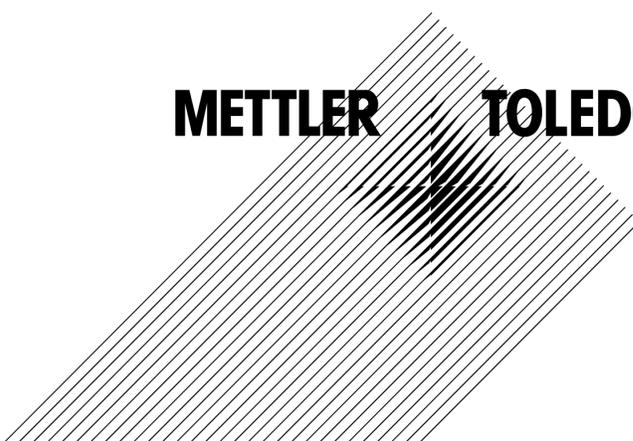


# **4000TOC Sensor Standard Operating Procedure for**

- **TOC Calibration**
- **Conductivity Calibration**
- **Temperature Calibration**
- **Flow Rate Calibration**

**METTLER TOLEDO**

A graphic element consisting of a series of parallel, slightly curved lines that create a sense of depth and movement, resembling a stylized 'M' or a series of steps. The lines are black and white, and they are positioned behind the Mettler Toledo logo text.

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# IMPORTANT SAFETY INFORMATION

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Please read thoroughly before operating the 4000TOC System Suitability Test Kit and the 4000TOC Calibration Kit -

- Follow all warnings, cautions, and instructions indicated on and supplied with this product.
- Install equipment as specified in this instruction manual. Follow appropriate local and national codes.
- Use only factory documented components for repair. Tampering or unauthorized substitution of parts and procedures can affect the performance and cause unsafe operation of your process as well as void factory warranties.
- Protective covers must be in place unless qualified personnel are performing maintenance.
- If this equipment is used in a manner not specified by the manufacturer, the protection provided by it against hazards may be impaired.
- Prior to shipping the sensor back to the factory for repair or re-calibration, water **MUST** be drained from sensor to avoid damage due to freezing.

## WARNINGS:

- Installation of cable connections and servicing of this product require access to shock hazard voltage levels.
- Main power must employ a switch or circuit breaker as the disconnecting device for the equipment.
- Electrical installation must be in accordance with the National Electrical Code and/or any other applicable national or local codes.
- Safety and performance require that this instrument be connected and properly grounded through a three-wire power source.

This manual includes safety information with the following designations and formats:

**WARNING:** POTENTIAL FOR PERSONAL INJURY.

**CAUTION:** possible instrument damage or malfunction.

**NOTE:** important operating information.

## Definition of Equipment Symbols



On the instrument indicates: Warning, risk of electric shock.



On the instrument indicates: Caution (refer to accompanying documents).



On the instrument indicates: There is alternating current present.

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# 1. Introduction

The Mettler-Toledo Thornton 4000TOC Total Organic Carbon Sensor and M300TOC transmitter measures the amount of organic carbon in high purity waters by oxidizing organic carbon to CO<sub>2</sub> with appropriate UV radiation. The resulting change between two temperature-compensated conductivity measurements of the sample flow stream at points before and after oxidation is used to calculate the amount of total organic carbon present.

# 2. Scope

This document provides procedures to calibrate the Thornton 4000TOC Total Organic Carbon Sensor (PN 58 036 021, PN 58 036 022, 58 036 023, 58 036 024). The 4000TOC Sensor is used with the Thornton M300 TOC transmitter. Calibration of the M300 transmitter is covered in separate documentation, and only effects the performance of the analog outputs.

# 3. Equipment Required

## 3.1. Full Calibration

For a complete calibration (flow, temperature, conductivity, and TOC), the following equipment is required.

- CAL/SST Module Kit (Thornton PN 58 091 559). This consists of a calibrated conductivity sensor, patch cable, 316L SS flow housing, holding brackets, SOP for Calibration, pump, power supply, and miscellaneous connectors and tubing, all stored in a case.
- TOC Calibration Solution Set (Thornton PN 58 091 529).
- Stop watch or other timing device with 1 second resolution for flow calibration process.
- 100 mL or larger volumetric container such as graduated cylinder with <3% tolerance for flow calibration process.
- Latex/nitrile gloves are recommended during the procedure when wetted components such as tubing are handled.

## 3.2. TOC Calibration

For a TOC calibration (TOC measurement only), the following equipment is required.

- 4000TOC Calibration Test Kit (Thornton PN 58 091 534) or System Suitability Test Kit (Thornton PN 58 091 525) is required. The 4000TOC Calibration Test Kit is described above. The System Suitability Test Kit consists of a holding brackets, pump, power supply, and miscellaneous connectors and tubing, all stored in a case.
- 4000TOC Calibration Solution Set (Thornton PN 58 091 529).

# 4. Reference and UUT Equipment Information

## 4.1. Record System Information

1. Record all relevant information regarding the unit under test (UUT) in Worksheet 1: Unit Under Test Information.
2. Record all relevant information regarding the reference system in Worksheet 2: Reference Equipment Information.

## 4.2. M300TOC Configuration

The M300TOC accepts an input from a single 4000TOC Sensor from which it is capable of displaying values for a variety of different measurements and units. This extensive variety is supported by a four-line display and the instrument's "custom names" feature, which allows labeling of each measurement. To simplify the calibration process, the M300TOC can be configured to display the following measurements and units (see, 4000TOC/M300TOC instruction Manual for details on how to configure the transmitter display setup).during the calibration process. However, this configuration is not required.

Line 1: TOC displayed in ppb (parts per billion)

Line 2: Conductivity displayed in  $\mu\text{S}/\text{cm}$  (resolution: 3 decimal places)

Line 3: Temperature displayed in degrees Celsius ( $^{\circ}\text{C}$ ) (resolution: 2 decimal places)

To simplify the calibration process, this procedure will use conductivity in units of  $\mu\text{S}/\text{cm}$  and temperature in degrees Celsius. Alternative measurement units may be used.

For a full system calibration, a separate conductivity sensor and appropriate transmitter/display must be used as the reference instrument. Please refer to the appropriate documentation for configuration instructions. It is recommended that this referencing instrument be configured to display conductivity in  $\mu\text{S}/\text{cm}$  (resolution: 3 decimal places), and temperature in degrees Celsius ( $^{\circ}\text{C}$ , resolution: 2 decimal places).

## 5. Calibration Equipment Preparation

**Note:** Under the Factory default settings, the Hold Outputs functionality is enabled when the transmitter enters calibration mode. This configuration will freeze the relay and analog outputs so that alarms are not triggered during any service procedures. Normal relay and analog output operation resumes shortly after the transmitter is returned to measurement mode. The Hold Outputs function may be turned off at the M300 TOC if desired by selecting Path: Menu/Configure/Hold Outputs.

**Caution:** Be sure to adjust needle valve to less than 3 turns from closed position before re-installing into process line!

