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# DAQ-13-007.1 Standard Operating Procedure (SOP)
# Teledyne-API Model T700U Calibrator Certification / Verification

## Revision 2.0

## 1.0 APPROVAL SIGN-OFF SHEET

I certify that I have read and approve of the contents of the Teledyne-API Model T700U Calibrator Certification / Verification Standard Operating Procedure with an effective date of June 3, 2022.

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Disclaimer: This document, and any revision hereto, is intended solely as a reference guide to assist individuals in the operation of the instrument, related to the North Carolina Division of Air Quality's Ambient Monitoring Program.

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## 2.0 SCOPE AND PURPOSE

The Teledyne-API Model T700U Dynamic Dilution Calibrator supplies precise levels of ozone, carbon monoxide, non-methane hydrocarbons, sulfur dioxide, nitric oxide, and nitrogen dioxide. The gas levels are used to calibrate instruments that perform zero, precision and Level 1 span checks, audits, and multi-point calibration of these gases. For detailed operational procedures and maintenance procedures, consult the Model T700U Instruction Manual (Operation Manual, Model T700U Dynamic Dilution Calibrator, 6 October 2010 and Model T700UCalibrator, Addendum to T700U Manual, 6 Oct 2010, 36876 Rev A).

The T700U "audit calibrator" must be certified every twelve (12) months and the "site calibrator" certifications must be completed every twelve (12) months.

The Alicat 10 M-SLPM (site calibrators) or the 20 M-SLPM (audit calibrators) mass flow meters are used to certify the T700U 10 LPM (site calibrators) and 20 LPM (audit calibrators) zero air mass flow controllers respectively. The Alicat 50 M-SCCM mass flow meter is used to certify the 50 SCCM gas mass flow controller of the calibrator and the 100 M-SCCM mass flow meter is used to certify the 100 SCCM gas mass flow controller of the calibrator.

The required period for calibration / certification for any Alicat mass flow device(s) is once every year. A label located on the back of the meter lists the calibration / certification due date. All meters should be returned to the factory for recalibration annually. Before calling to schedule a recalibration, note the Serial Number on the back of the meter.

All certification equipment mut be traceable to National Institute of Standards and Technology (NIST). A 'Certificate of Analysis' must accompany each piece of equipment. These certificates should be kept in a central file located at the ECB. Logbook records for the Alicat(s) will include the certifications and the complete repair records for the instrumentation.

All original records (electronic logbook, equipment logbook, etc.) must be legible, complete, dated and signed or initialed by the Electronics and Calibration Branch (ECB) technician and retained as a part of the permanent equipment record. The ECB technician's name and/or initials presented in the equipment logbook will certify that the activities indicated have been performed in accordance with this SOP and that the information contained on the form is accurate.

The calibration / verification consists of many processes which include:

- Leak Test
- Internal Pressure Sensors check
- Ultraviolet (UV) Source Lamp Intensity check
- Calibration of Mass Flow Controllers (3)
- Photometer Calibration

## 3.0 EQUIPMENT CHECKS AND MATERIALS

This section describes the equipment and materials that are required to complete the steps described in this document.

### 3.1 Equipment and Material List

- Teledyne-API Model T700U Calibrator (*The T700U calibrator should be set-up and equilibrated for 24 hours prior to the calibration / verification procedure)*
- Alicat 10 M-SLPM-D mass flow meter (see note below)
- Alicat 20 M-SLPM-D mass flow meter (see note below)
- Alicat M-50SCCM-D mass flow meter (see note below)

- Alicat M-100SCCM-D mass flow meter (see note below)
- Suitable air source capable of delivering 30 pounds per square inch (psi) air
- Thermo Model 49i-PS Ozone (O3) Calibrator (primary standard, set to average at 180 seconds)
- *APIcom* software installed on a connected computer, (optional)
- Hand tools (5/16-inch wrench or #6 nut driver)
- Swagelok fittings (Caps. Plugs, etc.)
- Data collection system (Data Logger, DAS, etc.)
- Excel T700U Calibrator Calibration and Verification Spreadsheet (hereafter referred to as Excel Workbook)

All certification equipment must be traceable to NIST. A 'Certificate of Analysis' must accompany each piece of equipment. These certificates should be kept in a central file located at the ECB. Logbook records for the Alicat(s) will include the certifications and the complete repair records for the instrumentation.

**NOTE:** The required period for calibration / certification for any Alicat mass flow device(s) is once every year. A label located on the back of the meter lists the calibration / certification due date. All meters should be returned to the factory for recalibration annually. Before calling to schedule a recalibration, note the Serial Number on the back of the meter.


**Figure 3.1 T700 Calibrator Display Screen**

## 4.0 LEAK CHECK

A leak check must be performed prior to the Certification procedure. (See pg. 221 of the User's Manual)

### 4.1 Set-up for Leak Check

1. Remove the cover from the Calibrator

2. Bypass the photometer flow sensor printed circuit assembly (PCA) and pump as follows *(see Figure 4.1 for reference)*
3. Remove the hexagonal nut located at the top of the Photometer Gas outlet of the photometer (see *Figure 4.1*)

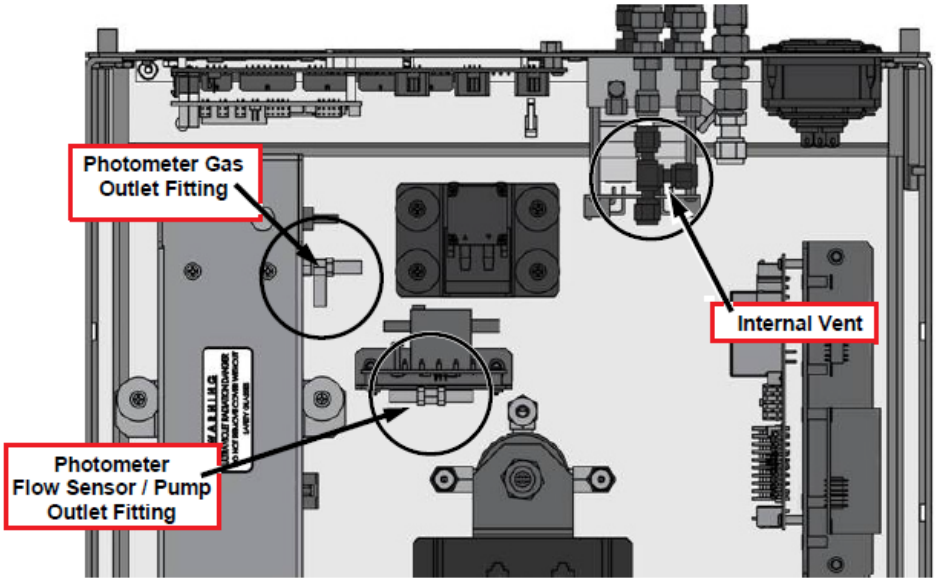



**Figure 4.1 Photometer Sensor PCA and Pump**

4. Remove the hexagonal nut located on the fitting on the back side of the Flow Sensor / Pump Outlet fitting *(Figure 4.1)*
5. Connect the end of the line removed from the Flow Sensor / Pump Outlet to the Photometer Gas Outlet fitting.
6. Securely cover the outlet of the Internal Vent, located just behind the valve relay PCA, using an 1/8” cap. (Normally vented internally)
7. Securely cover the outlet of the following gas outlet ports on the back of the T700U (see Figure 4.2 for reference) using a 1/4” cap.
   - The EXAHUST
   - Both CAL GAS outlet ports
   - The VENT port
8. Connect a delivery line from the zero-air gas source capable of delivering 30 psi to the Diluent IN and to the CYL1 port using a “T” type pneumatic fitting (*see Figure 4.2*).

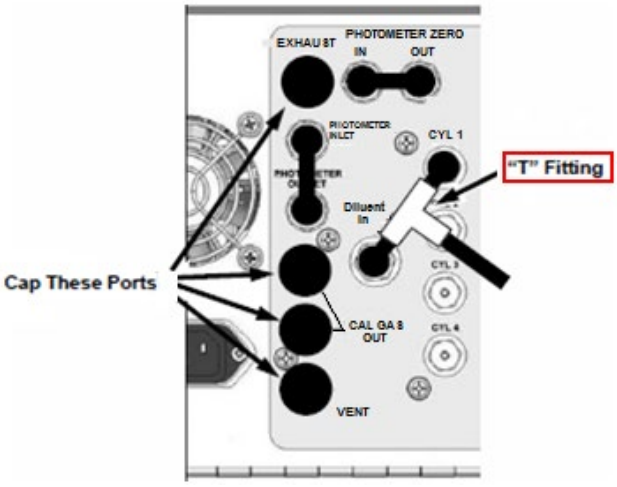
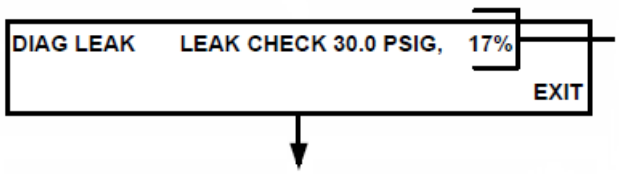



**Figure 4.2 Rear Panel Gas Port Setup for Auto-Leak Check Procedure**

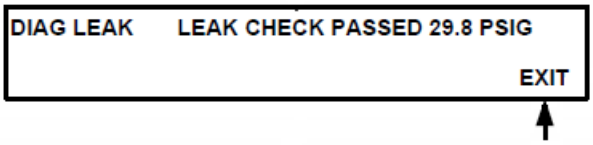
## 4.2 Perform an Auto Leak Check

1. Using the front panel of the calibrator, verify the calibrator is in the STBY mode, if not press STBY>
2. Select SETUP > MORE > DIAG> toggle the left most buttons to enter the default password (818) then press ENTR>.
3. Select NEXT until the AUTO LEAK CHECK option can be selected, then press ENTR> – the leak check runs automatically.

**NOTE:** At 17% of the elapsed time, the auto leak check program shuts the DILUENT IN and CYL1 port valves, then measures the total drop in internal gas pressure (if any) for the duration of the test. A drop of ≥ 2 pounds per square inch gauge (psig) causes the test to FAIL. Run time for the Auto Leak Check is approximately 5 minutes.




