount of time required to equilibrate will depend on the type of thermometer. For liquid in glass thermometers, you may need to wait several minutes to get a stable reading. For digital thermometers, equilibration will likely happen much more quickly.

6.4 Read and record temperature in degrees centigrade (°C), along with ancillary information such as project name, site, date, and time.

6.5 If temperature readings are unstable (which can occur in lakes or poorly mixed streams), take multiple readings at representative time intervals.

6.6 Complete quality control on the field thermometer, at intervals determined for your project (see section 8 below).

7.0 Records Management

7.1 Enter recorded temperature data in the appropriate database for the Ecology-conducted field project and into Ecology's Environmental Information Management database (EIM).

7.2 Document any adjustments (corrections) applied to the temperature data. For entry into EIM, qualify any calibration check-adjusted temperature data as 'IA' (Instrument result adjusted; reported result meets study objectives) and note this qualification in the project report. (See section 8.3 Temperature Correction for the temperature adjustment procedure.)

8.0 Quality Control and Quality Assurance

8.1 Annual or Project Calibration Checks

8.1.1 Check the accuracy of all field thermometers at the beginning and end of a project, or at least annually with a NIST traceable thermometer or thermistor[2]. Retest the thermometer and do not use it if it fails to meet the manufacturers or project accuracy requirements. *Note: for projects involving deployment of continuous temperature loggers, you can follow the calibration check methods noted in EAP080 (Ward, 2018).*

8.1.2 Perform calibration checks at a minimum of two test-bath temperatures (0 °C and room temperature). These two temperatures typically bracket the range of interest to verify field thermometer accuracy. You may perform additional temperature checks as needed to verify accuracy (for example at 10°, 15°, and/or 25 °C). Appendix A provides example methods for preparing test-baths.

8.1.3 Keep the test-baths at a constant temperature to obtain consistent test results. Often this requires a minimum volume of at least five gallons of water per insulated cooler (smaller water volumes are okay for room temperature baths). Note: Allow the room temperature water bath to match room temperature for several hours before the calibration check (preferably overnight).

8.1.4 Allow both the field and NIST traceable thermometers to equilibrate in the test bath, until the temperature readings are stable. The amount of time required to equilibrate will depend on the type of thermometer. Liquid in glass thermometers require longer stabilization times.

8.1.5 Once the thermometer readings are stable, record the temperatures from both the field and NIST traceable thermometers in each bath.

8.1.6 Based on the results of these checks, determine if any field thermometers need correction factors (optional). See sub-section 8.3 for correction factor information.

8.2 Monthly (or Weekly) Field Thermometer Calibration Checks

8.2.1 In the Ambient Monitoring Project, a one-point room-temperature water-bath calibration check is conducted for long-line thermistors before and after each monthly sampling run. Other projects may do this to document the accuracy of their thermistors over time.

8.2.2 During use, long-line thermistor cables (some are 150 feet long) may develop hidden damage that can change the wire/meter connection resistance and affect the calibration accuracy[3].

8.2.3 This test procedure is the same as noted in section 8.1.2 above, except there is just a one point check done near 20 °C.

8.2.4 If the results indicate that the long-line thermistor calibration accuracy changed more than 0.3°C from the expected test temperature, then use another instrument until we replace the long-line cable and determine a new correction factor.

8.3 Temperature Bias Correction (optional)

8.3.1 The NIST certified and field thermometer comparisons determined from procedure 8.1.2 above may be used to create a correction factor to adjust the field thermometer results (see example results in Table 2 below). Note: this method is required for all our Ambient Monitoring Program long-line thermistors. *This procedure may be used for other monitoring projects to improve the accuracy of the field-thermometer measurements.*

Table 2. Example NIST Traceable and Field Thermometer unadjusted comparison.

Meter	Ice bath Temperature (℃)	Mid-Range Temperature (℃)	Room Temperature (℃)
NIST Traceable Thermometer (Rt)	0.3	10.1	20
Field Thermometer (Ft)	0.2	9.9	19.8
Meter Difference (Rt – Ft)	0.1	0.2	0.2
Intercept (a)	0.116		
Slope (b)	1.005		

8.3.2 Example calculation of correction factors: Calculate the temperature correction for the Field thermistor (Ft) in Table 2 by computing the intercept (a) and slope (b) of the Ft temperature readings against the NIST Traceable Thermometer (Rt) temperature readings.