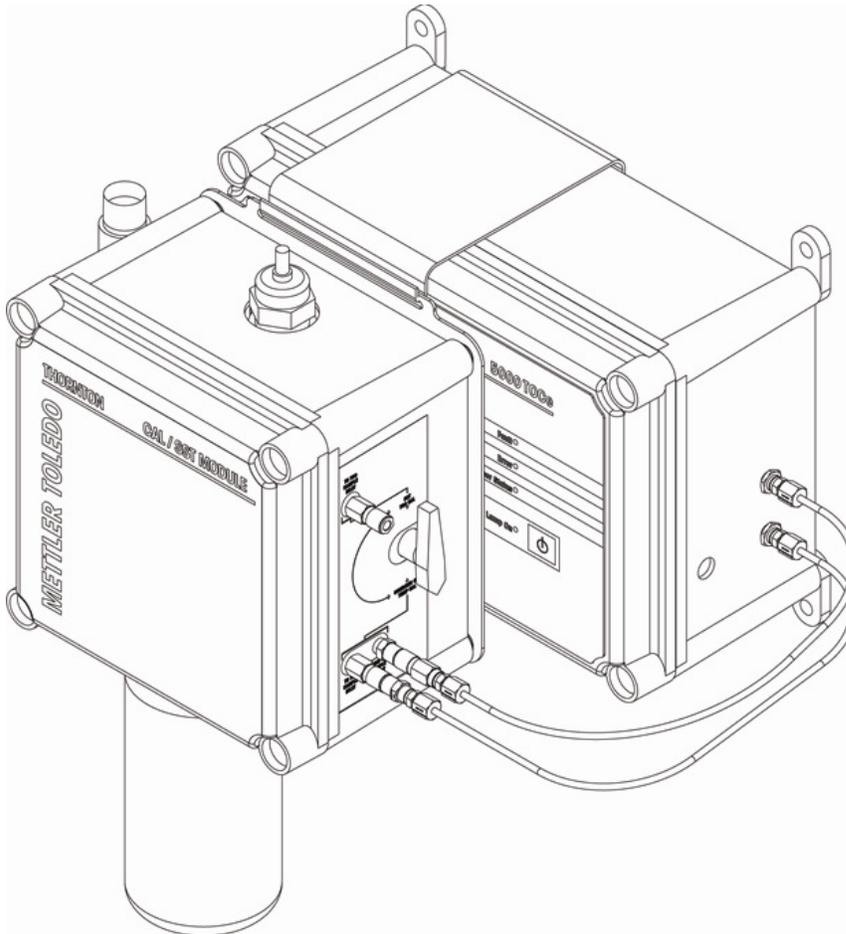
### 5.1. Install CAL/SST Module (part no. 58 091 559)

This section discusses the installation process for CAL/SST Module kit P/N 58 091 559. For use of the previous version of the 4000TOC Calibration and SST Kits (Thornton PN 58 091 534, or PN 58 091 525 with 58 091 528), refer to Appendix 3 – Using SST and Calibration kit 58 0791 534.

CAL/SST Module Kit 58 091 559 provides the apparatus needed to perform a system suitability test on the 4000TOC Sensor (PN's 58 036 001, 58 036 002, 58 036 003 and 58 036 004). Components contained in this kit include the pump module, a mounting bracket, connecting tubing equipped with quick-disconnect fittings, a universal power supply and assorted tools. This kit is designed for use with Thornton Standard Solution bottles included in the calibration Solutions Kit (p/n 58 091 529).

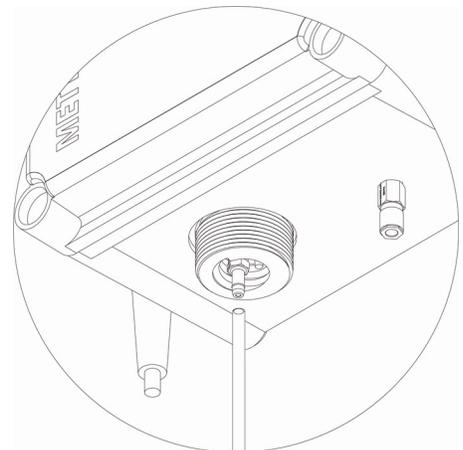
### 5.2. TOC CAL/SST Module Setup

1. Remove the mounting bracket from the carrying case and place on top of the 4000TOC Sensor to be tested. See Figure 1.
2. Connect the CAL/SST Module to the mounting bracket. Ensure that the bracket and module are aligned to the left side of the sensor so that UV Lamp power button is accessible and the indicating LED's are visible.
3. Remove the 60 micron filter assembly from the 4000TOC inlet.
4. Attach the threaded end of connection tube equipped with the male quick-disconnect fitting to the 4000TOC Sample Inlet connection. After the threaded connection is made, push the quick-disconnect fitting into mating connector found on the lower right side of the CAL/SST pump module. Ensure proper connection is made.
5. Attach the threaded end of connection tube equipped with the female quick-disconnect fitting to the 4000TOC Sample Outlet connection. After the threaded connection is made, push the quick-disconnect fitting into mating connector found on the lower right side of the CAL/SST pump module. Ensure proper connection is made.
6. Set selector valve on CAL/SST pump module to "Cond/Res CAL and Temp CAL" position. Figure 1 shows the proper installation of the CAL/SST pump module.
7. Verify the pump's power switch is in the off position. The switch is located on the right side of the module.
8. Connect the Universal Power Supply to the pump and to 100–240 VAC 50-60 Hz power. The kit includes a universal AC adaptor with assorted international standard connectors. Select the appropriate AC connector, and install it onto the AC adaptor and connect to the AC supply.



**Figure 1. CAL/SST Pump Module Installation and Setup**

9. Remove the threaded grey, protective cap from the bottom of the CAL/SST Pump Module.
10. Wearing clean protective gloves to avoid contamination, insert a silicone suction tube onto the suction fitting located in the bottle receptacle as shown in Figure 2. A fresh suction tube should be used for each calibration. Protective gloves and a replacement suction tube are provided with each solution kit.
11. Break the protective seal on a blank water bottle and remove cap. Set cap aside for re-use if any solutions remain after completion of the test.
12. Insert free end of the suction tube into the mouth of the bottle while raising the bottle into place. Attach the solution bottle directly into the solution bottle receptacle at the base of the CAL/SST pump module and proceed to the next section.



**Figure 2. Suction Tube installation**

### 5.3.Final Installation of the TOC Sensor Calibration Kit

1. Connect the Reference Conductivity sensor smart connector to a 770MAX patch cable.
2. Connect the other end of the 770MAX patch cable to an unused channel on a calibrated reference 770MAX transmitter.
3. Set up a measurement to display the Reference Sensor temperature and temperature compensated conductivity. For example, Measurement B could be set to display conductivity and Measurement C could be set to display temperature.
4. Turn on the pump. The setup should now be such that water continuously circulates through the Blank Water bottle and the 4000TOC Sensor.
5. Adjust the flow rate to its maximum rate. This may be done by adjusting the needle valve knob fully counterclockwise until it stops.
6. The system is now ready for temperature calibration. The pump may be left on if you are proceeding to the next section.

## 6. Record “As Found” Information

Prior to the calibration/adjustment process or prior to a lamp change, “As Found” data may be required prior to any changes. This section describes the procedure to acquire the “As Found” data. This is recommended for displayed measurements.

If a calibration of only the TOC measurement is scheduled, go to Section 6.3. TOC As Found. If the temperature and conductivity are to be calibrated, then continue to Section 6.1. T1 Temperature As Found.

### 6.1.T1 Temperature As Found

This procedure is to be performed on T1, which corresponds to the temperature sensor embedded in the inlet conductivity sensor.