4. If the leak check fails logical problem solving is needed to find the source of the leak and correct. Typical places leaks develop over time include:
   - O3 generator lamp – check the base, at the electrical sleeves, and at the connector
   - Tubing - check for wear or rubs
   - Mass flow controllers, pressure and flow sensors, and other devices as well as the tightness of fittings. *(See Figure 4.3 for mass flow controller (MFC) layout and flow directions)*
5. Repeat the leak check procedure until no leaks are detected.
6. Select EXIT when finished



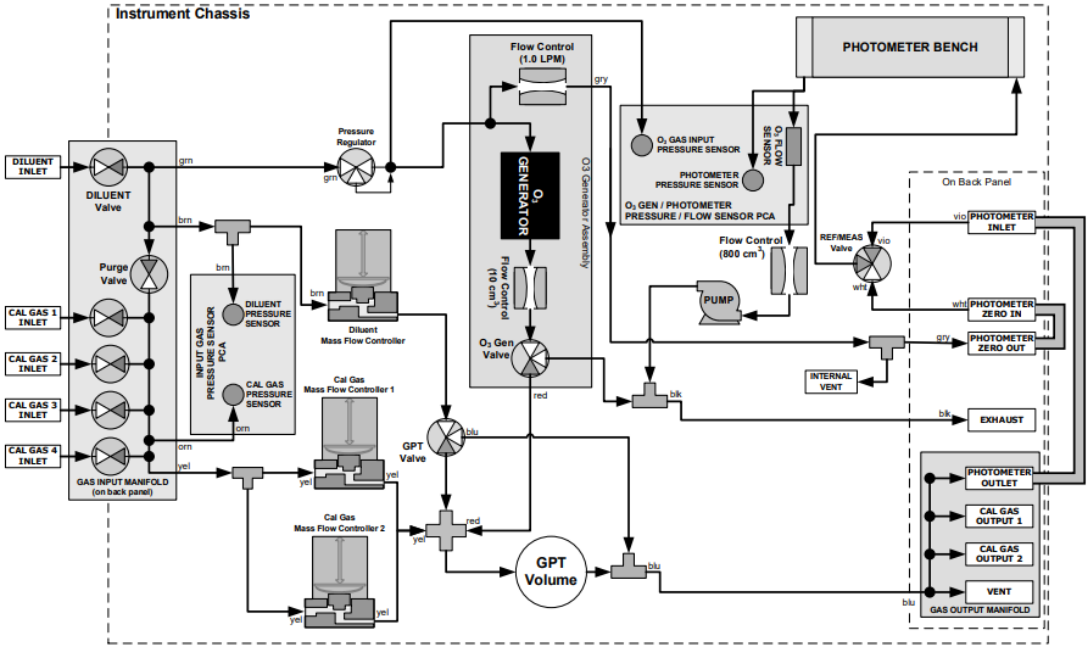



**Figure 4.3 Internal Pneumatics with All Options Installed**
(T700U, 3 MFC; T700, O3 Generator, Photometer and Gas Phase Titration (GPT) Chamber)

7. Remove the caps from the EXHAUST, VENT, CAL GAS OUTPUTS (2) ports and from the Internal Vent.
8. Carefully, reconnect the internal gas lines so that the Sensor PCA and pump are functional – these fittings are brass and can be stripped easily.
9. Assure a connection of a zero-air source to the DILUENT IN and CYL1 ports at 30 pisg.
10. Replace the calibrator's top cover and proceed.

## 4.3 Internal Pressure Sensors Check

The T700U calibrator has several sensors that monitor the pressure of the gases flowing through the instrument. The data collected by these sensors is used to compensate the final concentration calculations for changes in atmospheric pressure and is stored in the memory of the central processing unit (CPU) as a variable (VARS) test function. Verify that all internal pressure sensors are reading correctly. (See section 7.5 of the User's Manual).

Using an accurate pressure gauge capable of measuring a change of 0.1 psi.

1. Using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> 818 (password) ENTR> NEXT> until Pressure Calibration is displayed on the Param Ribbon then press ENTR>.
2. DIL_PRES (diluent gas pressure) is displayed – using the front panel of the calibrator or *APIcom* adjust if needed, record passing psi, then press ENTR>.
3. CAL_GAS_PRES (calibration gas pressure) is displayed on the Param Ribbon – using the front panel of the calibrator or *APIcom* adjust if needed, record passing psi, then press ENTR>.
4. O3_PRES (Ozonator pressure) is displayed on the Param Ribbon. Connect a certified monometer to the pressure regulator of the ozonator. The pressure should be 8 ±5 psi as specified in the "T700U Final Calibrated Test and Validation Data Spec Sheet as provided by the manufacturer (See Appendix E for example). Using the front panel of the calibrator or *APIcom* adjust if needed, record passing psi, then press ENTR>.

5. SAMP_PRESS (Sample pressure) should be equal to ambient pressure ±1 inch of mercury of the room pressure – using the front panel of the calibrator or *APIcom*, adjust as needed, the press ENTR>.
6. Press EXIT to return to the STBY screen.

## 4.4 UV Source Lamp Intensity Check

Using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> 818 (password) ENTR> SIGNAL I/O> ENTR> NEXT> or use the JUMP function until 53) PHOTO_DET is displayed in millivolts (mV). The mV value displayed should be between 2500 – 4800 mV. If lamp adjustment is needed reference Section 8.2.3 of the User's Manual for detailed procedures and options.

If the value displayed <2500 mV an adjustment to the UV Lamp should be completed. (See Section 8.1 of this SOP for a detailed procedure.)

## 4.5 Defaulting the Calibration Points (MFC Full Scale Flows)

The dilution mass flow controller for site calibrators has a range of 0 – 10 standard liters per minute (SLPM) and the dilution mass flow controller for the audit calibrators has a range of 0 – 20 SLPM. The term DIL1 will be used for either dilution mass flow controller – the ranges should be applied accordingly.

1. Using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> 929 (password) ENTR> NEXT> until MFC CONFIGURATION appears then press ENTR>.
2. Scroll through the menu and reset the values as follows:
    - DIL1:10.000 LPM Flow Range (site calibrator) or 20.000 Flow Range (audit calibrator), press EDIT> EDIT> Respond Yes to the prompt (Reset Table?) then press ENTR> then SET> DIL1 Slope should appear in the Param Ribbon.
    - DIL1 Slope – Edit to 1.000 then press ENTR> then SET>
    - DIL1 Offset – Edit to 0.000 LPM then press ENTR> then SET>
    - DIL1 Sensor Offset – Edit to 0.000 mV then press ENTR> then SET>
    - DIL1 Precision:3 – leave unchanged (value is expressed in liters per minute (LPM) but units are not shown) press SET> to advance in the menu.
    - DIL1 Table – press EXIT> to accept the changes. (Pressing EXIT> allows the user to check that the values were defaulted if desired.) (If the table is defaulted correctly the values will correspond to the values listed in the table included in Appendix A for the MFC being defaulted).
3. DIL1 10:10.000 LPM will appear in the Param Ribbon. Use the SET> key to advance the calibrator to the CAL1 menu.
4. Repeat Step 2 above to reset the CAL1 default values as listed below:
    - CAL1_Flow Range is 0.1000 LPM and
    - CAL1 Slope = 1.000
    - CAL1 Offset = 0.000
    - CAL1 Sensor Offset = 0.000
    - CAL1_Precision:4
    - CAL1 Table – press EXIT> to accept the changes. (Pressing EXIT> allows the user to check that the values were defaulted if desired.) (If the table is defaulted correctly the values will correspond to the values listed in Appendix A table for the MFC being defaulted).
    - The user can repeat to confirm that the values in CAL1 Table were defaulted or reset.

5. CAL1: 0.1000 LPM will appear in the Param Ribbon. Use the SET> key to advance the calibrator to the CAL2 menu.
6. Repeat Step 2 above to reset the CAL2 default values as listed below:
    - CAL2_Flow Range is 0.0500 LPM
    - CAL2 Slope = 1.000
    - CAL2 Offset = 0.000
    - CAL2 Sensor Offset = 0.000.
    - CAL2_Precision:4
    - CAL1 Table – press EXIT> to accept the changes. (Pressing EXIT> allows the user to check that the values were defaulted if desired.) (If the table is defaulted correctly the values will correspond to the values listed in Appendix A table for the MFC being defaulted).
    - The user can repeat to confirm that the values in CAL2 Table were defaulted or reset.

## 4.6 MFC Potentiometer Adjustments (Zero)

For adjustments to the Zero potentiometer of *each* MFC (dilution and gas) the output of *each* MFC must be capped/plugged. See Figure 4.4 for location of the Zero potentiometer adjustment.

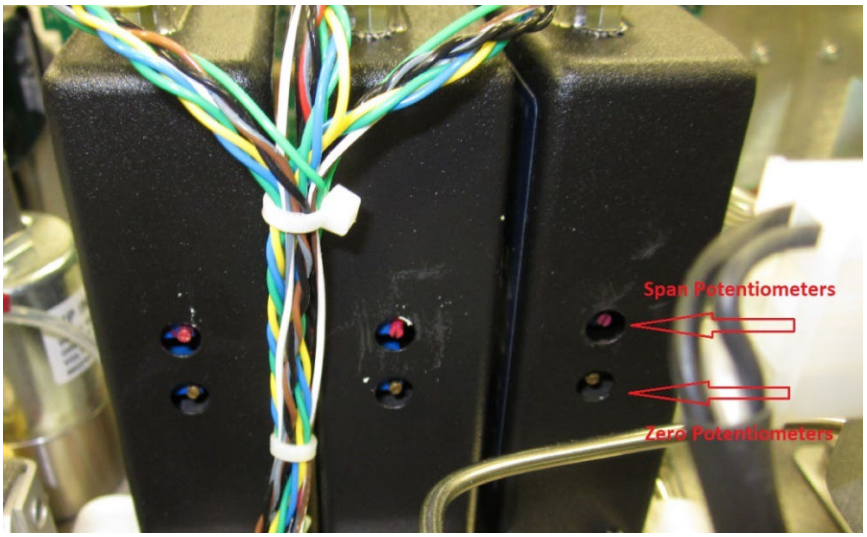



**Figure 4.4 Zero and Span Potentiometers for Mass Flow Meters**

1. Using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> 929 (password) ENTR> SIGNAL I/O> JUMP TO> and enter 62 entr> MFC_FLOW_1 (DIL1 0 – 10 or 20 LPM) will be displayed on the Param Ribbon
2. Adjust the zero potentiometer of the selected MFC until the mV value is less than 5 mV and the value is not negative then press NEXT>
3. The calibrator will display 63) MFC_FLOW_1 (CAL1 100 cc/min) in the Param Ribbon.
4. Adjust the zero potentiometer of the selected MFC_FLOW_1 until the mV value is less than 5 mV and the value is not negative then press < PREV or JUMP to display 58) ENTR>.
5. MFC_FLOW_2 (CAL2 50 cc/min) will be displayed on the Param Ribbon – Adjust the zero potentiometer of the selected MFC until the mV value is less than 5 mV and the value is not negative then press EXIT> until STBY is displayed.
6. Remove all caps from the MFC's

## 4.7 MFC Potentiometer Adjustments (Span)

For adjustments to the Span potentiometer of each MFC the output of the MFC must be connected to an Alicat of appropriate range for the MFC being adjusted. (A delivery line from a zero-air gas source capable of delivering 30 psi has already been established in Section 4.0) See Figure 4.4 for location of the Span potentiometer adjustment.

1. Connect the Alicat, cap the end and TARE the device until a stable TARE is achieved, then remove cap from the Alicat in use. (Appendix D provides the manufacturer's instructions for taring the device.)
2. Using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> SETUP > 929 (password) ENTR> NEXT> until MFC CONFIGURATION is displayed on the Param Ribbon, then press ENTR>.
3. Using the SET key advance to the DIL1 10.000 LPM is displayed, then press EDIT>.
4. Press the set> key until DIL1 Table is displayed, then press EDIT> then NEXT>.
5. Advance in the table until DIL1[20] is displayed.
6. Turn flow ON (Pressing OFF will turn the flow ON) ***NOTE:*** *there is a delay (up to 1 minute) for the mass flow controller in use to deliver flow when the flow controller is turned ON initially during this procedure.*
7. Allow the mass flow output value of the Alicat to stabilize (~10 – 15 minutes), adjust the Span potentiometer of the DIL1 MFC until the target value of 10.000 LPM ±5 cubic centimeters per minute (cc/min) (site calibrator) or 20.000 LPM ±10 cc/min (audit calibrator) is achieved.
8. When the SPAN for the DIL1 MFC Potentiometer has been adjusted, turn the flow OFF and proceed to the other MFCs installed in the calibrator.
9. Repeat Steps 1 through 8 to adjust the Span for CAL1, setting the target flow to 101.0 cc/min ± 0.5 cc/min.
10. Repeat Steps 1 through 8 to adjust the Span for CAL2, setting the target flow to 51.0 cc/min ± 0.5 cc/min.

**NOTE:** CAL1 and CAL2 target values are set slightly higher so that a total flow of 100 cc/min and 50 cc/min can be achieved if needed without causing an alarm/failure.

# 5.0 T700U DILUTION AIR MASS FLOW CONTROLLER – SITE CALIBRATOR

Calibration of the dilution mass flow controller must be followed by the Sensor Offset adjustment, then a verification. All air flow must go through the dilution solenoid DIL1 during the calibration / adjustment / verification procedure. The steps for calibration / adjustment / verification of audit calibrators are the same as for a site calibrator however the flow setpoints are different. Appendix F of this SOP details the differences in the flow settings and procedures. Separate tabs withing the Excel workbook have been created for recording DIL1 20 SLPM MFC calibration / adjustment / verification data for the audit calibrators.

