# DQM Standard Operating Procedure (SOP) 3.1.3.1 (V3)

By Revital Katznelson, Ph.D.

## Measurement of Electrical Conductivity Using a Pocket Meter

*(This paragraph is common to all DQM SOPs. If you have seen it already, please skip to Section 1 below).* This is a new type of guidance, created as part of the Data Quality Management (DQM) System implemented by the Clean Water Team (CWT) to support collection of reliable data of known quality in a fully documented, scientifically defensible manner.

### 1.0 Overview

These instructions describe how to measure conductivity using the battery-operated pocket meters manufactured by Oakton (and sold by numerous vendors) as the TDSTestr series or the EC-Testr series. Please refer to IP-3.1.3(EC), available with the Clean Water Team, for background information on total dissolved solids (TDS) and conductivity; this will explain the relationship between the term “TDS” in the product name and the output of these meters in conductivity reporting units, microsiemen or milisiemen. The reader is encouraged to select instruments that report in microsiemen. The TDSTestr3 model (recently renamed EC-Testr Low) provides for the range of 10 to 1990 microsiemen, and the range of the TDSTestr4 (now called EC-Testr High) is 0.1 to 19.90 milisiemen. Both are available in a waterproof model. If you anticipate monitoring water bodies with very little salts (e.g., waters dominated by rainwater or snowmelt), look for the more sensitive meters, e.g. those that have a resolution of 1 uS and a range of 1-200 uS. The old models had a screw for manual calibration, while some of the new models have arrow-buttons for manual calibration or an automatic calibration feature. All pocket meters of the TDSTestr series have a built-in automatic temperature compensation (ATC) device. Other TDS or EC meters may have minute differences in the appearance but the procedures and record keeping steps are probably identical.

*(This paragraph is common to all Instrument-specific DQM-SOPs).* The sections of this SOP are organized as follows: Equipment list, maintenance and storage, calibration and record keeping, conductivity measurement, monitoring tips, and detailed guidance on how to control, check, record, and report (CCRR) the accuracy and the precision of the measurements. Relevant definitions as well as contact information are provided at the end of this SOP. In must be noted that there are many other SOPs, available from different organizations, which also provide instructions for the use of pocket conductivity meters. However, the

objective of this particular SOP is to provide a new type of guidance as part of the Data Quality Management (DQM) System implemented by the Clean Water Team (CWT) of the State Water Resources Control Board. It provides guidance at the level of detail and specificity that will allow users to generate reliable data of known quality in a fully documented, scientifically defensible manner.

## 2.0 Equipment List

Apart from this SOP and the Pocket Meter itself, you will need the following:

1. Calibrator Standard
2. a small (1-oz) cup for Standard
3. a medium (9-oz) cup for sample solution
4. “Distilled water” in a squirt bottle
5. Liquid Waste Container, a wide-mouth jar for rinse water and used Calibration Standard
6. “Field Data Sheet for Water Quality Monitoring”
7. “Calibration and Accuracy Checks Sheet”.

The "distilled water" referred to in the instruction is sold in supermarkets as "distilled water", "deionized water", "purified water", or "drinking water”, and these are normally prepared by ion-exchange resins or reverse osmosis. The essential feature is zero conductivity and lack of contaminants.

## 3.0 Maintenance and Storage

The conductivity pocket meters are low-maintenance devices and can be stored dry. If the electrodes show a visible layer of covering material, clean them with solution as recommended per manufacturer instructions.

## 4.0 Calibration and Record Keeping

The temperature of the Calibrator Standard during calibration is very important, because conductivity is highly dependent on temperature. Your Calibrator Standard shows the conductivity value your instrument should be adjusted to at a specified temperature, usually 25 C. Even if you have the automatic temperature compensation (ATC) feature, calibrate your meter at 25 C (see instructions below). When you calibrate your instrument, use a copy of the “DQM Calibration and Accuracy Checks Sheet” provided with this SOP or by your technical liaison: this form has placeholders (“fields”) for all the documentation you will need to provide, and is essentially identical to the spreadsheet table in your Excel Project File. The recommended procedure for calibration of the manually-calibrated model involves the following steps:

**Step C1:** Enter the date, time, Instrument ID, Calibrator Standard ID, and other relevant information into your "DQM Calibration and Accuracy Checks Sheet".

**Step C2:** Pour about 15 ml of the Calibrator Standard into a small (1-oz) plastic cup and heat it in your hands, checking the temperature continuously until it reaches 25 C.

**Step C3:** Rinse the tip of your conductivity meter with DI and gently shake off the excess DI. Dip the conductivity meter in the warmed Calibrator Standard solution and record the reading value prior to calibration on your "DQM Calibration and Accuracy Checks Sheet".