1. Record all data in Worksheet 3: As Found Data for T1 and C1.
2. Turn off the UV lamp (if not already off). If necessary, press the Lamp button located on the front panel of the 4000TOC Sensor. The lamp shall remain off throughout this procedure.
3. If the pump is off, turn on the pump. Water should now be continuously circulating through the pump, 4000TOC Sensor, Reference Conductivity Sensor, the water container, and back through the pump.
4. Allow the pump to run until thermal equilibrium is achieved, typically 1/2 hour (less if the TOC lamp has been off).
5. Record the As Found Temperature T1 Multiplier and Adder found in the M300TOC:
  - a. Press the Info (▼) key on the M300.
  - b. Press ▲ or ▼ to select Calibration Data and press enter.
  - c. Press ▲ or ▼ to select Temperature and press Enter.
  - d. Record the calibration data displayed.
  - e. Simultaneously press Menu and Cal (◀ and ▶▶) to return to Measurement Mode.
6. Record the Reference Sensor temperature (to two decimal places) displayed on the 770MAX,  $T_{ref}$ .
7. Record the UUT temperature of T1 (to two decimal places) displayed on the M300TOC,  $T_{before}$ .
8. Compute the difference,  $T_{ref} - T_{before}$ .
9. If the absolute value of the difference is less than the limit, then a temperature calibration is not required.
10. Press Menu (exit) to return to measurement mode.

### 6.2.C1 Conductivity As Found

This procedure is to be performed on C1 which corresponds to the inlet conductivity sensors within the unit.

1. Record all data in Worksheet 3: As Found Data for T1 and C1.
2. Verify the UV lamp is off. If the lamp was on, wait until thermal equilibrium is achieved.
3. Continuing with the same Blank Water from the Temperature Calibration, verify that the water quality is  $<1.5 \mu\text{S}/\text{cm}$  ( $>0.67 \text{ M}\Omega\text{-cm}$ ) as reported by Reference Conductivity sensor. If the water conductivity has increased above  $1.5 \mu\text{S}/\text{cm}$ , then turn off the pump, install a fresh bottle of Blank Water, and restart the pump. Note that the conductivity sensors can be calibrated above  $1.5 \mu\text{S}/\text{cm}$  with no adverse measurement impact, but we recommend a lower conductivity calibration to simulate process water.
4. If the same bottle of Blank Water is still being used from the previous section, then continue to the next step. Otherwise, allow the pump to run until complete mixing is achieved, typically 30 minutes.
5. Record the As Found Conductivity C1 Multiplier and Adder found in the Measurement M300TOC:
  - a. Press the Info (▼) key. on the M300.
  - b. Press ▲ or ▼ to select Calibration Data and press enter.

- c. Press ▲ or ▼ to select Conductivity and press Enter.
  - d. Record the calibration data displayed.
  - e. Simultaneously press Menu and Cal (◀ and ▶) to return to Measurement Mode.
6. Record the conductivity (at least three significant figures) of the Reference Conductivity Sensor displayed on the 770MAX,  $C_{ref}$ .
  7. Record the UUT conductivity of C1 (at least three significant figures) displayed on the M300TOC,  $C_{before}$ .
  8. Compute the % difference according to eq 1.

$$\frac{100 \times (C_{before} - C_{ref})}{C_{ref}}$$

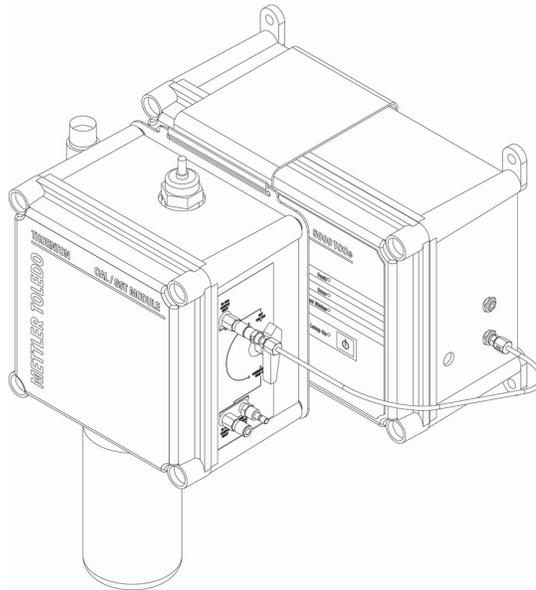
eq 1

9. If the absolute value of the % difference is less than the limit, then a C1 conductivity calibration is not required.
10. Turn off the Cal/SST pump.

### 6.3.TOC As Found

Record all data in the following worksheet: Worksheet 4: As Found Data for TOC

1. Disconnect tube from the TOC sample outlet and remove it completely from the test assembly.
2. At the CAL/SST Module, disconnect the tube attached to the TOC Sample Inlet, and re-connect it to the mating connector found on the top right-side of the CAL/SST Module.
3. Re-position the selector valve on the CAL/SST pump module to “SST/TOC CAL” position.
4. Record the As Found TOC Multiplier(s) and Adder(s) as follows:
  - a. Press the Info (▼) key on the M300.
  - b. Press ▲ or ▼ to select Calibration Data and press enter.
  - c. Press ▲ or ▼ to select TOC and press Enter.
  - d. Record the calibration data displayed.
  - e. Simultaneously press Menu and Cal (◀ and ▶) to return to Measurement Mode.
5. Record Lamp Lifetime (hrs) as follows:
  - a. Press the Info (▼) key. on the M300.
  - b. Press ▲ or ▼ to select TOC Sensor Info and press enter.
  - c. Press ▲ or ▼ to select UV Lamp Time Remaining and press Enter.
  - d. Record the lamp life data displayed.
  - e. Simultaneously press Menu and Cal (◀ and ▶) to return to Measurement Mode.
6. To record the TOC of the Reference Solution,  $TOC_{ref}$ , turn off the Cal/SST pump, remove the Blank Water bottle from the CAL/SST Module and replace it with a 500 ppb TOC (sucrose) solution bottle.
7. Re-connect the original drain tube to the Sample Outlet of the 4000TOC Sensor and run it to atmospheric drain. It is critical not to re-circulate this solution. Tubing should now appear as in Figure 3.



**Figure 3**

8. Turn on the pump. Water should now be visible at the drain line at the atmospheric drain. Note: the ~500 mL volume of the calibration solution will provide more than 20 minutes of operation at the nominal flow rate of 20 mL/min.
9. Verify that UV Lamp is on. The lamp must be on to measure and display TOC.
10. Adjust the flow rate to 20 mL/min per Section 14.
11. Allow the 500 ppb TOC (sucrose) solution to flow through the 4000TOC Sensor until the readings stabilize, approximately 5 minutes.
12. Record the TOC of the 4000TOC Sensor for the 500 ppb Solution,  $TOC_{before}$ .
13. Compute the difference,  $TOC_{ref} - TOC_{before}$ .
14. If the absolute value of the difference for both the 500 ppb is less than the limit, then a TOC calibration is not required.

**“As Found” is complete.**

## 7. Flow Rate Calibration

### 7.1. Introduction to Flow Rate Calibration Process

This section describes the calibration/adjustment process for the flow rate. If a calibration of only the TOC measurement is scheduled, proceed directly to Section 10. TOC Calibration. If flow, temperature, and conductivity are to be calibrated, then proceed to Flow Rate Calibration. Since flow rate is not a reported process measurement, “As Found” data is not required. This procedure uses a “volume and time” method for calibrating the flow sensor. Process water is sufficient to use for this calibration. The end of the drain tube at the sample outlet is the measurement point.

**NOTE:** Since it is possible for the person performing this calibration to come into contact with the process water, use of protective gloves, or other suitable safety equipment is recommended.