## 5.1 T700U Zero Air Mass Flow Controller (DIL1) Calibration (Site Calibrator)

The term certification (calibration and verification) means determining the actual flow versus the flow settings for the calibration points. A table exists in the memory of the T700U for each mass flow controller that sets the output of the mass flow controller at each of 20 control points along its entire performance range. This table may be accessed in the calibrator via the DIAG> MFC CONFIGURATION submenu. For each certification point, the following is displayed:

- The drive voltage in 20 equal, incremental steps from 0.0 mV to 5000 mV.
- The expected flow rate corresponding to each drive voltage point (each equal to 1/20$^{th}$ of the full scale for the selected mass flow controller).

See Appendix A for the default Calibration point, drive voltage and corresponding flow within the calibrator menu for each mass flow controller. The table can also be used to calibrate the output of the mass flow controllers by adjusting either the control voltage of a point or its associated flow output value (See Section 7.2 of the User's Manual).

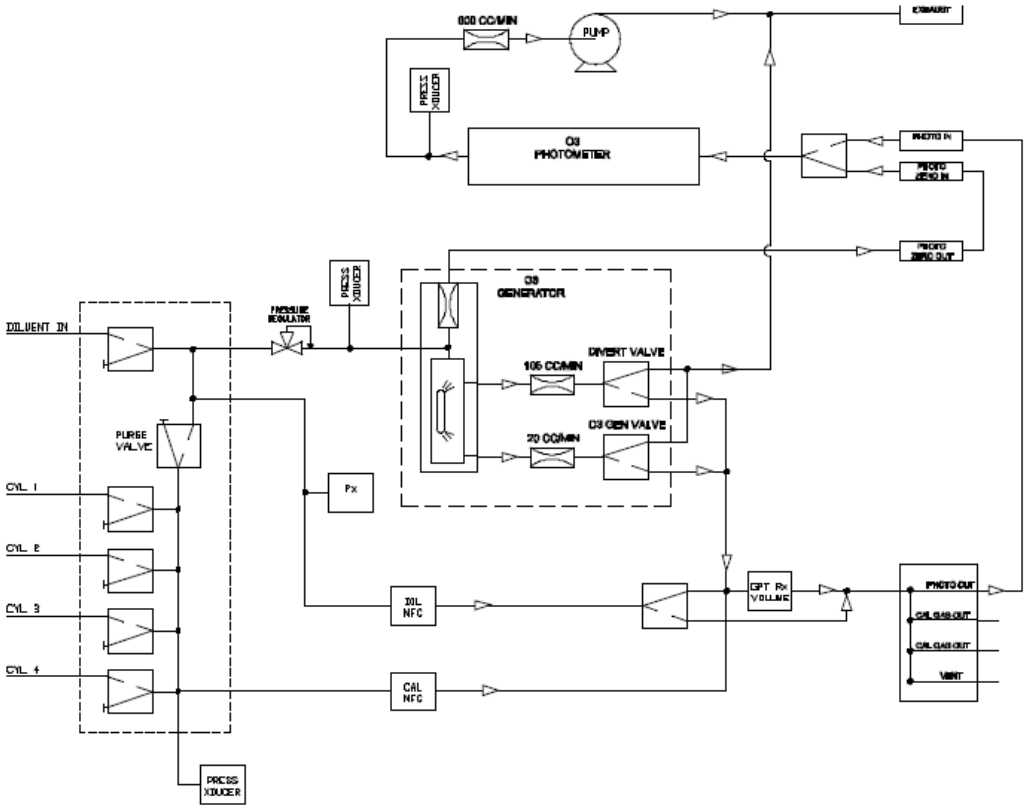



**Figure 5.1 T700U MFC Layout**

1. Confirm the T700U is connected to a suitable zero air source, set to deliver 30 psi of air.
2. Confirm the MFC flow points were defaulted (See Section 4.5 of this SOP) using the DIAG menu as follows:
    - DIL1 = 10.000 LPM (20.000 LPM for audit calibrator)
    - CAL1 = 0.100 LPM (100 cc/min)
    - CAL2 = 0.050 LPM (50 cc/min)
3. Connect power to the Alicat mass flow meter being used an allow the instrument to stabilize (~ 5 minutes)
4. If using a data collection system (DAS, data logger, etc.) connect both the Alicat and the Calibrator to the data collection system.
5. Using the Alicat mass flow meter, perform an initial flow tare by pressing the button labeled “TARE” for approximately 5 seconds (*see Figure 5.2*). This action tares the flow meter and provides the mass flow meter a reference point for zero flow. (Appendix D provides the manufacturer’s instructions for taring the device.)

**NOTE:** It is a good practice to “TARE” the Alicat mass flow meter each time it is powered up. It is critical to have a stable tare before starting any flow certification procedure. If the flow reading varies significantly from zero after an initial TARE (10/20 LPM mass flow meter = 3 cc/min) allow more time for the instrument to warm up then repeat the TARE process.

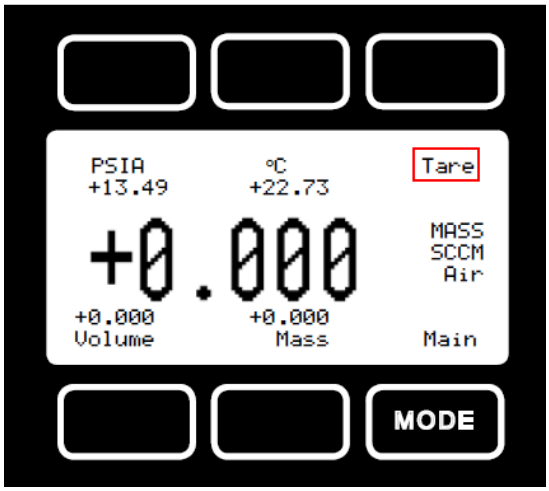



**Figure 5.2 Alicat Mode Screen**

6. When the Alicat TARE is stable, remove the cap and connect the Alicat to the T700U calibrator mass flow controller being certified, observing the correct flow direction.
7. Using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> 929 (password) ENTR > press NEXT> until MFC CONFIGURATION is displayed on the Param Ribbon, then press ENTR>.
8. Press EDIT> SET> until DIL1 Table is displayed in the Param Ribbon, then press EDIT> NEXT> DIL1[1] DRV = 250 FLW = 0.500 is displayed, then press ON to initiate flow through the mass flow controller. (Pressing OFF will turn the flow ON) ***NOTE:*** *there is a delay (up to 1 minute) for the mass flow controller in use to deliver flow when the flow controller is turned ON initially during this procedure.*
9. Once the flow has stabilized (~10 minutes) record the 5-minute average value using the calibration spreadsheet
10. Using the front panel of the calibrator or *APIcom* click NEXT> to advance to the next pre-set drive voltage/flow in the calibration points table. See Appendix A for the default mass flow controller calibration points specific for each mass flow controller. Once the flow has stabilized (~10 minutes) record the 5-minute average values using the Excel Workbook, DIL1 10 SLPM MFC tab. Repeat this step for all 20 drive voltage settings and recording average values.
11. Once completed, turn OFF the flow then EXIT>.
12. Manually enter the recorded flow values into the DIL1 table stored in the calibrator, beginning with DIL1 FLOW [20] > ENTR> then press PREV> until all flows have been edited, making sure the drive voltages correspond with the measured flows. Press EXIT> and Y> at the prompt to save the changes.

## 5.2 T700U Zero Air Mass Flow Controller (DIL1) Sensor Offset Adjustment (Site Calibrator)

Sensor Offset adjustment is a procedure used to adjust the actual flow to the target flow. The procedure compares the Calibrator flow to the actual Alicat flow. Values are averaged across the collected flow readings and converted into a millivoltage.

1. Using the front panel of the calibrator or *APIcom* select SETUP> GAS> CYL> PRT1> ENTR>.
2. The NO cylinder concentration will be displayed.
3. Press EDIT> press the “NO” key and scroll through the gas choices displayed until USR1 is displayed, then press ENTR> then EXIT>.

4. With the Alicat still connected to the DIL1 mass flow controller, cap the ends and TARE the device until a stable TARE is achieved, then remove caps. (Appendix D provides the manufacturer's instructions for taring the device.)
5. Using the front panel of the calibrator or *APIcom* select GEN> MAN> using left most key select "USR1" press ENTR>.
6. Set CAL gas flow to any value between 10 and 150 cc/min (75 cc/min is recommended)
7. Set Diluent Flow = 1000 cc ENTR>.
8. Leave O3 Gen mode OFF and press ENTR>.
9. Using <TST> key scroll through until A-DIL (actual dilution flow) is displayed on the Param Ribbon.
10. When stable, record the calibrator and Alicat flow readings using the Excel Workbook on the DIL1 Sensor Offset Adjustment tab.
11. Using the front panel of the calibrator or *APIcom,* advance to the next target Dilution flow setting GEN> MAN USR1> ENTR>, leaving the CAL gas flow unchanged, and setting the target Dilution flow to 3000 cc/min and again leaving the O3 Gen mode OFF and press ENTR>.
12. When stable, record the calibrator and the Alicat flow readings using the Excel workbook on the DIL1 Sensor Offset Adjustment tab.
13. Repeat for flow settings at 5000 cc/min, 7000 cc/min and 9000 cc/min, always leaving the CAL gas unchanged and the O3 Gen mode OFF.
14. Enter the values into the Excel Workbook, DIL1 Sensor Offset Adjustment tab to determine the DIL1 Sensor Offset value in millivolts.
15. Enter the DIL1 Sensor Offset value into the calibrator SETUP> MORE> DIAG> 929 (password) ENTR>.press NEXT> until MFC CONFIGURATION appears in the Param Ribbon then press ENTR>.
16. Scroll until the correct mass flow controller can be selected, press EDIT>, then press the SET> key until DI1 SENSOR OFFSET can be selected then press EDIT>.
17. Enter the DIL1 SENSOR OFFSET value (from Excel workbook) then press ENTR> then EXIT> until the value is saved. (The message "storing MFC properties will appear briefly on the Param Ribbon.) **Make sure the DIL1 Sensor Offset is being edited and *NOT* the DIL1 Offset.**
18. Once completed, turn OFF the flow then EXIT>.

## 5.3 T700U Zero Air Mass Flow Controller (DIL1) Verification (Site Calibrator)

1. With the Alicat still connected to the DIL1 mass flow controller, cap the output and TARE the device until a stable TARE is achieved, then remove cap. (Appendix D provides the manufacturer's instructions for taring the device.)
2. Using the front panel of the calibrator or *APIcom* select GEN> MAN> USR1> ENTR> set gas flow to 1000 cc ENTR> leave O3 Gen mode OFF and diluent flow unchanged then press ENTR>.
3. Using < TST > key scroll through until A-DIL (actual dilution flow) is displayed on the Param Ribbon.
4. When stable, record the calibrator and Alicat flow readings using the Excel workbook on the DIL10 SLPM MFC tab.
5. Using *APIcom* advance to the next target flow setting GEN> MAN> USR1> ENTR> setting the target flow to 3000 cc/min.
6. Repeat for flow settings at 5000 cc/min, 7000 cc/min and 9000 cc/min.
7. Enter the values into the certification Excel workbook to determine the percent error between the calibrator and the Alicat for each point. The percent error between each point should be less than 2% difference.
8. Once completed, turn OFF the flow then EXIT>.