8.3.2.1 In a spreadsheet[4], copy Table 2 starting from cell A1 (Column A, Row 1), as shown in Table 3.

8.3.2.2 In the spreadsheet, to calculate the Intercept, in cell B5 (Column B, Row 5) enter the formula “=INTERCEPT(B2:D2,B3:D3)”, and to calculate the Slope, in cell B6 (Column B, Row 6) enter the formula “=SLOPE(B2:D2,B3:D3)”.

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[2] EAP annually sends the accurate mercury-filled NIST certified reference thermometer, kept at the Lacey Operations Center, to a certified testing laboratory for a multi-point calibration check. EAP then uses it to confirm the accuracy of our regional NIST traceable thermometers. This avoids the expense of sending all the thermometers in to the certified testing laboratory.

[3] The most common cause for long-line thermistor damage is torsion, from the electrode snagging in the stream or stretching during retrieval. This can allow water to enter the insulated wire or fracture the wire and change the electrode accuracy.

[4] Note: Common spreadsheet programs (e.g. Microsoft® Excel or LibreOffice Calc) have SLOPE and INTERCEPT functions for this calculation.

Table 3. Correction factor calculation showing the underlying spreadsheet calculations for the Table 2 example.

	Column A	Column B	Column C	Column D
Row 1	**Meter**	**Ice bath Temperature (℃)**	**Mid-Range Temperature (℃)**	**Room Temperature (℃)**
Row 2	NIST Traceable Thermometer (Rt)	0.3	10.1	20
Row 3	Field Thermometer (Ft)	0.2	9.9	19.8
Row 4	Meter Difference (Rt – Ft)	0.1	0.2	0.2
Row 5	Intercept (a)	=INTERCEPT(B2:D2,B3:D3)		
Row 6	Slope (b)	=SLOPE(B2:D2,B3:D3)		

8.3.2.3 Calculate the field thermometer adjustment to correct the field results (see the Table 4 example below). The adjusted (corrected) temperature of the Field thermistor (Ft) for this example is calculated as 0.116 + 1.005 * Ft.

Table 4. Linearly adjusted field thermometer temperatures for the above example.

Site Location Example	Field Thermometer (Ft) Measured Temperature (°C)	Adjusted (Corrected) Temperature (°C)
Headwaters	9.0	9.2
Warm springs	15.7	15.9
Glacial stream	5.1	5.2
Large tributary confluence	11.3	11.5
Below confluence	12.1	12.3

9.0 Safety

9.1 Select an area in which you will be safe and secure from both water and land hazards when measuring water temperature.

9.2 Ecology does not use mercury thermometers to measure surface and ground water, due to their potential environmental impact hazard if they break. Safely collect and dispose of broken mercury thermometer waste at a hazardous waste disposal facility.

9.3 For further field health and safety measures, please refer to the EAP safety manual (EAP, 2019).

10.0 References

10.1 Anderson, P. 2020. Standard Operating Procedures for Hydrolab® DataSonde®, MiniSonde®, and HL4 Multiprobes. Washington State Department of Ecology, SOP EAP033, Version 2.2. https://apps.ecology.wa.gov/publications/SummaryPages/2003201.html

10.2 Bilhimer, D. and A. Stohr., 2019. Standard Operating Procedures for Collecting Data to Support a Temperature Total Maximum Daily Load (TMDL) Study. Washington State Department of Ecology, SOP EAP044, Version 4.0. https://apps.ecology.wa.gov/publications/SummaryPages/1903219.html

10.3 Ecology. 2019. Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC. Revised December 2019. Washington State Department of Ecology, Water Quality Program, Publication Number 06-10-091. https://apps.ecology.wa.gov/publications/summarypages/0610091.html

10.4 Environmental Assessment Program, 2019. Environmental Assessment Program Safety Manual. March 2019. Washington State Department of Ecology. Olympia, WA.

10.5 McGee, T.D. 1988. Principles and Methods of Temperature Measurement. Materials Science and Engineering Department, Iowa State University, Arnes, Iowa. John Wiley & Sons, Inc. New York.

10.6 Payne, S. 2011. Waters Requiring Supplemental Spawning and Incubation Protection for Salmonid Species. Washington State Department of Ecology, Water Quality Program, Publication Number 06-10-038. https://apps.ecology.wa.gov/publications/SummaryPages/0610038.html

10.7 Ward, W. 2018. Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams. Washington State Department of Ecology, SOP Number, EAP080, Version 2.1. https://apps.ecology.wa.gov/publications/SummaryPages/1803205.html

11.0 Appendix

Example test bath temperature methods; also consider the test bath methods in EAP080 (Ward, 2018). To ensure a uniform temperature, gently stir the bath or use an aquarium pump, as described below.