**Caution:** If the process water is hot, protection from direct contact should be used, or an alternate source of water must be provided.

### 7.2. Flow Rate Verification Before Calibration

1. Record all data in Worksheet 5: Flow Rate Verification and Calibration.
2. Set up equipment as shown in Figure 3 using Blank Water. Optionally, the flow rate verification and calibration may be done using process water, with the TOC sensor connected to the water system as normal.
3. If using the CAL/SST Module, ensure the selector valve is set to the ‘SST/TOC Cal’ position.
4. Adjust the 4000TOC Sensor flow rate to 20 mL/min (4 LEDs) as described in Section 14. Leave “Set Flow Rate” set to “Yes”.
5. Arrange the drain tube at the atmospheric drain such that the water dripping from it may be collected into the volumetric container.
6. Place a dry volumetric container under the drain line to capture the water, and begin the time measurement using the stop watch. It is important that the water collection and start time be closely matched.
7. Collect a known volume of water with the volumetric container for a specific time, at least 3 minutes.

8. In Section A of Worksheet 5, record the volume of water in mL and the elapsed time in seconds. These two values determine the reference flow rate,  $F_{ref}$ .
9. Calculate the reference flow rate and record as  $F_{ref}$  according to the equation below. The volume may also be determined by weight. Measure the mass increase of the container in grams, and divide the mass by the density of the water (typically, 1.00 g/mL at room temperature).

$$\text{Flow Rate (mL/min)} = F_{ref} = \frac{60 \text{ sec/min} \times \text{volume collected (mL)}}{\text{Elapsed Time (sec)}}$$

eq 2

10. Record the number of LEDs on the front of the 4000TOC as the Set Flow Rate.
11. If  $(F_{ref} - 20)$  is within the limit, then flow rate adjustment is not required. Change "Set Flow Rate" back to "No", and press ◀ and ▶ simultaneously to exit. If no flow adjustment is required, proceed to Section 8. Temperature Calibration. Otherwise, proceed to the next section to perform a flow rate calibration.

### 7.3. Flow Rate Calibration

NOTE: All flow adjustments are to be made using the needle valve located near the inlet of the 4000TOC Sensor.

1. On the M300, press 'Cal' (▶) to enter calibration mode.
2. Press ◀ or ▶ so that 'TOC' is flashing, then press ▲ or ▼ to select 'Flow' and press 'Enter'.
3. Energize the CAL/SST pump.
4. Using the needle valve on the 4000TOC Sensor, adjust the flow rate through the 4000TOC Sensor to  $24 \pm 1$  mL/min as indicated on line 4 of the M300 TOC display.

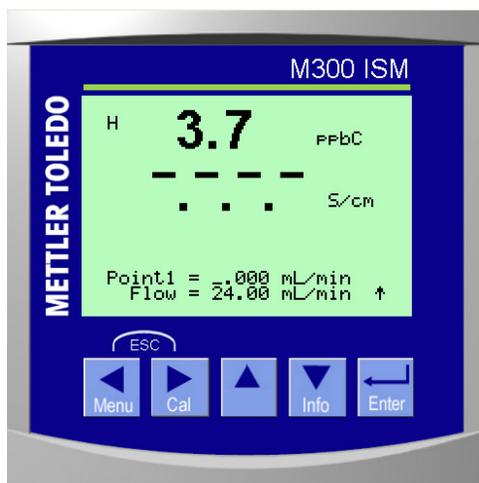


Figure 4

5. Place a dry volumetric container under the drain line to capture the water, and begin the time measurement using the stop watch. It is important that the water collection and start time be closely matched.
6. Collect a known volume of water with the volumetric container for a measured time, at least 3 minutes.
7. In Section B, record the volume of water in mL and the elapsed time in seconds.
8. Using eq 2, calculate the water flow rate and record as  $F_{ref1}$ .
9. Enter the reference flow rate into the M300TOC and press Enter.
10. Using the needle valve on the 4000TOC Sensor, adjust the flow rate to  $16 \pm 1$  mL/min as indicated on line 4 of the M300 TOC.
11. Empty the volumetric container, and repeat steps 5-7.
12. Using eq 2, calculate the water flow rate and record data as  $F_{ref2}$ .
13. Enter the reference flow rate into the M300 TOC and press Enter.
14. Select 'Yes' to save the new calibration data within the 4000TOC Sensor. If 'No' is selected, the previous calibration will be restored.

### 7.4. Flow Rate Verification After Calibration

1. Repeat steps 1-10 in Section 7.2 to verify the flow sensor is in calibration.
2. Record data in section C of Worksheet 5.

Flow Calibration is complete.

## 8. Temperature Calibration

This procedure is to be performed on T1 and T2, which correspond to the temperature sensors embedded in the two conductivity sensors.

### 8.1.T1 Temperature Calibration

1. Record data in Worksheet 6: Temperature Sensor Verification and Calibration.
2. Turn off the UV lamp (if not already off) by pressing the lamp button so that it's green LED is off. The lamp shall remain off throughout this procedure.
3. Set up the Cal/SST Module using Blank Water as described in sections 5.1 and 5.2 above. .
4. Ensure that selector valve is set to "Cond/Res and Temp Cal' position.
5. Turn on the pump. Water should now be continuously circulating through the pump, 4000TOC Sensor, Reference Conductivity Sensor, the water container, and back through the pump.
6. Allow the pump to run until thermal equilibrium is achieved, typically 1/2 hour (less if the lamp has been off).
7. Compare the reading of T1 to the reading of the reference temperature sensor. If the difference between T1 and  $T_{ref}$  is 0.5 °C or less, then T1 does not require adjustment; proceed to Section 8.2 T2 Temperature Calibration.
8. If T1 requires adjustment, press 'Cal' (▶) on the M300 to enter calibration mode.
9. Press ◀ or ▶ so that 'TOC' is flashing, then press ▲ or ▼ to select 'T1' and press 'Enter'.
10. Press ▲ or ▼ to select 1-point off-set. Press Enter or ▶.
11. After the readings for T1 and the reference temperature have become stable, enter the temperature of the Reference Sensor into the M300TOC using the arrow keys, and press Enter. To avoid inaccuracy due to changes in ambient temperature, this value should be entered as soon as practical after reading the Reference Sensor.
12. Record the T1 multiplier and adder on the worksheet. Select YES and press Enter to save the new calibration data within the 4000TOC Sensor.

**Note:** If NO is selected, the calibration data will only be discarded, and the sensor will revert back to the previous calibration.

13. Verify that the new computed calibration factors for T1 are within acceptable limits as indicated on the worksheet.
14. After returning to measurement mode on the M300TOC, record the temperature of  $T_{ref}$  and  $T_{after}$  (for T1) on the worksheet.
15. Verify that  $T_{ref} - T_{after}$  is within limits for T1.
16. Verify that the Multiplier and Adder for T1 are within limits. If they exceed limits, repeat Section 8.1 T1 Temperature Calibration.

### 8.2.T2 Temperature Calibration

1. Repeat steps 1-12 in Section 8.1 T1 Temperature Calibration, except select T2 when entering the Sensor Calibration menu.
2. Verify that the new computed calibration factors for T2 are within acceptable limits as indicated on the worksheet.
3. After returning to measurement mode on the M300TOC, record the temperature of  $T_{ref}$  and  $T_{after}$  (for T2) on the worksheet.
4. Verify that  $T_{ref} - T_{after}$  is within limits for T2.
5. Verify that the Multiplier and Adder for T2 are within limits. If they exceed limits, repeat Section 8.2 T2 Temperature Calibration.