## 6.0 T700U GAS MASS FLOW CONTROLLERS (CAL1 AND CAL2)

The Alicat M-50SCCM-D mass flow meter is used to certify the 50 SCCM gas mass flow controller of the calibrator and the M-100SCCM-D mass flow meter is used to certify the 100 SCCM gas mass flow controller of the calibrator. These mass flow controllers are identified as CAL1 and CAL2 in the calibrator. Calibration of each gas mass flow controller must be followed by the Sensor Offset adjustment of each and a CAL1 and CAL2 verification for the calibrator to be field ready for use. All air flow must go through the gas solenoid during the calibration / adjustment / verification procedure.

The term certification means determining the actual flow versus the flow settings for the calibration points. A table exists in the memory of the T700U for each mass flow controller that sets the output of the mass flow controller at each of 20 control points along its entire performance range. This table may be accessed in the calibrator via the DIAG > MFC CONFIGURATION submenu. For each certification point, the following is displayed:

- The drive voltage in 20 equal, incremental steps from 0.0 mV to 5000 mV.
- The expected flow rate corresponding to each drive voltage point (each equal to 1/20$^{th}$ of the full scale for the selected mass flow controller).

See Appendix A for the default Calibration point, drive voltage and corresponding flow within the calibrator menu for each mass flow controller. The table can also be used to calibrate the output of the mass flow controllers by adjusting either the control voltage of a point or its associated flow output value (See Section 7.2 of the User's Manual).

### 6.1 T700U Gas Mass Flow Controller (CAL1) Calibration

1. Confirm the T700U is connected to a suitable zero air source, set to deliver 30 psi of air.
2. Confirm the default of the MFC CONFIGURATION using the DIAG menu as follows:
    - CAL1 = 0.100 LPM (100 cc/min) (see Section 4.5)
3. Connect power to the Alicat mass flow meter being used and allow the instrument to stabilize (~ 5 minutes)
4. If using a data collection system (DAS, data logger, etc.) connect both the Alicat and the Calibrator to the data collection system.
5. Using the Alicat mass flow meter, perform an initial flow tare by pressing the button labeled "TARE" for approximately 5 seconds (See Figure 5.2). This action tares the flow meter and provides it with a reference point for zero flow. (Appendix D provides the manufacturer's instructions for taring the device.)

**NOTE:** It is a good practice to "TARE" the Alicat mass flow meter each time it is powered up. It is critical to have a stable tare before starting the air certification procedure. If the flow reading varies significantly from zero after an initial TARE (0.100 and 0.050 LPM mass flow meter = 3 cc/min) allow more time for the instrument to warm up then repeat the TARE process.

6. When the Alicat TARE is stable, remove the caps and connect the Alicat to the T700U calibrator mass flow controller being certified, observing the correct flow direction.
7. Using the front panel of the calibrator or *APIcom* select SETUP > MORE> DIAG > 929 (password) ENTR> NEXT> until MFC CONFIGURATION is displayed on the Param Ribbon, then press ENTR>.
8. Press EDIT> SET> until CAL1 Table is displayed in the Param Ribbon, then press NEXT> until CAL1 [1] DRV = 250 FLW = 5.000, then press ON (Pressing OFF will tun the flow ON) ***NOTE:*** *There is a delay (up to 1 minute) for the mass flow controller in use to deliver flow when the flow controller is turned ON initially during this procedure.*
9. Once the flow has stabilized (`10 min) record the 5-minute average value using the Excel workbook on the CAL1 100 SCCM MFC tab.

10. Using the front panel of the calibrator or *APIcom* click NEXT> to advance to the next pre-set drive voltage/flow in the calibration points table. See Appendix A for the default mass flow controller calibration points specific for each mass flow controller. Once the flow has stabilized (~10 min) record the 5-minute average values using the Excel workbook, CAL1 100 SLPM MFC tab. Repeat this step for all 20 drive voltage settings and recording average values.
11. Once completed, turn OFF the flow then EXIT>.
12. Manually enter the collected flow values into the CAL1 table stored in the calibrator, beginning with CAL1 FLOW [20] > ENTR> then press PREV> until all flows have been edited, making sure the drive voltages correspond with the measured flows. Press EXIT> and Y at the prompt to save the changes.

## 6.2 T700U Gas Mass Flow Controller (CAL1) Sensor Offset Adjustment

Sensor Offset adjustment is a procedure used to adjust the actual flow equal to the target flow. The procedure compares the Calibrator flow to the actual Alicat flow. Values are averaged across the data points collected and converted into a millivoltage.

1. Using the front panel of the calibrator or *APIcom* select SETUP> GAS> CYL> PRT1> ENTR>.
2. The NO cylinder concentration will be displayed.
3. Press EDIT> press the "NO" key and scroll through the gas choices displayed until USR1 is displayed, then press ENTR> then EXIT>.
4. With the Alicat still connected to the CAL1 mass flow controller, cap the ends and TARE the device until a stable TARE is achieved, then remove caps (Appendix D provides the manufacturer's instructions for taring the device).
5. Using the front panel of the calibrator or *APIcom* select GEN> MAN> using the left most key select "USR1" and press ENTR>.
6. Set CAL1 gas flow to 50.1 cc/min > ENTR> leave diluent flow unchanged and O3 Gen mode OFF then press ENTR>.
7. Using <TST> key scroll through until A-CAL is displayed on the Param Ribbon.
8. When stable, record the calibrator and Alicat flow readings using the Excel workbook, CAL1 Sensor Offset Adjustment tab.
9. Using the front panel of the *APIcom* advance to the next target flow setting GEN> MAN> USR1> ENTR> setting the CAL1 gas target flow to 60.0 cc/min, leaving the diluent flow unchanged and the O3 Gen mode OFF then press ENTR>.
10. When stable, record calibrator and the Alicat flow readings using the Excel workbook.
11. Repeat for flow settings at 70.0, 80.0, 90.0 and 100.0 cc/min always leaving the diluent flow unchanged and the O3 Gen mode OFF.
12. Enter the values into the Excel workbook, CAL1 Sensor Offset Adjustment tab to determine the CAL1 Sensor Offset value in millivolts.
13. Enter the CAL1 Sensor Offset value into the calibrator SETUP> MORE> DIAG> 929 (password) ENTR> MFC CONFIGURATION appears in the Param Ribbon then press ENTR>.
14. Scroll until the correct mass flow controller can be selected, press EDIT> then press the SET key until CAL1 SENSOR OFFSET can be selected then press EDIT.
15. Enter the CAL1 SENSOR OFFSET value (from workbook) then press ENTR> then EXIT> until the value is saved. (The message "storing MFC properties will appear briefly on the Param Ribbon.) **Make sure the CAL1 Sensor Offset is being edited and *NOT* the CAL1 Offset.**
16. Once completed, turn OFF the flow then EXIT>.

## 6.3 T700U Gas Mass Flow Controller (CAL1) Verification

1. With the Alicat still connected to the CAL1 mass flow controller, cap the ends and TARE the device until a stable TARE is achieved, then remove caps (Appendix D provides the manufacturer's instructions for taring the device).
2. Using the front panel of the calibrator or *APIcom* select GEN> MAN> USR1> ENTR> set gas flow to 50.1 cc ENTR> leave O3 Gen mode OFF and diluent flow unchanged then press ENTR>.
3. Using < TST > key scroll through until A-CAL is displayed on the Param Ribbon.
4. When stable, record the calibrator and Alicat flow readings using the Excel workbook CAL1 100 SCCM MFC tab.
5. Using *APIcom* advance to the next target flow setting GEN> MAN> USR1>ENTR> setting the target flow to 60 cc/min, when stable record the flow setting in the calibrator
6. Repeat for flow settings at 70 cc/min, 80 cc/min 90 cc/min and 100 cc/min, recording stable flow measurements after each flow setting.
7. Enter the values into the certification Excel workbook to determine the percent error between the calibrator and the Alicat for each point. The percent error between each point should be less than 2% difference.
8. Once completed, turn OFF the flow then EXIT>.

## 6.4 T700U Gas Mass Flow Controller (CAL2) Calibration

1. Confirm the T700U is connected to a suitable zero air source, set to deliver 30 psi of air.
2. Confirm the default of the MFC CONFIGURATION using the DIAG menu as follows:
    - CAL2 = 0.050 LPM (50 cc/min) (see Section 4.5)
3. Connect power to the Alicat mass flow meter being used and allow the instrument to stabilize (~ 5 minutes).
4. If using a data collection system (DAS, data logger, etc.) connect both the Alicat and the Calibrator to the data collection system.
5. Using the Alicat mass flow meter, perform an initial flow tare by pressing the button labeled "TARE" for approximately 5 seconds (See Figure 5). This action tares the flow meter and provides it with a reference point for zero flow. (Appendix D provides the manufacturer's instructions for taring the device.)

**NOTE:** It is a good practice to "TARE" the Alicat mass flow meter each time it is powered up. It is critical to have a stable tare before starting the air certification procedure. If the flow reading varies significantly from zero after an initial TARE (0.100 and 0.050 LPM mass flow meter = 3 cc/min) allow more time for the instrument to warm up then repeat the TARE process.

6. When the Alicat TARE is stable, remove the caps and connect the Alicat to the T700U calibrator mass flow controller being certified, observing the correct flow direction.
7. Using the front panel of the calibrator or *APIcom* select SETUP > MORE> DIAG > 929 (password) ENTR> NEXT> until MFC CONFIGURATION is displayed on the Param Ribbon, then press ENTR>.
8. Press EDIT> SET> until CAL2 TABLE is displayed in the Param Ribbon, then press NEXT> until CAL2 [1] DRV = 250 FLW = 2.50, then press ON (Pressing OFF will tun the flow ON) ***NOTE:*** *There is a delay (up to 1 minute) for the mass flow controller in use to deliver flow when the flow controller is turned ON initially during this procedure.*
9. Once the flow has stabilized (~10 minutes) record the 5-minute average value using the calibration spreadsheet.
10. Using the front panel of the calibrator or *APIcom* click NEXT> to advance to the next pre-set drive voltage/flow in the calibration points table. See Appendix A for the default mass flow controller calibration

points specific for each mass flow controller. Once the flow has stabilized (~10 minutes) record the 5-minute average values using the certification Excel workbook, CAL2 50 SLPM MFC tab. Repeat this step for all 20 drive voltage settings and recording average values.

11. Once completed, turn OFF the flow then EXIT>.
12. Manually enter the collected flow values into the CAL1 table stored in the calibrator, beginning with CAL2 FLOW [20] > ENTR> then press PREV> until all flows have been edited, making sure the drive voltages correspond with the measured flows. Press EXIT and Y at the prompt to save the changes.

## 6.5 T700U Gas Mass Flow Controller (CAL2) Sensor Offset Adjustment

Sensor Offset adjustment is a procedure used to adjust the actual flow equal to the target flow. The procedure compares the Calibrator flow to the actual Alicat flow. Values are averaged across the data points collected and converted into a millivoltage.