11.1 Aquarium Pump Method for mixing the water in the temperature baths:

11.1.1 Place an aquarium pump, with outlet tubing attached, in the cooler at one end. Extend the outlet tubing to the other end of the cooler ice. **CAUTION: DANGER OF ELECTRIC SHOCK: Use a ground fault circuit interrupter (GFCI) plug for 120-volt outlet-powered pumps. Keep the area near the plug dry. See section 9.3.**

11.1.2 Turn the pump on.

11.1.3 Wait 5 minutes for the bath to stabilize.

11.1.4 Place thermometers directly between the inlet and outlet of the aquarium pump, at least 6 inches away from each, to minimize local temperature biases at these points.

11.2 Room-temperature (~20 °C) temperature bath method:

11.2.1 Equipment:

11.2.1.1 12-gallon (or similarly sized) portable cooler

11.2.1.2 Water

11.2.2 Procedure

11.2.2.1 Fill the portable cooler about 50% with tap water.

11.2.2.2 Leave the cooler with the lid open in a room temperature (~22 °C) room for several hours, preferably overnight.

11.2.2.3 Close the doors to the room to ensure stable temperatures during measurement.

11.2.2.4 To mix the water, gently stir the bath or use an aquarium pump (see 11.1).

11.2.2.5 Take several measurements over a few minutes to ensure there is a stable relationship between the NIST and field thermometer readings.

11.2.2.6 Record the stable readings.

11.3 Cold bath preparation (Option 1) using a walk-in refrigerator:

11.3.1 Equipment:

11.3.1.1 12-gallon (or similarly sized) portable cooler

11.3.1.2 Water

11.3.1.3 Walk-in refrigerator

11.3.2 Procedure

11.3.2.1 Fill the portable cooler about 50% with tap water.

11.3.2.2 Leave the portable cooler in a walk-in refrigerator set to low temperature (0.1 °C to 4 °C) for several hours, preferably overnight.

11.3.2.3 Close the doors to the walk-in refrigerator to ensure stable temperatures during measurement.

11.3.2.4 To mix the water, gently stir the bath, or use an aquarium pump. See the procedure in 11.1.

11.3.2.5 Take several measurements over a few minutes to ensure there is a stable relationship between the NIST and field thermometer readings.

11.3.2.6 Record the stable readings.

11.4 Cold bath preparation (Option 2) using water ice and an aquarium pump. **Warning: Freezing temperatures damage certain water-quality probes.** For these probes, conduct the calibration check in an ice-free bath.

11.4.1 Protect the probes from freezing temperatures by either:

11.4.1.1 Remove the water ice from the bath, and immediately place the probes in the bath for equilibration, or

11.4.1.2 Install a barrier in the bath to prevent the ice from touching the probes.

11.4.2 Equipment

11.4.2.1 12-gallon (or similarly sized) portable cooler

11.4.2.2 Water

11.4.2.3 Water ice

11.4.2.4 Aquarium pump

11.4.2.5 3 feet of pump outlet tubing

11.4.2.6 Power source for aquarium pump

11.4.2.7 Optional barrier for freeze sensitive probes

11.4.3 Procedure

11.4.3.1 Fill the portable cooler about 50% with water ice.

11.4.3.2 Add tap water until the top layer of water ice is half-immersed in the liquid water.

11.4.3.3 To cycle the water, gently stir the bath, or use an aquarium pump. See the procedure in 11.1.

11.4.3.4 Take several measurements over a few minutes to ensure there is a stable relationship between the NIST and field thermometer readings.

11.4.3.5 Record the stable readings.

11.5 Mid-range temperature bath preparation

11.5.1 Equipment

11.5.1.1 12-gallon (or similarly sized) portable cooler

11.5.1.2 Water

11.5.1.3 Water ice

11.5.2 Procedure

11.5.2.1 Reduce the volume of your room temperature bath to 3 gallons.

11.5.2.2 In a room-temperature room, add at least 3 gallons of water from a cold bath until the water temperature is near 8 ℃.

11.5.2.3 Place thermometers in the bath for at least 5 minutes. The bath temperature will increase to about 10 ℃.

11.5.2.4 Gently stir the water.

11.5.2.5 Take several measurements over a few minutes to ensure there is a stable relationship between the NIST and field thermometer readings.

11.5.2.6 Record the stable readings.

11.6 Always use caution to prevent electric shock when operating meters or pumps in or near water. Use GFCI power plugs for any waterproof instruments with outlet power.