Temperature Calibration is complete.

## 9. Conductivity Calibration

This procedure is to be performed on C1 and C2 which correspond to the two conductivity sensors within the unit.

### 9.1. C1 Conductivity Calibration

1. Record data in Worksheet 7: Conductivity Sensor Verification and Calibration.
2. Verify the UV lamp is off. Turn off the UV lamp (if not already off) by pressing the lamp button so that it's green LED is off. The lamp shall remain off throughout this procedure. Wait until stable readings are achieved.
3. If not already done, set up the Cal/SST Module using Blank Water as described in sections 5.1 and 5.2 above. .
4. Ensure that selector valve is set to "Cond/Res and Temp Cal' position.
5. Continuing with the same Blank Water from the Temperature Calibration, verify that the water quality is  $<1.5 \mu\text{S}/\text{cm}$  ( $>0.67 \text{ M}\Omega\text{-cm}$ ) as reported by Reference Conductivity sensor. If the water conductivity has increased above  $1.5 \mu\text{S}/\text{cm}$ , then turn off the pump, install a fresh bottle of Blank Water, and restart the pump. Note that the conductivity sensors can be calibrated above  $1.5 \mu\text{S}/\text{cm}$  with no adverse measurement impact, but we recommend a lower conductivity calibration to emulate process water.

6. If the same bottle of Blank Water is still being used, then continue to the next step. Otherwise, allow the pump to run until complete mixing and thermal equilibrium is achieved, typically 30 minutes.
7. If C1 does not require adjustment based on the as-found readings recorded on Worksheet 3: As Found Data for T1 and C1, proceed to Section 9.2 C2 Conductivity Calibration.
8. If C1 requires adjustment, press 'Cal' (▶) on the M300 to enter calibration mode.
9. Press ◀ or ▶ so that 'TOC' is flashing, then press ▲ or ▼ to select 'C1' and press 'Enter'.
10. Press ▲ or ▼ to select the conductivity compensation method to be used during the calibration. 'Standard' compensation is recommended.
11. Select the conductivity calibration method that will be used then press Enter or ▶. A 1-point calibration is recommended for most circumstances.
12. Once the readings from the reference sensor and C1 have stabilized, enter the conductivity reading of the Reference Sensor into the M300TOC using the arrow keys and press Enter. To avoid inaccuracy due to changes in ambient temperature, this value should be entered as soon as practical after reading the Reference Sensor.
13. Record the C1 multiplier and adder on the worksheet. Select YES and press Enter to save the new calibration data within the 4000TOC Sensor and wait for calibration to complete.

**Note:** If NO is selected, the calibration data will only be discarded, and the sensor will revert back to the previous calibration.

14. Press Enter to return to measurement mode.
15. Record the conductivity of the C1 and  $C_{after}$  on the worksheet.
16. Compute the % difference according to eq 2.

$$\frac{100 \times (C_{after} - C_{ref})}{C_{ref}}$$

eq 2

17. Verify that the % difference is within limits.
18. Verify that the new computed conductivity factor is within acceptable limits as indicated on the worksheet. If they exceed limits, repeat Section 9.1 C1 Conductivity Calibration.

## 9.2.C2 Conductivity Calibration

1. Repeat steps 1-14 in Section 9.1 C1 Conductivity Calibration except select C2 when entering calibration mode.
2. Record the conductivity of the C2 and  $C_{after}$  on the worksheet.
3. Compute the % difference according to eq 2.
4. Verify that the % difference is within limits.
5. Verify that the new computed conductivity factor is within acceptable limits as indicated on the worksheet. If they exceed limits, repeat Section 9.2 C2 Conductivity Calibration.
6. Turn off the pump on the CAL/SST Module.

**Conductivity Calibration is now complete.**

## 10. TOC Calibration

Calibration is performed using a solution(s) of known TOC concentration(s). Mettler-Toledo Thornton provides the 4000TOC Calibration Solution Set (P/N 58 091 529) with a bottle of 500 ppb TOC (sucrose) and 250 ppb TOC (sucrose) calibration solutions for this purpose. If performing a 1-point slope calibration, then only use the bottle of 500 ppb TOC (sucrose) calibration solution.

### 10.1. Set Up TOC Calibration Kit

1. Record data in Worksheet 8: TOC Calibration and Verification.
2. Set up the equipment as shown in Figure 3.
3. Ensure that selector valve is repositioned to SST/TOC Cal position.
4. Verify the UV lamp is off.
5. Install the 500 ppb TOC (sucrose) solution on the CAL/SST module.
6. Connect the original drain tube to the Sample Outlet of the 4000TOC Sensor and run it to atmospheric drain. It is critical not to recirculate this solution.

7. Turn on the pump. Solution should now be visible at the drain line at the atmospheric drain. Note: the 500 mL volume of the calibration solution will provide more than 20 minutes of operation at the nominal flow rate of 20 mL/min.
8. Verify that UV Lamp is on. The lamp must be on to measure and display TOC.
9. Adjust the flow rate to 20 mL/min per Section 14, if necessary.
10. Allow the 500 ppb TOC (sucrose) solution to flow through the 4000TOC Sensor until the readings stabilize, approximately 5-10 minutes.

## 10.2. TOC Calibration Procedure

1. Record data in [Worksheet 8: TOC Calibration and Verification](#).
2. If not already completed, set up the CAL/SST kit as described in Section 5 and attach the 500 ppb calibration solution bottle to the CAL/SST module.
3. On the M300, press 'Cal' (▶) to enter calibration mode.
4. Press 'Enter' to select Calibrate Sensor, TOC.
5. Press ▲ or ▼ to select calibration type, then press 'Enter'. The 4000TOC will enter the 'Set Flow' mode.  
**Note: A multi-linear calibration is highly recommended for most applications.**
6. Energize the CAL/SST pump.
7. The LED lights on the 4000TOC front panel will now indicate sample flow rate. Adjust the flow rate to 20 mL/min per Section 14, if necessary. Press enter when flow has been set to 20 ml/min.
8. Allow the 500 ppb TOC solution to flow through the 4000TOC Sensor until the readings stabilize, approximately 5 minutes.
9. Use the arrow keys on the M300TOC to enter the TOC value of the Reference Solution as written on the label or its certificate into the M300TOC for Cal point 1 and press Enter. The 4000TOC will enter Set Flow mode in preparation for the next calibration step.
10. Turn off pump.
11. Remove the 500 ppb TOC solution bottle from the calibration apparatus and replace it with 250 ppb TOC solution.
12. Turn on the pump.
13. Verify that UV Lamp is on. The lamp must be on to measure and display TOC. If the 4000TOC is not set to automatically re-start, the lamp will need to be energized manually.
14. The LED lights on the 4000TOC front panel will now indicate sample flow rate. Adjust the flow rate to 20 mL/min per Section 14, if necessary. Press enter when flow has been set to 20 ml/min.
15. Allow the 250 ppb TOC solution to flow through the 4000TOC Sensor until the readings stabilize, approximately 5 minutes.
16. Use the arrow keys on the M300TOC Enter the TOC of the Reference Solution as written on the label or its certificate into the M300 for Cal point 2 and press Enter.
17. Select YES to save the new calibration data within the 4000TOC Sensor and wait for the calibration process to finish. The M300 will return to normal measurement mode when completed.

**Note:** If NO is selected, the calibration data will only be discarded, and the sensor will revert back to the previous calibration.