1. Using the front panel of the calibrator or *APIcom* select SETUP> GAS> CYL> PRT1> ENTR>.
2. The NO cylinder concentration will be displayed.
3. Press EDIT> press the "NO" key and scroll through the gas choices displayed until USR1 is displayed, then press ENTR> then EXIT>.
4. With the Alicat still connected to the CAL2 mass flow controller, cap the ends and TARE the device until a stable TARE is achieved, then remove caps. (Appendix D provides the manufacturer's instructions for taring the device).
5. Using the front panel of the calibrator or *APIcom* select GEN> MAN> using the left most key select "USR1" and press ENTR>.
6. Set CAL2 gas flow to 5.0 cc/min ENTR> leave diluent flow unchanged and O3 Gen mode OFF then press ENTR>.
7. Using <TST> key scroll through until A-CAL is displayed on the Param Ribbon.
8. When stable, record the calibrator and Alicat flow readings using the calibrator spreadsheet.
9. Using the front panel of the *APIcom* advance to the next target flow setting GEN> MAN>USR1> ENTR> setting the CAL2 gas target flow to 15.0 cc/min, leaving the diluent flow unchanged and the O3 Gen mode OFF then press ENTR>.
10. When stable, record calibrator and the Alicat flow readings using the calibrator worksheet.
11. Repeat for flow settings at 25.0, 35.0, and 45.0 cc/min always leaving the diluent flow unchanged and the O3 Gen mode OFF.
12. Enter the values into the Certification Excel workbook, CAL2 Sensor Offset tab to determine the CAL2 Sensor Offset value in millivolts.
13. Enter the CAL2 Sensor Offset value into the calibrator SETUP> MORE> DIAG> 929 (password) ENTR> MFC configuration ENTR>. MFC CONFIGURATION appears in the Param Ribbon then press ENTR>.
14. Scroll until the correct mass flow controller can be selected, press EDIT> then press the SET key until CAL2 SENSOR OFFSET can be selected then press EDIT>.
15. Enter the CAL2 SENSOR OFFSET value (from workbook) then press ENTR> then EXIT> until the value is saved. (The message "storing MFC properties will appear briefly on the Param Ribbon.) **Make sure the CAL2 Sensor Offset is being edited and *NOT* the CAL2 Offset.**
16. Once completed, turn OFF the flow then EXIT>.

### 6.6 T700U Gas Mass Flow Controller (CAL2) Verification

1. With the Alicat still connected to the CAL2 mass flow controller, cap the ends and TARE the device until a stable TARE is achieved, then remove caps (Appendix D provides the manufacturer's instructions for taring the device.)
2. Using the front panel of the calibrator or *APIcom* select GEN> MAN> USR1> ENTR> set gas flow to 5.0cc ENTR> leave O3 Gen mode OFF and diluent flow unchanged then press ENTR>.
3. Using < TST > key scroll through until A-CAL is displayed on the Param Ribbon.
4. When stable, record the calibrator and Alicat flow readings using the Excel workbook CAL2 50 SCCM MFC tab.
5. Using *APIcom* advance to the next target flow setting GEN> MAN> USR1> ENTR> setting the target flow to 15.0 cc/min; when stable record the flow setting in the calibrator.
6. Repeat for flow settings at 25.0 cc/min, 35.0 cc/min and 45.0 cc/min, recording stable flow measurements after each flow setting.
7. Enter the values into the certification Excel workbook to determine the percent error between the calibrator and the Alicat for each point. The percent error between each point should be less than 2% difference.
8. Once completed, turn OFF the flow then EXIT>.

## 7.0 PHOTOMETER CALIBRATION

The T700U calibrator photometer will be calibrated and verified against a Model 49i-PS ozone primary standard. The 49i-PS ozone primary standard is to be certified annually by the EPA. Presently ECB configures the T700U as an ozone generator for this procedure by connecting the T700U calibrator to a Model 49i-PS Ozone primary standard, configured as an ozone monitor. Connecting to a DAS is optional for fractionator verification / calibration / certification procedure.

### 7.1 Run a Back Pressure Compensation

The back pressure compensation test compensates for pneumatic configuration changes when initiated using the following keystrokes on the front panel of the T700U calibrator. The test takes approximately 4 minutes to complete. Back Pressure Compensation should only be completed with the 49i-PS ON, in operation and connected to the calibrator.

- Using *APIcom* select SETUP> MORE> DIAG> 929 (password) > scroll until Back Pressure Compensation is displayed then press ENTR>.

Back Pressure Compensation Test will run automatically. When completed the calibrator will display a Pressure Comp Passed message: 37.78 PPB/dIn-Hg, found in VARS#23 PDELTA-GAIN. Once completed press EXIT> to return the calibrator to STBY.

### 7.2 Run an "As Found" Test

The "As Found" parameters should be recorded using the Excel workbook for the following parameters:

- PH Slope – found on the Param Ribbon with <TST> button (VARS#26 O3_SLOPE = X.XXX Gain)
- PH Offset – found on the Param Ribbon with <TST> button (VARS#27 O3_OFFSET = -0.2 PPB)
- Low_Range_Frac (see CFAC VARS#43 - the Param Ribbon only shows a precision of 2, labeled as O3_GEN FRAC = 1.00)

1. Using the front panel of the T700U calibrator or *APIcom*, record the "As Found" values for PH Slope, PH Offset and the CFRA value. With the calibrator at STBY> press SETUP> MORE> VARS> 929 (password) > NEXT> until PH SLOPE is displayed, record value, then press NEXT> until PH OFFSET is displayed, record value, then press NEXT> until LOW_RANGE_FRAC (variable number 43) is displayed, record value.
2. Initiate the "As Found" test.
3. With the calibrator in STBY mode Press SETUP> GAS> O3>PHOT>BCAL>, toggle the left most buttons to enter the password (717) then press ENTR>. Next press CAL> ZERO> ENTR>. The T700U will generate "zero air" through the phonometer at the default flowrate of 4.0 LPM.
4. Using the front panel of the Thermo 49i-PS turn the pump to ON and press ENTR>.
5. Allow the ZERO to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once both values are stable (~15 minutes) record the T700U and 49i-PS values for ZERO on the Photo Cert tab of the Excel workbook. Press EXIT> until the CAL screen EDIT> option is displayed.
6. Select CAL> SPAN> ENTR> then key in 425 ppb ENTR>.
7. Allow the SPAN to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once both values are stable (approximately 15 minutes) record the T700U and the 49i-PS values for SPAN on the Photo Cert tab of the Excel workbook. Press EXIT> until the CAL screen EDIT> option is displayed.
8. Select CAL> SPAN> ENTR> then key in 150 ppb ENTR>.
9. Allow the SPAN to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once both values are stable (approximately 15 minutes) record the T700U and the 49i-PS values for SPAN on the Photo Cert tab of the Excel workbook. Press EXIT> until the CAL screen EDIT> option is displayed.
10. Select CAL> SPAN> ENTR> then key in 50 ppb ENTR>.
11. Allow the SPAN to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once both values are stable (approximately 15 minutes) record the T700U and the 49i-PS values for SPAN on the Photo Cert tab of the Excel workbook. Press EXIT> until the CAL screen EDIT> option is displayed.
12. Select CAL> SPAN> ENTR> then key in 25 ppb ENTR>.
13. Allow the SPAN to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once both values are stable (approximately 15 minutes) record the T700U and the 49i-PS values for SPAN on the Photo Cert tab of the Excel workbook.
14. When all flow measurements have been recorded, using the front panel of the calibrator, press EXIT> until the STBY screen is reached.
15. Turn the 49i-PS pump OFF until needed.

## 7.3 Run an O3 Photometer Dark Calibration

The Dark Calibration Test turns off the Photometer UV Lamp and records any offset signal level of the UV Detector-Preamp-Voltage to Frequency Converter circuitry. This allows the calibrator to compensate for any voltage levels inherent in the Photometer detection circuit that might affect the output of the detector circuitry and therefore the calculation of O3 concentration.

The O3 Dark Calibration runs automatically beginning at 0% and progressing to 100%. Once the test is complete the status of the calibrator will return to O3 Photometer Config. During the test, values in the calibrator will be adjusted automatically – there are no values to record.

1. With the calibrator in STBY mode Press SETUP> GAS>O3>PHOT> DARK>.
2. When complete a message indicating the procedure was or was not successful will be displayed.

## 7.4 Photometer Calibration

1. With the calibrator in STBY mode, press SETUP> GAS> O3> PHOT> BCAL> toggle the left most buttons to enter the password (717) then press ENTR>. Next press CAL> ZERO>ENTR>. Next press CAL> ZERO> (*not XZRO)* > Param Ribbon will display the test function A-O3 = X.X PPB O3.
2. The T700U will generate "zero air" through the photometer at the default flowrate of 4.0 LPM.
3. Using the front panel of the Thermo 49i-PS turn the pump to ON and press ENTR>.
4. Allow the ZERO to run until stable O3 values are observed on both the 49i-PS and the T700U (photometer). Once both values are stable (~15 minutes), press ZERO> Respond Y to the automatic response 'Are you sure' of the calibrator.
5. Wait until stable values are observed on both the calibrator and the 49i-PS – values should agree ± 1ppb – then record the T700U and 49i-PS values for ZERO on the Photo Cert tab of the Excel workbook. Press EXIT>. until the CAL screen can be selected.
6. Select CAL> SPAN> ENTR> then key in 425 ppb then press ENTR>.The Param Ribbon should display A-O3 = XXX.X PPB O3.
7. Allow the SPAN of the T700U calibrator to run until stable O3 values are observed on both the 49i-PS and the T700U (photometer). Once the values are stable (approximately 15 minutes) enter the O3 value displayed on the 49i-PS front panel into the T700U calibrator then press SPAN>. Respond Y to the automatic response 'Are you sure' of the calibrator (to adjust the span). ***NOTE:*** *This is the only time Span is pressed during the calibration of the photometer calibration.*
8. Once both values are stable (~5 minutes) record the actual concentration (displayed on the Param Ribbon) of the T700U and the 49i-PS values for SPAN on the Photo Cert tab of the Excel workbook. These values should agree to within ± 1ppb.
9. Press EXIT> until the CAL screen can be selected.
10. Select CAL> SPAN> ENTR> key in 150 ppb ENTR>.
11. Allow the SPAN to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once Stable enter the O3 value displayed on the 49i-PS front panel (~5 minutes) record the observed concentration (displayed on the Param Ribbon) of the T700U and the 49i-PS values on the Photo Cert tab of the Excel workbook.
12. Press EXIT> until the CAL screen can be selected.
13. Select CAL> SPAN> ENTR> key in 50 ppb ENTR>.
14. Allow the SPAN to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once Stable enter the O3 value displayed on the 49i-PS front panel (~5 minutes) record the observed concentration (displayed on the Param Ribbon) of the T700U and the 49i-PS values on the Photo Cert tab of the Excel workbook.
15. Press EXIT> until the CAL screen can be selected.
16. Select CAL> SPAN> ENTR> key in 25 ppb ENTR>.
17. Allow the SPAN to run until stable values are observed on both the 49i-PS and the T700U (photometer). Once Stable enter the O3 value displayed on the 49i-PS front panel (~5 minutes) record the observed concentration (displayed on the Param Ribbon) of the T700U and the 49i-PS values on the Photo Cert tab of the Excel workbook.
18. Press EXIT> until the STBY screen is reached.
19. Turn the 49i-PS pump OFF until needed.

## 7.5 Fractioning (CFRA) Calibration Procedure

For calibrators equipped with the O3 photometer option, the accuracy of calibration mixtures involving O3 produced by the calibrator depends entirely on the accuracy of the photometer; therefore, it is very important to verify its accuracy and calibrate if necessary. Photometer bench calibration should be done first on a new calibrator and should be completed as part of any calibration / verification procedure. Photometer bench calibration / verification should be completed without any back pressure or restrictions (i.e., not connected to any manifold or long tubing runs). See Section 7.1 of this SOP for details detailing Back Pressure Compensation testing.

1. Using the VARS43 function, record the "As Found" CFAC value, if not previously recorded. With the calibrator at STBY press SETUP> MORE> DIAG> 929 (password) ENTR> NEXT> until O3 CALIBRATION is displayed then press ENTR> then select CFAC>.
2. Turn the 49i-PS pump ON if it is in the OFF position.
3. The calibrator will initiate the "Fraction Calibration" procedure. The Fractioning test / procedure is installed by the factory and no modifications are needed. The Param Ribbon will display "O3 Flow Frac, beginning at 0% and ending at 100%, then "completed" when finished.

Once completed the CFRA (VARS#43) value is an estimate, to generate the low O3 target concentration values needed the CFAC value may need to be adjusted to optimize the calibrators' ability to deliver accurate and consistent low concentrations of O3.