**Step C4:** If the reading is more than 20 microS from the specified (theoretical) Calibrator Standard value (for the Testr3 model), hold the instrument inside the Calibrator Standard solution in its cup **without touching the cup itself** and turn the calibration screw with a tiny screwdriver until the reading is the closest you can get to the standard (it will probably fluctuate by 10 microS back and forth – we have to live with that). **Caution! Do not turn the screw more than a fraction of a circle at a time, and watch the response**. In other words, do not lose the calibration "thingie" that is held by the calibration screw (as sometimes happens when people turn the screw too much, the "thingie" falls off the screw, and gets lost inside the instrument). If you have a newer model with calibration arrow buttons, use those to adjust the reading up or down while the instrument is in the solution, at 25 C, and is not touching the cup itself.

**Step C5**: If you have made any adjustments, enter "manual cal" in the "Action" field on your "DQM Calibration and Accuracy Checks Sheet", and record the reading after calibration in the appropriate field. If the result showed the theoretical value of your Calibration Standard, and you did not adjust the screw, write "none" in the "Action" field.

**Step C6**: Rinse the tip of your conductivity meter thoroughly with DI and gently shake off the excess DI.

Note: If your instrument has automatic calibration, make sure that the **Calibrator Standard used is the correct one as specified by the manufacturer** (and if it is not specified in the manufacturer's instructions, do not use the instrument). As in the case of manual adjustment, always use Calibrator Standard at 25 C (even if the manufacturer's instructions do not tell you to). Keep all records in the relevant fields of the "DQM Calibration and Accuracy Checks Sheet" as instructed above (in steps C1, 2,3) for the manual calibration. In the "action" field, write "none" if you have not adjusted the reading and skip the next field; or "auto cal" if you have used the automatic calibration feature (and be sure to enter the theoretical value of the Calibrator Standard you have used in the appropriate field).

## 5.0 Conductivity measurements

Step 5.1 Pour some of your water sample into a small clean container. If your meter is not the waterproof model, fill container with enough sample liquid to submerge 1" of the tip (not more).

Step 5.2 Record the Instrument ID which is written on your meter in the appropriate field, in the conductivity row on the "DQM Field Data Sheet for Water Quality Monitoring"

Step 5.3 Remove the conductivity meter protective cap. Turn the meter on, and dip the electrode into sample solution. Do not wet above the cap line! Watch for the flashing range indications and the units on the display panel.

Step 5.4 Stir gently every few seconds, until the readings stabilize. This probe automatically compensates for temperature, so it may take a couple of minutes for the values to stabilize. If you do not have an ATC feature, put a thermometer in the cup together with your conductivity meter and record the temperature in the cup in the Comment field, conductivity row, of your "DQM Field Data Sheet for Water Quality Monitoring".

Step 5.5 Record units on your "DQM Field Data Sheet for Water Quality Monitoring", as micromhos per centimeter (microsiemen) or as millisiemen, depending on the instrument you have used.

Step 5.6 Hold the instrument inside the solution in the cup **without touching the cup itself** and read the result. Record the Result value (reading) on the "DQM Field Data Sheet for Water Quality Monitoring", making sure the Instrument ID has been entered correctly.

Step 5.7 Turn off meter. Remove meter from sample. Rinse tip with distilled water and cap.

## 6.0 Monitoring Tips

The meters do not have an automatic OFF function, so care must be taken to turn them off. They require 4 button batteries of 1.5 V. Make sure you get the type that is equivalent to the type you already had in the meter. Under normal use, batteries can function for over 30 field days. It is always a good idea to keep a spare set with the field kit.

If you are using the low-range meter (0 to 1990 microsiemen) in slightly salty waters you may find that the conductivity is outside the range of your meter. You can still gather data by diluting your sample in distilled water. Use the small, 1 oz cup, to take one full-cup volume of sample into a larger cup, and then to take one full 1-oz cup of distilled water into the same larger cup. Mix and measure the conductivity of the mixture. If it is within range, record the reading and note that it should be multiplied by 2. However if it is still out of range you can keep adding increments of full 1-oz cup of distilled water – keeping track of how many you have added – till your meter can read it within range, and then record the reading and the total number of full 1-oz cups (including the one with sample). When you dilute a sample, always record the result of the actual measured value in the "**2nd/rep/dup/dil**" cell and always record the dilution factor; thus you will be writing something like "1300uS x 3 dil".

## 7.0 Accuracy and Precision CCRR (control, check, record, and report)

### 7.1 Accuracy

Accuracy is the extent of agreement between an observed value (measurement result) and the accepted, or true, value of the parameter being measured. The best way to control accuracy is to calibrate often, and at the prescribed temperature! The temperature of the Standard during accuracy checks and calibration adjustments is very important, because conductivity is highly dependent on temperature. For routine monitoring, when a conductivity meter is used only by one crew, the accuracy checks and calibration adjustments should be done at ambient temperature. However, in situations where many crews are using the same instrument sequentially (typically for mass monitoring events, e.g., snapshot monitoring day), it is recommended to check and calibrate at 25 C every time so all users will have the same reference point for the instrument drift.