18. On [Worksheet 8: TOC Calibration and Verification](#), record the TOC as written on the label of the 250 ppb and 500 ppb solutions or the associated certificates. This is TOC<sub>ref</sub>.
19. Record the measured TOC displayed on the M300TOC, TOC<sub>after</sub>.
20. Verify that difference is within acceptable limits.
21. Turn off pump.
22. Remove the 250 ppb TOC solution bottle from the calibration apparatus and replace it with 500 ppb TOC solution.
23. Turn on pump.
24. Verify that UV Lamp is on. The lamp must be on to measure and display TOC.
25. Adjust the flow rate to 20 mL/min per Section 14.
26. Ensure that the M300TOC is in measurement mode by setting 'Set Flow Rate' to 'Off', and then pressing ▲ and ▼ simultaneously.
27. Allow the 500 ppb solution to flow through the 4000TOC Sensor until the readings stabilize, approximately 5 minutes.
28. Record the measured TOC displayed on the M300, TOC<sub>after</sub>.
29. Verify that difference is within acceptable limits in this worksheet.
30. Find the UV Lamp Life:
  - a. Press Info
  - b. Press ▲ or ▼ to select TOC Sensor Info and press Enter

- c. Press ▲ or ▼ to select UV Lamp Time Remaining and press Enter
  - d. Record the data on Worksheet 3
31. Press ► and ◀ keys simultaneously to return to measurement mode.
  32. Press 'Info' (▼), and press ▲ or ▼ to select 'Calibration Data', then press 'Enter'.
  33. Press ▲ or ▼ to select TOC then press 'Enter'.
  34. Record the value of new TOC Multiplier(s) and adder(s) from the M300 display.
  35. If the difference is not within acceptable limits, repeat Section 10.2. TOC Calibration Procedure.
  36. Press ► and ◀ keys simultaneously to return to measurement mode.

**TOC Calibration is complete. Proceed to Section 11.**

## 11. Restore to Operation

**Caution:** Be sure to adjust needle valve to less than 3 turns from closed position before re-installing into process line!

1. Restore the connections to the unit in the same operational configuration prior to calibration.
2. Connect the process water line to the 4000TOC Sensor sample inlet.
3. Turn on the process water supply to the 4000TOC Sensor using the shut off valve (recommended in the 4000TOC Sensor Instruction Manual). Insure the process water supply is turned on by viewing the discharge line at the atmospheric drain.
4. Adjust the flow rate to 20 mL/min per Section 14. Appendix 2 - Setting Sample Flow Rate.
5. Turn on the UV Lamp.
6. Flush the CAL/SST Module and connected tubing with blank water for 3 to 5 minutes. If there is not adequate blank water remaining, a blank water bottle may be filled with RO quality water or better. Flush the CAL/SST Module. Ensure that the drain tube is directed to an appropriate drain. If an adequate drain is not available, use an empty test solution bottle to collect the flushing water.
7. If a temperature and/or conductivity calibration was performed, proceed to the next section to flush and drain the reference conductivity sensor and housing. Otherwise, remove the blank water bottle from the CAL/SST module, remove and discard the silicon suction tube, and replace the protective cap for the solution bottle interface. Remove the CAL/SST module and mounting bracket from the TOC Sensor.

## 12. Flush and Drain Reference Conductivity Sensor and Housing

During conductivity and temperature calibration, the flow housing containing the reference conductivity sensor will become filled with test solution. It is necessary to flush and drain the conductivity sensor flow housing prior to storage of the CAL/SST Module.

1. Connect both provided tubes to the quick-disconnect fittings on the lower right side of the CAL/SST Module.
2. Set the selector valve to the "Cond/Res and Temp Cal" position.
3. Connect a bottle of the supplied blank water to the CAL/SST Module. If the remaining blank water is not sufficient, a blank water bottle may be filled with process water of RO quality or better to flush the CAL/SST Module.
4. Turn the pump on and flush the CAL/SST Module for a minimum of 5 minutes. Ensure that the discharge tube from the CAL/SST module (marked "To TOC Sample Inlet") is directed to an appropriate drain. If an adequate drain is not available, use an empty test solution bottle to collect the flushing water.
5. Remove the blank water bottle from the CAL/SST module. Allow the CAL/SST Module pump to run until all solution has been discharged from the CAL/SST module.
6. Remove and discard the silicon suction tube from the solution bottle interface, and replace the protective cap.
7. With both lines attached to the CAL/SST module and the selector valve in the Con/Res and Temp Cal position, connect the provided syringe and quick-disconnect assembly to the quick-disconnect fitting located at the bottom of the CAL/SST module. Pull the plunger of the syringe back to draw the residual water out of the Conductivity sensor flow housing. Remove the syringe from the silicone tubing and empty the syringe into an appropriate drain or container. If necessary, repeat this process until all solution has been removed.
8. Remove the CAL/SST module and mounting bracket from the TOC Sensor. Remove all connected tubing from the CAL/SST module and return all components to the supplied storage case.

# Worksheet 1: Unit Under Test Information

Use the table below to record relevant information for the unit under test (UUT).

Note: The reference 770MAX and conductivity sensor can be substituted with any suitable conductivity measurement instrument that has been calibrated in accordance with the appropriate procedure.

M300TOC and 4000TOC Sensor Unit Under Test (UUT) Data			
M300TOC UUT		4000TOC Sensor UUT	
Part Number		Part Number	
Serial Number		Serial Number	
ID Tag (if available)		ID Tag (if available)	
Date Last Calibrated		Date Last Calibrated	
Date Calibration Due		Date Calibration Due	
Name (printed)			
Signature			
Date			
Comments			

## Worksheet 2: Reference Equipment Information

Use the table below to record relevant information for reference equipment.

Note: The reference 770MAX can be substituted with any suitable conductivity measurement instrument that has been calibrated in accordance with the appropriate procedure.

Reference Transmitter Data			
Model:			
Part Number:		Date Last Calibrated:	
Serial Number:		Date Calibration Due:	
Notes:			
Reference Conductivity/Temperature Sensor Data (if needed)			
Model:			
Part Number:		Date Last Calibrated:	
Serial Number:		Date Calibration Due:	
Notes:			
Reference TOC Solution Manufacturing Dates/Lot #/Notes			
500 ppb TOC Solution:			
250 ppb TOC Solution:			
Other Reference Information and Notes			
Glassware:			
Other:			
Name (printed):			
Signature:			
Date:			
Notes:			

# Worksheet 3: As Found Data for T1 and C1

Check if not applicable

Measurement Type and Sensor #	Reference Temperature $T_{ref}$ (°C)	As Found Temperature $T_{before}$ (°C)	$T_{ref} - T_{before}$ (°C)	Limit (°C)	Adjustment Required (Y/N)
Temperature T1				±0.5	
Temperature Calibration Factors		Multiplier		Adder	
Measurement Type and Sensor #	Reference Conductivity $C_{ref}$ (µS/cm)	As Found Conductivity $C_{before}$ (µS/cm)	$\frac{100 \times (C_{before} - C_{ref})}{C_{ref}}$ (%)	Limit (%)	Adjustment Required (Y/N)
Conductivity C1				±2.0	
Conductivity Calibration Factors		Multiplier		Adder	
Name (printed)					
Signature					
Date					
Comments					