4. Using the front panel of the calibrator or *APIcom* select SETUP> GEN> GPTPS>. Set the "NO" concentration to 110 ppb > Set O3 concentration to 100 ppb > TOTAL Flow should be 4.000 LPM > ENTR>.
5. Keep the T700U in GPTPS mode until the "Actual" value for 03 is within 1 ppb of the "Target" value entered. (Active LED not flashing + 5 minutes, ~ 10 minutes).
6. Press GEN> GPT> Check the "NO" concentration remains set to 110 ppb, O3 concentration remains set to 100 ppb, and TOTAL FLOW is set to 4.000 LPM, pressing ENTR> for each.

**NOTE:** During the GPTPS the 49i-PS and the calibrator *will not* be in agreement but should agree during the GPT

7. Allow the output of the calibrator to stabilize then record the O3 values for both the T700U calibrator and the 49i-PS on the Photo Cert Tab of the Excel workbook.
8. Using the following equation provided by API calculate the ratio needed for optimal LOW_RANGE_FRAC value:
    - 1 ÷ CFRA is the ratio of the Ozonator Flow between fractioning of (1) and fraction of CFRA
    - The CFRA value previously recorded should be used as a guide or starting point for adjustments
9. Compare the O3 concentration value displayed on the front panel of the T700U with the observed value displayed on the 49i-PS. The values should be in agreement to within ± 1 ppb. If not the CFRA value needs to be adjusted slightly. It is recommended to adjust only the "thousands" digit (i.e., change the value from 0.198 to 0.195)

**NOTE:**The higher the CFRA value is adjusted, the lower the subsequent value of O3 production will be when running a GPT. (i.e., the value displayed by the 49i-PS for O3 during a GPT run)

10. Repeat steps 4 – 9 until the optimal CFRA value had been achieved and the O3 concentrations on both the 49i-PS and the T700U calibrator are in agreement to within ± 1 ppb. Record the O3 values for both the T700U and the 49i-PS on the Photo Cert tab of the Excel workbook, along with the final CFRA value.
11. Using the front panel of the calibrator or *APIcom* select SETUP> GEN> GPTPS>. Set the "NO" concentration to 30 ppb > Set O3 concentration to 25 ppb > TOTAL Flow should be 6.000 LPM > ENTR>.

12. Keep the T700U in GPTPS mode until the "Actual" value for 03 is within 1 ppb of the "Target" value entered. (Active LED not flashing + 5 minutes, ~ 10 minutes).
13. Press GEN> GPT>, check the "NO" concentration remains set to 30 ppb, O3 concentration remains set to 25 ppb, and TOTAL FLOW is set to 6.000 LPM, pressing ENTR> for each.
14. Allow the output of the calibrator to stabilize then record the O3 values for both the T700U calibrator and the 49i-PS on the Photo Cert Tab of the Excel workbook. The 49i-PS and T700U calibrator O3 values should be in agreement within ± 1.5 ppb.
15. Using the front panel of the calibrator or *APIcom* select SETUP> GEN> GPTPS>. Set the "NO" concentration to 7 ppb > Set O3 concentration to 2.5 ppb > TOTAL Flow should be 8.000 LPM > ENTR>.
16. Keep the T700U in GPTPS mode until the "Actual" value for 03 is within 1 ppb of the "Target" value entered. (Active LED not flashing + 5 minutes, ~ 10 minutes).
17. Press GEN> GPT>, check the "NO" concentration remains set to 7 ppb, O3 concentration remains set to 2.5 ppb, and TOTAL FLOW is set to 8.000 LPM, pressing ENTR> for each.
18. Allow the output of the calibrator to stabilize then record the O3 values for both the T700U calibrator and the 49i-PS on the Photo Cert Tab of the Excel workbook. The 49i-PS and T700U calibrator should be in agreement within ± 1.5 ppb.

# 8.0 ROUTINE MAINTENANCE

Chapter 8 of the User's Manual provides guidance for how to replace subassemblies. The section describes the step-by-step adjustment and replacement procedures for the Model T700U. The section assumes the failed subassembly has been identified and needs service or replacement.

Chapter 9 of the User's Manual provides a troubleshooting guide for locating and correcting problems that can affect the normal operation of the calibrator. The section describes malfunctions, possible causes, and corrective actions.

## 8.1 UV Source Lamp Adjustment

This procedure provides in detail the steps for adjustment of the UV source lamp in the optical bench assembly. This procedure should be done when the **PHOTO REFERENCE** test function value drops below 3000mV. See page 232-233 of the manual for reference.

1. Using the front panel of the T700U calibrator, record the "As Found" CFRA value, if not previously recorded. With the calibrator at STNDBY press SETUP> MORE> DIAG> 818 (password) ENTR> SIGNAL I/O continue pressing NEXT> or press JUMP> until (53) PHOTO_DET is displayed.
2. Using an insulate potentiometer adjustment tool, turn the UV Detector Gain Adjustment POT until the value of PHOTO_DET is as close as possible to 4600.0 mV. (i.e., 4200.0 mV to 4500.0 mv)
3. Additional adjustments can be made by physically rotating the lamp in its housing.
    - To do this, slightly loosen the UV lamp setscrew.
    - Next, slowly rotate the lamp up to ¼ turn in either direction while watching the PHOTO_DET signal.
    - Once the optimum lamp position is determined, re-tighten the lamp setscrew.

*Verbal directions from API support staff for UV Source Lamp Adjustments are as follows:*

1. *Turn the UV Detector gain adjust potentiometer all the way down (i.e., negative).*
2. *Peak lamp for highest intensity.*
3. *Adjust the UV Detector gain potentiometer for 4200 – 4500 mV.*

## 8.2 UV Source Lamp Replacement

This procedure details the steps for replacement of the UV source lamp in the optical bench assembly. This procedure should be done whenever the lamp can no longer be adjusted as described in Section 8.2.4 of the User's Manual.

1. Turn the calibrator off and remove the cover
2. Locate the Optical Bench Assembly (*See Figure 8.1*)
3. Locate the UV lamp cable from the power supply connector on the side of the optical bench. (*See Figure 8.1*)

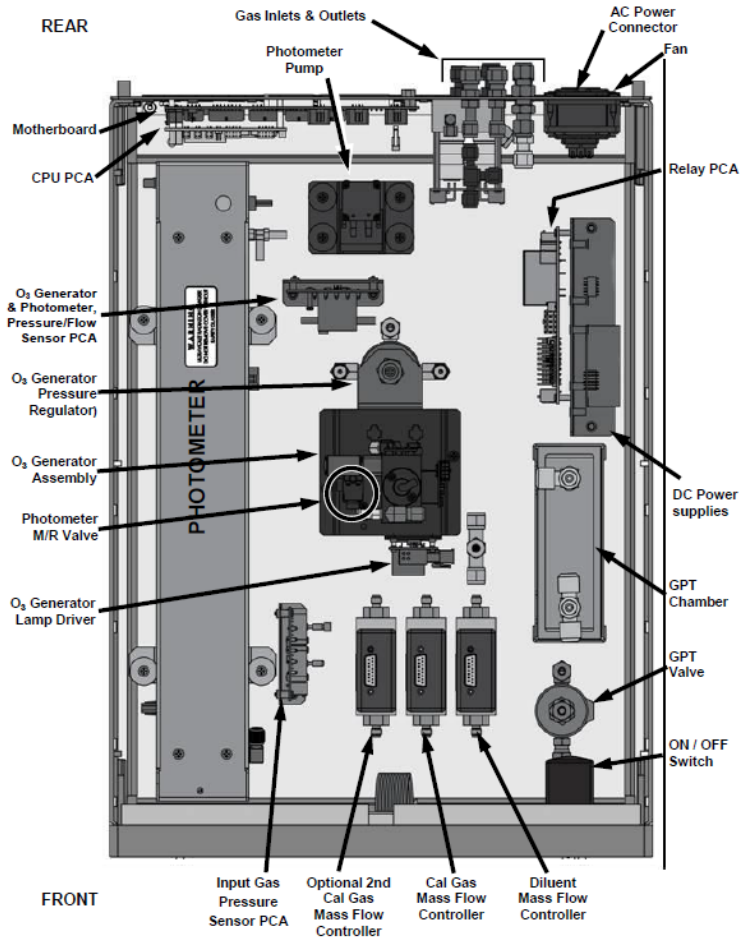



**Figure 8.1 T700 Internal Layout – Top View – with Optional O3 Generator and Photometer Assembly**

**NOTE:** The UV lamp contains mercury (Hg), which is considered hazardous waste. The lamp should be disposed of in accordance with local regulations regarding waste containing mercury.

4. Unplug the lamp cable from the power supply connector on the side of the optical bench.
5. Slightly loosen (do not remove) the UV lamp setscrew and pull the lamp from its housing.
6. Install the new lamp in the housing, pushing it all the way in. Leave the UV lamp setscrew loose for now.
7. Turn the calibrator back ON and allow it to warm up for at least 30 minutes.

8. Turn the UV detector gain adjustment potentiometer (*See Figure 8.2*) clockwise to its minimum value. The potentiometer may click softly when the limit is reached.
9. Adjust the potentiometer to the middle, 7 turns. ***NOTE:*** *the potentiometer has a maximum of 14 turns.*

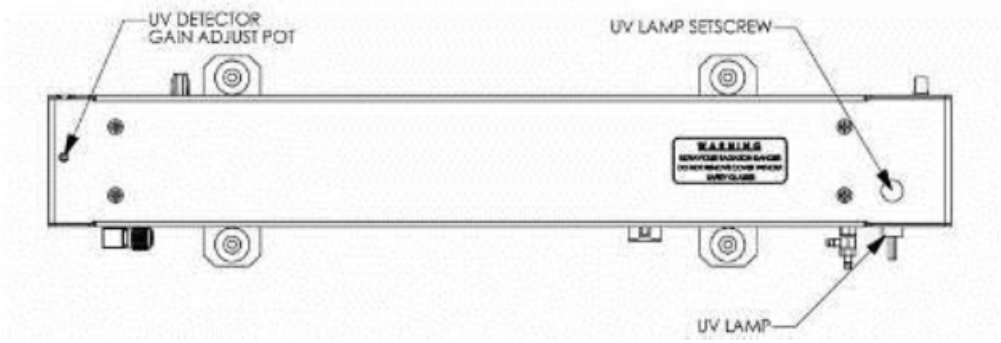



**Figure 8.2 Photometer Assembly – Lamp Adjustment / Installation**

10. Perform the UV Lamp Adjustment procedure described in Section 8.1 of this SOP, with the following exceptions:
    a. Slowly rotate the lamp in its housing (up to ¼ turn in either direction) until a MINIMUM value is observed.
    b. Ensure the lamp is pushed all the way into the housing while performing this rotation.
    c. If the PHOTO_DET value will not drop below 5000mV while performing this rotation, contact Teledyne API's Customer Service for assistance.
    d. Once a lamp position is found that corresponds to a minimum observed value for PHOTO_DET, tighten the lamp setscrew at the approximate minimum value observed.
11. Adjust the PHOTO_DET within the range of 4400 – 4600 mV.
12. Replace the cover on the calibrator.

## 8.3 Adjustment or Replacement of the Ozone Generator UV Lamp

This procedure details the steps for replacement and initial adjustment of the ozone generator lamp.

1. Turn the calibrator OFF and remove the cover.
2. Locate the O3 generator UV lamp *(see Figure 8.3, below).*
3. Remove the two setscrews on the top of the O3 generator and gently pull out the old lamp.
4. Inspect the O-ring beneath the nut and replace if damaged.
5. Install the new lamp in the O3 generator housing, ensuring that it is fully seated.
6. Tighten the two setscrews.
7. Replace the calibrator cover, turn on the calibrator and allow it to stabilize for at least 30 minutes.
8. Perform an auto-leak check (*See Section 4.2*).
9. Perform an Ozone Generator calibration (See Section 8.4 of this SOP).