#### 7.1.1 First measure of inaccuracy: Drift from the calibrated state:.

How often should you check/calibrate? That would probably depend on the drift of your instrument, i.e., on how fast it moves away from the correct value as represented by your Standard. When you are not familiar with your instrument, check the calibration status every trip to see if the instrument still reads the Standard correctly, and calibrate again if needed. Follow the instructions in Section 4.0 above when recording your activities on the "DQM Calibration and Accuracy Checks Sheet". Always record the value your instrument reads before calibration to keep careful documentation of the drift; this is your **first measure of accuracy.**

Once you are more comfortable with your instrument you can pace your accuracy checks at longer time intervals. The recommended frequency of accuracy checks (and calibration adjustments if needed) is different for two distinct Scenarios:

- Snapshots and other one-time monitoring events – do an accuracy check (and adjust reading if needed) before the event. Then do an accuracy check immediately after the event; record the drift between the two.
- Routine monitoring – if you conduct accuracy checks/calibration every second trip; record the drift that occurred between the calibration at the start of the first trip and the reading of the accuracy check (before calibration adjustment) at the start of the third trip.

### 7.1.2 Second measure of inaccuracy: Deterioration of the Standard

Many groups use their "Resident" Standard for routine accuracy checks and calibration adjustments. However, Standards do change over time, and it is prudent to perform "Comparison of Standards" wherein the Resident is compared to an External Standard (or the old bottle of Standard is compared to the new one). Any instrument with good resolution can be used for this type of comparison (preferably after it has been checked/calibrated against one of the Standards). Comparisons of "Resident" to External Standards are needed to account for drift in the Resident Standard itself, which is your **second measure of accuracy**. Comparisons with External Standard can be done at regional Intercalibration Exercise events, otherwise known as "instrument calibration party", particularly when CWT coordinators bring fresh batches of certified Standards. If you are a Technical Leader or a Trainer it is your responsibility to attend, compare your Standard with the External Standard, and make sure you know how far you may be from the true value. The CWT provides a Field Data Sheet for Comparisons of Standards to capture that information.

### 7.1.3 Drift and Data Quality Indicators for Accuracy

Your Trainer will use your calibration and accuracy checks records to calculate inaccuracy –sometimes called bias – based on the Drift. Note that this drift, i.e., the differential between the reading of the instrument in the Standard and the "true" value of the Standard, has to reflect accuracy checks done **before** calibration adjustments, and is relevant to the set of Results that were collected prior to that accuracy check. In other words, you essentially adjust the reading in the morning – to make your data as accurate as possible by eliminating the drift – and then you do an accuracy check at the end of day. Assuming that the instrument drifts from the calibrated state in one direction only, the drift you see in the evening reflects the worst case distance that your day's Results can be from the "true" value. If you attach that distance (i.e., the drift you found in the evening) to the results of that day, the person using your data will know that it could not be further than that.

The same principle applies if you conduct periodic accuracy checks and calibration adjustments (rather than morning calibration adjustment and evening accuracy check). For each monitoring period (say, Trips # 4 to # 6), the reading in the Standard - as captured at the end of Trip # 6 of that period (and **before** any adjustment) - is the Drift you report in association with all the Results collected during Trips #4, #5, and # 6 of that period. If you find that your Resident Standard has drifted (as compared to Certified standard) over the time that includes Trips #4 to #6, add the extent of the Standard Drift to the drift from the calibrated state you found for Trips #4, #5, and # 6 of that period.

This data quality indicator, or measure of inaccuracy, can be reported either as the differential (in uS) or as a percent of the Result value. Further guidance for the Trainer on how to use the Data Quality Management tools to report inaccuracy will be provided in DQM-SOP-9.3.2.2(err).

### 7.2 Precision

The precision of your instrument is a measure of how close repeated measurements, done with the same instrument, are to each other. You can control the precision of your instrument by eliminating sources of error or reducing their effect on the result of the measurements, for example by waiting for the reading to stabilize, avoiding contact between the instrument and the cup when taking the reading, and adhering to consistent measurement conditions in terms of sample volume, temperature, mixing, etc.

To check precision, collect two samples from the creek at the same time and measure their conductivity; these "field duplicates" are a part of your routine Field QA/QC. You can also have two people measure conductivity of the same sample, or otherwise generate sets of "replicate" results that pertain to the same sample. Generate such pairs every third trip, and every time you introduce new monitors to your team, and record the additional measurement results in the "**2nd/rep/dup/dil**" field on your "DQM Field Data Sheet for Water Quality Monitoring".