# Worksheet 4: As Found Data for TOC

Check if not applicable

Nominal	Reference TOC <sub>ref</sub> (ppb)	As Found TOC <sub>before</sub> (ppb)	TOC <sub>ref</sub> - TOC <sub>before</sub> (ppb)	Limit (ppb)	Adjustment Required (Y/N)
TOC, 500 ppb				±50	
TOC Calibration Factors		Multiplier1 Multiplier2		Adder1 Adder2	
Lamp Life (hrs)					
Name (printed)					
Signature					
Date					
Comments					

# Worksheet 5: Flow Rate Verification and Calibration

Check if not applicable

Section A: Flow Sensor Verification Before Calibration							
Calibration point and conditions	Volume (mL)	Elapsed Time (sec)	Reference Flow Rate $F_{ref}$ (mL/min)	Set Flow Rate # LEDs		Limit (mL/min)	Adjustment Required (Y/N)
As found ~20 mL/min						±1.5	
Section B: Flow Sensor Calibration							
Calibration point and conditions	Volume (mL)	Elapsed Time (sec)			Reference Flow Rate (mL/min)		
#1 ~24 mL/min				$F_{ref1}$			
#2 ~16 mL/min				$F_{ref2}$			
Section C: Flow Sensor Verification After Calibration							
Calibration point and conditions	Volume (mL)	Elapsed Time (sec)	Reference Flow Rate $F_{ref}$ (mL/min)	Set Flow Rate # LEDs		Limit (mL/min)	Within Limits (Y/N)
~20 mL/min						±1.5	
Name (printed)							
Signature							
Date							
Comments							

# Worksheet 6: Temperature Sensor Verification and Calibration

Check if not applicable

Measurement Type and Sensor #	Reference Temperature $T_{ref}$ (°C)	Temperature After $T_{after}$ (°C)	$T_{ref} - T_{after}$ (°C)	Limit (°C)	Within Limits (Y/N)
Temperature T1				±0.5	
Temperature T2				±1.0	
<b>Temperature Calibration Factor Limits</b>					
Calibration Factors	Factor	Limit	Within Limits (Y/N)		
T1 Multiplier1		0.9900 to 1.0100*			
T1 Adder1		-0.500 to +1.500			
T2 Multiplier2		0.9900 to 1.0100*			
T2 Adder2		-0.500 to +1.500			
<b>Name (printed)</b>					
<b>Signature</b>					
<b>Date</b>					
<b>Comments</b>					

\* The Temperature Multiplier factor typically set to 1.0000 and it is the Temperature Adder that is adjusted during calibration.

# Worksheet 7: Conductivity Sensor Verification and Calibration

Check if not applicable

Measurement Type and Sensor #	Reference Conductivity $C_{ref}$ ( $\mu\text{S}/\text{cm}$ )	As Found Conductivity $C_{after}$ ( $\mu\text{S}/\text{cm}$ )	$\frac{100 \times (C_{after} - C_{ref})}{C_{ref}}$ (%)	Limit (%)	Within Limits (Y/N)
Conductivity C1				$\pm 2.0$	
Conductivity C2				$\pm 5.0$	

Conductivity Calibration Factor Limits			
Calibration Factors	Factor	Limit	Within Limits (Y/N)
C1 Multiplier1		0.095 - 0.105	
C1 Adder1		-5.000 - 5.000*	
C2 Multiplier2		0.095 - 0.105	
C2 Adder2		-5.000 - 5.000*	

Name (printed)	
Signature	
Date	
Comments	

\* The Conductivity Adder factor typically set to 0.000 and it is the Conductivity Multiplier that is adjusted during calibration.

## Worksheet 8: TOC Calibration and Verification

Check if not applicable

	Reference TOC <sub>ref</sub> (ppb)	TOC <sub>after</sub> (ppb)	TOC <sub>ref</sub> - TOC <sub>after</sub> (ppb)	Limit (ppb)	Within Limits? (Y or N)
TOC, 500 ppb				±50	
TOC, 250 ppb				±25	
TOC Calibration Factors	Multiplier1 Multiplier2			Adder1 Adder2	
Lamp Life (hrs)					
Name (printed)					
Signature					
Date					
Comments					

## 13. Appendix 1: Calibration Process

The Thornton 4000TOC Total Organic Carbon Sensor and M300TOC transmitter measure the amount of organic carbon in high purity waters by oxidizing organic carbon to CO<sub>2</sub> with appropriate UV radiation. The resulting increase between two temperature-compensated conductivity measurements of the sample flow stream at points before and after the oxidation process is used to calculate the amount of organic carbon present. The complete calibration of the 4000TOC Sensor consists of calibration of the following.

- flow rate sensor measurement
- two temperature sensor measurements
- two conductivity sensor measurements
- TOC measurement

### 13.1. Scope

This document provides procedures to calibrate the Thornton 4000TOC Total Organic Carbon Sensor (PN's 58 036 021 and 58 036 022). The 4000TOC Sensor is used with the Thornton M300TOC transmitter. Calibration of the M300TOC transmitter is described in separate documentation.

This document provides strategies for the frequency and content of "As Found" data and the calibration process with respect to lamp changes and performing System Suitability Tests (SST) to meet specific pharmacopeial requirements.

### 13.2. Sequence of Operations for Calibration, SST and Lamp Changes

When performing a calibration, the sequence of operations depends on other process decisions. For example:

- If a lamp change is intended, does "As Found" data need to be collected?
- Is an SST scheduled during this time?
- If an SST is required, does "As Found SST" data need to be collected?
- Is a TOC calibration required, or is a full calibration for TOC, conductivity, and temperature required.

Determination of answers for these questions, as shown in the flowchart, will determine the sequence of operations. The answers are determined by the users of this instrumentation, but the following is recommended by Thornton as a minimum service cycle.

**Table 1. Scheduled Calibration, Lamp change, and SST Service**

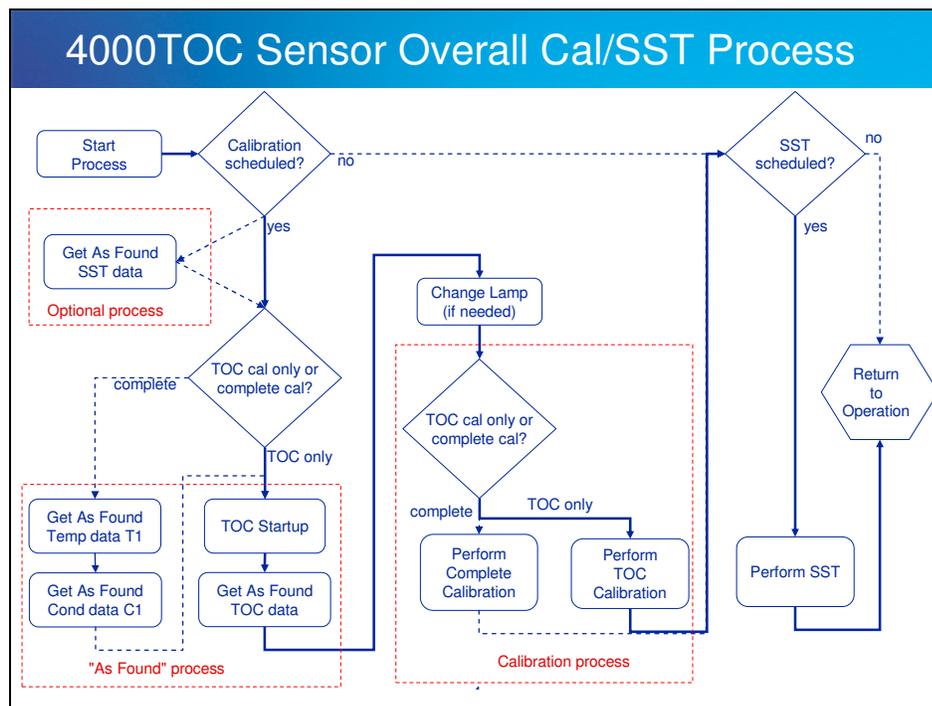
Maintenance	Frequency/Schedule	Recommendations/Comments
Replace lamp	4500 hours of lamp operation or 1 calendar year, whichever is shorter.	<ul style="list-style-type: none"> <li>• TOC Calibration recommended after lamp change.</li> <li>• SST recommended after lamp change (where SST is required). Refer to SST Standard Operating Procedure.</li> </ul>
TOC Calibration	As determined by user.	<ul style="list-style-type: none"> <li>• Recommended after lamp change, not to exceed 1 calendar year.</li> </ul>
Complete Calibration (includes flow, TOC, conductivity, temperature)	As determined by user.	<ul style="list-style-type: none"> <li>• Recommended not to exceed 1 calendar year.</li> </ul>
System Suitability Test (SST)	As determined by user.	<ul style="list-style-type: none"> <li>• Recommended after lamp change, not to exceed 4500 hrs operation.</li> </ul>