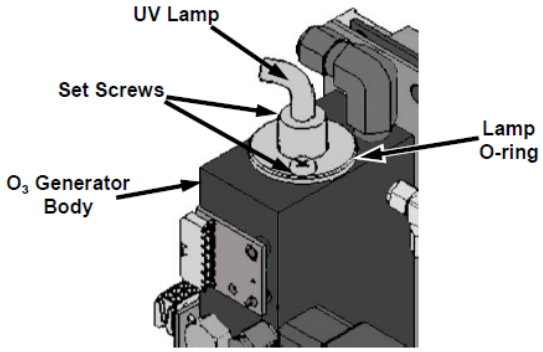



**Figure 8.3 O3 Generator UV Lamp Location**

## 8.4 Performing an Automatic Calibration of the O3 Generator

1. With the calibrator in STANDBY mode, using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> enter 818 (password) then press ENTR>.
2. Select SIGNAL I/O then SIGNAL I/O > then NEXT> until O3 GEN CALIBRATION appears then press ENTR> CAL> O3 GEN CAL should appear on the Param Ribbon.
3. The calibration of the O3 generator runs automatically from 0% to 100% (See section 7.4.2 of the User's Manual for additional details).

# 9.0 TROUBLESHOOTING AND CORRECTIVE ACTIONS

The T700U calibrator has been designed so that problems can be rapidly detected, evaluated, and repaired. During operation, it continuously performs diagnostic tests and provides the ability to evaluate its operating parameters without disturbing monitoring operations. The table below lists some of the common warning messages and possible causes.

**Table 9.1 Warning Messages in Front Panel Display Param Field**

| Warning | Fault Condition | Possible Causes |
|---|---|---|
| MFC Pressure Warning | One of the calibrator's mass flow controllers' internal gas pressures is <15 psig or > 36 psig | ➢Zero or source air supply is incorrectly set up or improperly vented.<br>➢Leak or blockage exists in the T700's internal pneumatics<br>➢Failed CAL GAS or DILUENT pressure sensor |
| Photo Lamp Stability Warning | Value output during the Photometer's reference cycle changes from measurement to measurement more than 25% of the time | ➢Faulty UV source lamp<br>➢Noisy UV detector<br>➢Faulty UV lamp power supply<br>➢Faulty ± 15 VDC power supply |
| Photo Reference Warning | Occurs when Ref is <2500 mV DC or >4950 mV DC | Possible failure of:<br>➢UV lamp<br>➢UV Photo-Detector Preamp |
| Regulator Pressure Warning | Regulator pressure is < 15 psig or > 25 psig | ➢Zero or source air supply is incorrectly set up or improperly vented<br>➢Incorrectly adjusted O3 zero air pressure regulator<br>➢Leak or blockage exists in the T700's internal pneumatics<br>➢Failed O3 Generator Input pressure sensor |

**Table 9.2 Test Functions – Indicated Failures**

| Test Function | Diagnostic Relevance and Causes of Fault Conditions |
|---|---|
| CAL PRES | Affects proper flow rate of Cal gas MFCs. Possible causes of faults are the same as MFC pressure warning (see Table 9.1) |
| DIL PRES | Affects proper flow rate of Diluent gas MFCs. Possible causes of faults are the same as MFC pressure warnings (see Table 9.1) |
| REG PRES | Same as Regulator Pressure Warning (see table 9.1) |
| BOX TMP | Box Temperature typically runs ~7° C warmer than ambient temperature. If the Box Temperature is out of range, ensure that:<br>➢The exhaust fan is running<br>➢There is sufficient space on the exterior sides and rear of the instrument to allow adequate ventilation |

## 10. REVISION HISTORY

1. This SOP replaces the draft SOP Section 2.3.7 which was never finalized.

## 11.0 REFERENCES

1. Model T700 and T700U Dynamic Dilution Calibrators - User Manual
2. Addendum Model T700U Calibrator
3. Model T700 Dynamic Dilution Calibrator User Manual
4. NumaView Remote Software User Guide
5. Alicat Mass Flow Meter Manual
6. Teledyne API Gas Calibrators

## 12.0 APPENDICES

A. T700U MFC Default Mass Flow Controller Calibration Points
B. T700U Password Setup Variables for Serial I/O (Password 929)
C. T700U Calibrator Diagnostic Menu
D. Tare Instructions for Alicat Mass Flow Meter
E. Example of T700U Final Calibrated Test and Validation Data
F. T700U Dilution Air Mass Flow Controller – Audit Calibrator

## Appendix A T700U Default Mass Flow Controller Calibration Points

| Cal Point | Drive Voltage | MFC Full Scale | | | |
|---|---|---|---|---|---|
| | | CAL2 | CAL1 | DIL1 Site Calibrator | DIL1 Audit calibrator |
| | | 50 SCCM | 100 SCCM | 10 SLPM | 20 SLPM |
| 0 | 000 mV | 0.00 | 0.000 | 0.000 | 0.000 |
| 1 | 250 mV | 2.50 | 5.000 | 0.500 | 1.000 |
| 2 | 500 mV | 5.00 | 10.00 | 1.000 | 2.000 |
| 3 | 750 mV | 7.50 | 15.00 | 1.500 | 3.000 |
| 4 | 1000 mV | 10.00 | 20.00 | 2.000 | 4.000 |
| 5 | 1250 mV | 12.50 | 25.00 | 2.500 | 5.000 |
| 6 | 1500 mV | 15.00 | 30.00 | 3.000 | 6.000 |
| 7 | 1750 mV | 17.50 | 35.00 | 3.500 | 7.000 |
| 8 | 2000 mV | 20.00 | 40.00 | 4.000 | 8.000 |
| 9 | 2250 mV | 22.50 | 45.00 | 4.500 | 9.000 |
| 10 | 2500 mV | 25.00 | 50.00 | 5.000 | 10.000 |
| 11 | 2750 mV | 27.50 | 55.00 | 5.500 | 11.000 |
| 12 | 3000 mV | 30.00 | 60.00 | 6.000 | 12.000 |
| 13 | 3250 mV | 32.50 | 65.00 | 6.500 | 13.000 |
| 14 | 3500 mV | 35.00 | 70.00 | 7.000 | 14.000 |
| 15 | 3750 mV | 37.50 | 75.00 | 7.500 | 15.000 |
| 16 | 4000 mV | 40.00 | 80.00 | 8.000 | 16.000 |
| 17 | 4250 mV | 42.50 | 85.00 | 8.500 | 17.000 |
| 18 | 4500 mV | 45.00 | 90.00 | 9.000 | 18.000 |
| 19 | 4750 mV | 47.50 | 95.00 | 9.500 | 19.000 |
| 20 | 5000 mV | 50.00 | 100.00 | 10.000 | 20.000 |

## Appendix B T700U Calibrator Password Setup Variables for Serial I/O (Password 929)

| | Setup Variable | Default Value | Description |
|---|---|---|---|
| | Los Access Level Setup Variables (929 password) | | |
| 0) | PHOTO_LAMP | 58 °C | Photometer lamp temperature set point and warning limits |
| 1) | O3_GEN_LAMP | 48 °C | O3 generator lamp temperature set point and warning limits |
| 2) | O3_CONC_RANGE | 500 PPB | O3 concentration range for test channel analog output |
| 3) | O3_PHOTO_BENCH_ONLY | ON | O3 bench control flag. ON turns on pump and switches measure/reference value only in bench generation mode |
| 4) | STD_TMP | 25 °C | Standard temperature for unit conversions – should be set to 25 °C |
| 5) | STD_PRESS | 29.92 mm Hg | Standard pressure for unit conversions |
| 6) | CLOCK_ADJ | 0 Sec / Day | Time-of-day clock speed adjustment |
| 7) | SERVICE_CLEAR | OFF | ON resets the service interval timer |
| 8) | TIME_SINCE_SVC | Hours | Time since last service |
| 9) | SVC_INTERVAL | Hours | Sets the interval between service reminders |
| 10) | DAYLIGHTSAVING_ENABLE | ON | Turn to OFF |
| 11) | LANGUAG_SELECT | English | |
| 12) | MAINT_TIMEOUT | Hours | |
| 13) | LATCH_WARNINGS | ON | |
| 14) | O3_DWELL | 2.5 seconds | |
| 15) | O3_SAMPLE | 1 sample | |
| 16) | DARK_OFFSET | (-) 0.9 mV | |
| 17) | FILT_SIZE | 32 samples | |
| 18) | FILTASIZE | 6 samples | |
| 19) | FILT_DELTA | 20.0 PPB | |
| 20) | FILT_PCT | 5.0% | |
| 21) | FILT_DELAY | 60 seconds | |
| 22) | FILT_ADAPT | ON | |
| 23) | PDELTA_GAIN | 42.12 PPB / d In-Hg | |
| 24) | PDELTYA_CAL_DUR | 5.0 minutes | |
| 25) | O3_SLOPE_CONST | 1.0 Gain | |
| 26) | O3_SLOPE | 1.003 Gain | Photometer slope |
| 27) | O3_OFFSET | -0.00PPB | Photometer offset |
| 28) | O3_BCAL_SET | 500.0 PPB | Span adjusted (photometer) |
| 29) | O3_PUMP_STARTUP | ON | |
| 30) | O3_PUMP_MIN_FLOW | 0.20 LPM | |
| 31) | O3_PUMP_TIMEOUT | 30 seconds | |
| 32) | O3_PUMP_PULSE | 0.5 seconds | |
| 33) | PHOTO_CYCLE | 10.0 seconds | |
| 34) | PHOTO_PROP | 0.050 1/deg C | |
| 35) | PHOTO_INTEG | 0.050 Gain | |

| | Setup Variable | Default Value | Description |
|---|---|---|---|
| 36) | PHOTO_DERIV | 0.200 Gain | |
| 37) | PHOTO_FLOW_SLOPE | 0.941 Gain | |
| 38) | O3_DEF_DRIVE | 800.0 mV | |
| 39) | O3_GEN_FLOW | 0.126 LPM | Enter sum of (2) O3 Gen Flows |
| 40) | O3_GEN_MODE | BNCH | |
| 41) | O3_MIN_CONC | 1 PPB | |
| 42) | LOW_RANGE_THRESH | 100 PPB | |
| 43) | LOW_RANGE_FRAC | 0.210 Frac | |
| 44) | REF_DELAY | 60 seconds | |
| 45) | REF_FREQ | 1.0 seconds | |
| 46) | REF_FSIZE | 4 samples | |
| 47) | REF_INTEG | 0.100 Gain | |
| 48) | EWF_DERIV | 0.200 Gain | |
| 49) | BENCH_DELAY | 120.0 seconds | |
| 50) | BENCH_FREQ | 10.0 seconds | |
| 51) | BENCH_FSIZE | 3 samples | |
| 52) | BENCH_INTEG | 0.200 Gain | |
| 53) | BENCH_DERIV | 0.500 Gain | |
| 54) | SEIVE_STABIL | 10.0 mV | |
| 55) | CACHE_RESOL | 2.0 PPB | |
| 56) | O3_LAMP_CYCLE | 2.0 seconds | |
| 57) | O3_LAMP_PROP | 0.200 1/Deg C | |
| 58) | O3_LAMP_INTEG | 0.100 Gain | |
| 59) | O3_LAMP_DERIV | 0.200 Gain | |
| 60) | MFC_PRESS_LIMIT | 25.00psig | |
| 61) | REG_PRESS_LIM | 8.00 psig | |
| 62) | TARGET_FLOW | 4.000 LPM | Default total flow |
| 63) | RS232_MODE | 288 Bit Flag | |
| 64) | BAUD_RATE | 115200 | 115200 prevent MODE flicker |
| 65) | MODEM_INIT | AT YO DO HO IO SO = | |
| 66) | RS232_MODEZ | O Bit Flag | |
| 67) | BAUD_RATE2 | 115200 | 115200 prevent MODE flicker |
| 68) | MODEM_INIT2 | AT YO DO HO IO SO | |
| 69) | RS232_PASS | 940331 | Pass |
| 70) | TCP2_MODE2 | 32768 | Bit Flag |
| 71) | MACHIN_ID | 700 ID | |
| 72) | COMMAND_PROMPT | “CMD” | |
| 73) | TEST_CHAN_ID | Chassis Temp | |
| 74) | PASS_ENABLE | OFF | |
| 75) | DEF_CC_OUTPUT | 000000000000 | |
| 76) | PHOTO_LAMP_POWER | 4500.0 mV | |
| 77) | LAMP_PWR_ENABLE | ON | |
| 78) | LAMP_PWR_PERIOD | 24.00 hours | |
| 79) | LAMP_OFFDELAY | 60.0 seconds | |

| | Setup Variable | Default Value | Description |
|---|---|---|---|
| 80) | DET_VALID_DELAY | 60.0 seconds | |
| 81) | REF_SDEV_LIMIT | 3.0 mV | |
| 82) | PATH_LENGTH | 41.960 cm | |
| 83) | BOX_SET | 30.0 °C | |
| 84) | GAS_MOL_WEIGHT | 32.000 | Molecular Weight |
| 85) | SERIAL_NUMBER | “151” | |
| 86) | DISP_INTENSITY | High | |
| 87) | I2C_RESET_ENABLE | ON | |
| 88) | CLOCK_FORMAT | Time %H:%M:%S | |
| 89) | FACTORY_OPT | 46 Bit Flag | |