You should have several pairs of repeated measurements (replicates or duplicates) for each Project. Once entered into the DQM Project File, your Trainer or Technical leader will use them to calculate and report the precision of your instrument as the Relative Percent Difference (RPD) per DQM-SOP-9.3.2.2(err). RPD is the arithmetic difference between the two Results, multiplied by 100 and divided by their average, and is usually reported as absolute numbers because negative numbers are not indicators of bias in this case. In the rare situation where you obtains triplicates or even more than three repeated measurements of the same sample, calculate the Coefficient of Variation (%CV), which is the standard deviation multiplied by 100 and divided by the mean. Note that RPDs and %CV are not the same, kind of like apples and oranges, and you cannot add them up. Please seek further guidance on these Precision measures.

If the resolution of your instrument is low – as is the case when you use the TDSTestr4 that has increments of 100 microsiemen – you may not be able to see any difference between your repeated readings (especially if you are monitoring waters of low conductivity), because these differences are minute in comparison to the increments available on the instrument. In that case you can report your precision as "better than the resolution of the instrument". This statement emphasizes the need to get the instrument with the resolution and range that are appropriate for your work.

### 7.3 Blanks

Testing the response of your instrument in distilled or deionized water is a very good practice (if you know that your water is indeed of zero conductivity…). Keep routine checks and record them on the "DQM Calibration and Accuracy Checks Sheet" as separate accuracy check records (i.e., enter "DI" in the Tested Material cell). Note: I have never seen a drift from zero, and I do not know if these instruments can show negative values (RK, 7/8/02). If you trust your DI and your instrument reads something different than zero in it, call your tech support coordinator…

### 7.4 CCRR Definitions

*(This section is common to all Instrument-specific DQM-SOPs)* These terms are defined here because they are essential for understanding the instructions. These and many other terms are defined in the Glossary at the end of the generic SOPs for Field Operators (DQM-SOP-9.2.1.1(Field) and DQM-SOP-9.2.1.2(Calib), and in the comprehensive Compendium glossary..

**Instrument**: a probe, electrode, reagent kit, indicator strip, or any other type of device used for field or laboratory measurements.

**Accuracy Check**: Comparison of the reading, or output, of a measurement device with a value believed to be the "true" value. The "true" value may be represented by any Standard Material (e.g., known natural reference conditions such as freezing point, Standard Solution, etc). An "Accuracy Check" is different from a Calibration, since it is only a comparison and does not result in an adjustment of the reading of the measurement device.

**Calibration (or Calibration Adjustment)**: Modification of the output of an adjustable-reading instrument, to make it reflect a value that represents the "true value" (as manifested by a given Standard or by a natural value). Note: The EPA's definition for "Calibration" is, essentially, a combination of "accuracy check (comparison) and adjustment if needed"; it is not specific enough for communication of what you did when you say "I calibrated the instrument".

**Standard Material:** A catch-all term for Solutions (e.g., Standard Buffer), devices (e.g., Certified thermometer), or natural reference points (e.g., Water saturated with dissolved oxygen at a given temperature), that represent a value believed to be the "true" value.

**Standard Solution**: A solution containing a known concentration of a substance or has a known property, prepared or purchased for use in the analytical laboratory or in the field. Each bottle of these types of Standards has a **unique Standard ID,** for example "STB-EC2". Every bottle of Standard with its unique ID can be described in one or more of the following definitions:

- "**Resident Standards**" – solutions that each monitoring entity or group owns and uses routinely for calibration and/or accuracy checks.
- "**External Standards**" - solutions used in events such as Intercalibration Exercises, often brought by the QA/QC officer for comparison with the Resident Standards brought by the participating groups;
- "**Certified Standards**" include any Standard that is traceable to NIST or ASTM. Resident and External Standards can all be Certified Standards as well. A Certified Standard is considered the "ultimate authority" if valid, i.e., if the bottle was (a) used before the expiration date; (b) has been stored tightly capped; and (c) has not been exposed to extreme temperatures or sunlight.

## 8.0 Sources and Resources

*(This section is common to all DQM-SOPs, except for the title and SOP number in the citation)* This SOP is an integral part of the Data Quality Management (DQM) System implemented by the Clean Water Team, the Citizen Monitoring Program of the California State Water Resources Control Board.

For an electronic copy, to find many more CWT guidance documents, or to find the contact information for your Regional CWT Coordinator, visit our website at www.swrcb.ca.gov/nps/volunteer.html

If you wish to cite this SOP in other texts you can use "CWT 2004" and reference it as follows:
"Clean Water Team (CWT) 2004. Measurement of Electrical Conductivity Using a Pocket Meter, DQM SOP-3.1.3.1. in: The Clean Water Team Guidance Compendium for Watershed Monitoring and Assessment, Version 2.0. Division of Water Quality, California State Water Resources Control Board (SWRCB), Sacramento, CA."