\*See USP <643> and EP 2.2.44

### 13.3. Summary of Calibration Process

1. Determine if the TOC measurement or all measurements will be calibrated.
2. Collect all equipment.
3. Install equipment and tubing.
4. Fill out Worksheet 1: Unit Under Test Information.
5. Fill out Worksheet 2: Reference Equipment Information.
6. If TOC only calibration is to be performed, go to step 8 if as found data is required, or step 16 if as found data is not required.
7. Fill out Worksheet 3: As Found Data for T1 and C1. If required, get As Found T1 and C1 data. Get As Found T1 and C1 Calibrations Factors.
8. Fill out Worksheet 4: As Found Data for TOC. If required, get As Found TOC data. Get As Found TOC Calibrations Factors.
9. If required, change lamp.
10. If TOC only calibration is to be performed, go to step 16.

11. Fill out Worksheet 5: Flow Rate Verification and Calibration. Perform Flow Rate Verification. If acceptable, to go to step 12. Otherwise, perform Flow Rate Calibration, then perform Flow Rate Verification.
12. Fill out Worksheet 6: Temperature Sensor Verification and Calibration. Perform T1 Calibration. This step may be skipped if the T1 As Found was acceptable. Verify T1 Calibration factors are acceptable.
13. Continue with Worksheet 6: Temperature Sensor Verification and Calibration. Perform T2 Calibration. Verify T2 Calibration factors are acceptable.
14. Fill out Worksheet 7: Conductivity Sensor Verification and Calibration. Perform C1 Calibration. This step may be skipped if the C1 As Found was acceptable. Verify C1 Calibration factors are acceptable.
15. Continue with Worksheet 7: Conductivity Sensor Verification and Calibration. Perform C2 Calibration. Verify C2 Calibration factors are acceptable.
16. Fill out Worksheet 8: TOC Calibration and Verification. Perform TOC Calibration with 250 ppb and 500 ppb TOC solutions. Record all as Found TOC Calibrations Factors for reference. This step may be skipped if the TOC As Found was acceptable.
17. Restore unit to operation or perform SST, as required.

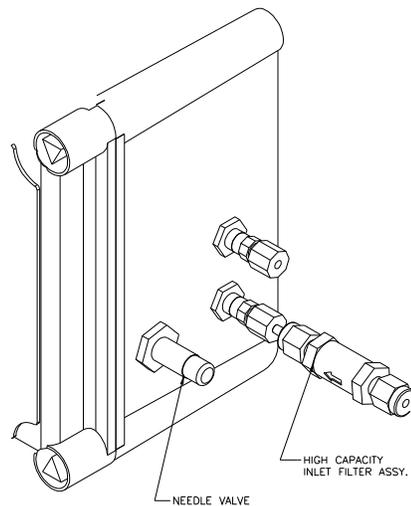


## 14. Appendix 2 - Setting Sample Flow Rate

At various times during the calibration of TOC, the flow rate needs to be set using this procedure. This is an informational section. This section is only required as needed.

### 14.1. Flow Rate Adjustment Procedure

1. During the calibration process, the M300 Transmitter will automatically enter the 'Set Flow Mode'. To manually enter Set Flow mode, proceed as follows:
  - a. Press Menu.
  - b. Press ▲ or ▼ to select the Configure menu and press Enter.
  - c. Press ▲ or ▼ to select the TOC Setup menu and press Enter.
  - d. Press ▲ or ▼ to select the TOC General Para menu and press Enter.
  - e. Press Enter to accept and bypass the options for Sensor Keylock and Autostart. The Set Flow Rate control option will now be displayed.
  - f. Press ▲ or ▼ to select Yes, and activate the Set Flow mode. This immediately initiates the Set Flow Rate mode at the sensor. It will stay in this mode until the user changes the "Set Flow: Yes" back to "Set Flow: No". If the user does not set the flow rate once the Set Flow Rate mode has been initiated, the M300 will time out, at which time the mode automatically goes back to "Set Flow: No" and the instrument returns to the measurement display screen.
2. See Figure 5. The flow rate is set by adjusting the needle on the 4000TOC Sensor. NOTE: Clockwise (CW) to decrease flow, counterclockwise (CCW) to increase flow.



**Figure 5. Needle Valve Location**

3. In this mode, the LEDs on the front cover of the 4000TOC Sensor act as a bar-graph indicator as described according to Figure 6.
4. Adjust the inlet Needle Valve until three or four LEDs light on the 4000TOC for at least 30 seconds.
5. If a calibration is in progress, then press Enter to advance to the next calibration step. If Set Flow mode was entered manually, go to the M300 and change "Set Flow: Yes" to "Set Flow: No". The flow rate setting operation is now complete.

## 14.2. Flow Rate Indication

The flow rate value is indicated by the four LEDs (lights) on the front of the 4000TOC Sensor.

Fault	●	
Error	●	
Sensor Status	●	
UV Lamp On	●	

● = LED illuminated      ○ = LED not illuminated

When the flow rate is at 20 mL/min ( $\pm 2.5\%$ ), all four LEDs will be on. This is acceptable.

When the flow rate is at 20 mL/min ( $\pm 7.5\%$ ), the top three LEDs OR the bottom three LEDs will be on. This is acceptable.

If the flow rate is too high, the top two LEDs will be on. Turn the adjustment knob clockwise.

If the flow rate is too low, the bottom two LEDs will be on. Turn the adjustment knob counterclockwise.

If the flow rate is far from 20 mL/min, only the top (Fault) LED or the bottom (UV Lamp) LED will be on.

As the flow rate approaches the correct value, more LEDs will turn on. For example, if the flow rate is too high, as the adjustment knob is turned clockwise, first the Fault LED will be on, then the Fault and Error LEDs will be on, then the Fault, Error and Sensor Status LEDs will be on and finally all four LEDs will be on when the flow rate is 20 mL/min ( $\pm 2.5\%$ ).

	Very LOW	LOW	NEAR SET	SET	NEAR SET	HIGH	Very HIGH
Fault	○	○	○	●	●	●	●
Error	○	○	●	●	●	●	○
Sensor Status	○	●	●	●	●	○	○
UV Lamp On	●	●	●	●	○	○	○

● = LED illuminated      ○ = LED not illuminated

**Figure 6. LED Indicator for Flow rate**





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