## Appendix C T700U Calibrator Diagnostic Menu

| | Signal I/O | |
|---|---|---|
| 0) | CONTROL_IN_1 | OFF |
| 1) | CONTROL_IN_2 | OFF |
| 2) | CONTROL_IN_3 | OFF |
| 3) | CONTROL_IN_4 | OFF |
| 4) | CONTROL_IN_5 | OFF |
| 5) | CONTROL_IN_6 | OFF |
| 6) | CONTROL_IN_7 | OFF |
| 7) | CONTROL_IN_8 | OFF |
| 8) | CONTROL_IN_9 | OFF |
| 9) | CONTROL_IN_10 | OFF |
| 10) | CONTROL_IN_11 | OFF |
| 11) | CONTROL_IN_12 | OFF |
| 12) | CONTROL_OUT_1 | OFF |
| 13) | CONTROL_OUT_2 | OFF |
| 14) | CONTROL_OUT_3 | OFF |
| 15) | CONTROL_OUT_4 | OFF |
| 16) | CONTROL_OUT_5 | OFF |
| 17) | CONTROL_OUT_6 | OFF |
| 18) | CONTROL_OUT_7 | OFF |
| 19) | CONTROL_OUT_8 | OFF |
| 20) | CONTROL_OUT_9 | OFF |
| 21) | CONTROL_OUT_10 | OFF |
| 22) | CONTROL_OUT_11 | OFF |
| 23) | CONTROL_OUT_12 | OFF |
| 24) | ST_SYSTEM_OK | OFF |
| 25) | ST_CAL_ACTIVE | OFF |
| 26) | ST_DIAG_MODE | ON |
| 27) | ST_TEMP_ALARM | OFF |
| 28) | ST_PRESS_ALARM | OFF |
| 29) | RELAY_WATCHDOG | OFF/ON |
| 30) | VWBT_VALVE | OFF |
| 31) | GPT_VALVE | OFF |
| 32) | PHOTO_REF_VALVE | OFF |
| 33) | O3_GEN_VALVE | OFF (ON during fractioning, low and high |
| 34) | O3_PUMP_ON | OFF |
| 35) | O3_DIVERT_VALVE | OFF |
| 36) | OUTPUT_VALVE_B | OFF |
| 37) | PHOTO_LAMP_HEATER | OFF/ON |
| 38) | O3_GEN_HEATER | OFF/ON |
| 39) | VALVE_WATCHDOG | OFF/ON |
| 40) | CYL_VALVE_1 | OFF (Turn on to test MFC) |
| 41) | CYC_VALVE_2 | OFF |

| | Signal I/O | |
|---|---|---|
| 42) | CYC_VALVE_3 | OFF |
| 43) | CYC_VALVE_4 | OFF |
| 44) | PURGE_VALVE | OFF |
| 45) | INPUT_VALVE | ON (Diluent input valve – turn on for MFC testing) |
| 46) | MAINT_MODE | ON |
| 47) | LANG2_SELECT | ON |
| 48) | ACTIVE LED | OFF |
| 49) | AUTO_LED | OFF |
| 50) | FAULT_LED | OFF (Changes state with fault LED) |
| 51) | AUDIBLE_BEEPER | OFF |
| 52) | O3GEN_STATUS | ON |
| 53) | PHOTO_DET | 4517.4 Mv |
| 54) | O3_GEN_REF_DET | 207.7 mV |
| 55) | DIL_PRESS | 1601.8 mV |
| 56) | CAL_PRESS | 1361.0 Mv |
| 57) | O3_PERM_PRESS | 599.6 mV |
| 58) | MFCFLOW_3 | 2.3 Mv (voltage used to set zero) |
| 59) | REF_4096_MV | 4095.5 mV |
| 60) | PHOTO_FLOW | 963.9 mV |
| 61) | PHOTO_SAMP_PRESS | 4629.1 mV |
| 62) | MFC_FLOW_1 | 25.4 mV (voltage used to set zero) |
| 63) | MFC_FLOW_2 | -14.6 mV (voltage used to set zero) |
| 64) | REF_GND | -0.0 Mv |
| 65) | BOX_TEMP | 1400.4 Mv |
| 66) | PHOTO_SAMP_TEMP | 1897.0mV |
| 67) | PHOTO_LAMP_TEMP | 2764.0 mV |
| 68) | O3_GEN_TEMP | 2289.7 mV |
| 69) | DAC_CHAN_1 | -0.4 mV |
| 70) | DAC_CHAN_2 | -0.3 mV |
| 71) | DAC_CHAN_3 | 0.1 mV |
| 72) | DAC_CHAN_4 | 2052.6 mV |
| 73) | MFC_DRIVE_1 | 0.0 mV |
| 74) | MFC_DRIVE_2 | 0.0 mV (cyl valve on #40) |
| 75) | MFC_DRIVE_3 | 0.0 mV (cyl valve on #40) |
| 76) | TEST_OUTPUT | 2056.9 mV (Chasis Temperature) |
| 77) | PHOTO_LAMP_DRIVE | 4500.0 mV |
| 78) | O3_GEN_DRIVE | 800 mV |

## Appendix D Tare Instruction for Alicat Mass Flow Meter

### M Series Mass Flow Meter Operation

The M Series Mass Flow Meter provides a multitude of useful flow data in one simple, rugged device. The M Series can have several screen "modes" depending on how the device is ordered. All M Series meters have a default Main Mode, Select Menu Mode, a Gas Select Mode (the Gas Select Mode may not be available on meters calibrated for a custom gas or blend), a Communication Select Mode, Manufacturer Data Mode and a Miscellaneous Mode. In addition, your device may have been ordered with the optional Totalizing Mode (page 38). The device defaults to Main Mode as soon as power is applied to the meter.

**Main Mode**

The main mode screen defaults on power up with the mass flow on the primary display. The following parameters are displayed in the main mode as shown in Figure 6:

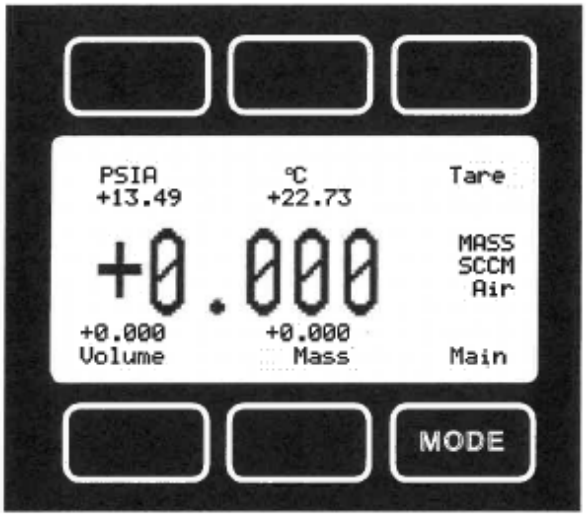



Figure 6. Main Mode Display, M Series Flow Meter

The "MODE" button in the lower right hand corner toggles the display between the Main display and the Select Menu display.

**Tare** – Pushing the dynamically labeled "Tare" button in the upper right hand corner tares the flow meter and provides it with a reference point for zero flow. This is a simple but important step in obtaining accurate measurements. It is good practice to "zero" the flow meter each time it is powered up. If the flow reading varies significantly from zero after an initial tare, give the unit a minute or so to warm up and re-zero it.

If possible, zero the unit near the expected operating pressure by positively blocking the flow downstream of the flow meter prior to pushing the "Tare" button. Zeroing the unit while there is any flow will directly affect the accuracy by providing a false zero point. If in doubt about whether a zero flow condition exists, remove the unit from the line and positively block both ports before pressing the "Tare" button. If the unit reads a significant negative value when removed from the line and blocked, it is a good indication that it was given a false zero. It is better to zero the unit at atmospheric pressure and a confirmed no flow conditions than to give it a false zero under line pressure.

## Appendix E Example of T700U Final Calibrated Test and Validation Data

TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
A Teledyne Technologies Company

**T700U Final Calibrated Test and Validation Data**

5 11/19/18

| | | | | | |
|---|---|---|---|---|---|
| Model: | T700U | | | | |
| Firmware: | NVS82840000 1.2.3.152 | Serial Number: | 475 | Sales Order: | 329830 |
| Date: | 11/17/2018 | Technician: | DNG | SP#: | |

| Parameter | Displayed As | Observed Value | Units | Final Test Process Control Limits at Factory** | Acceptable Limits in Use |
|---|---|---|---|---|---|
| Act Cal Gas [3] | ACT CAL | 0.03210 | LPM | ± 1% of TARG CAL | ± 1% of TARG CAL |
| Target Cal Gas [3] | TARG CAL | 0.03200 | LPM | | |
| Act Dilution [3] | ACT DIL | 3.976 | LPM | ± 1% of TARG DIL | ± 1% of TARG DIL |
| Target Dilution [3] | TARG DIL | 3.968 | LPM | | |
| O3 Gen Ref [1,3] | O3 GEN REF | | mVDC | 25 - 600 mV | 25 - 600 mV |
| O3 Flow [1,3] | O3 FLOW | 0.120 | LPM | 0.115 - 0.145 LPM | 0.115 - 0.145 LPM |
| O3 Gen Drive [1,3] | O3 GEN DRIVE | 800 | mVDC | 800 mV | 800 mV |
| Ozone Lamp Temp | O3 LAMP TEMP | 48 | °C | 48 ± 0.5 °C | 48 ± 0.5 °C |
| Cal Pressure | CAL PRESSURE | 30 | PSIG | 25 - 35 PSIG | 25 - 35 PSIG |
| Dilution Pressure | DIL PRESSURE | 30 | PSIG | 25 - 35 PSIG | 25 - 35 PSIG |
| Regulator Pressure | REG PRESSURE | 8 | PSIG | 8 ± 0.5 PSIG | 8 ± 0.5 PSIG |
| ACT NO Conc [3] | | 799 | PPB | ± 1% of TARG= | ± 1% of TARG= |
| Target NO Conc [3] | TARG= | 800 | PPB | | |
| Box Temp | BOX TEMP | 27.3 | °C | 20 - 35 °C | 8 - 48 °C |
| Photo Measure [1,3] | PHOTO MEASURE | 4469 | mVDC | 4400 - 4600 mV | 2500 - 4800 mV |
| Photo Reference [1,3] | PHOTO REFERENCE | 4469 | mVDC | 4400 - 4600 mV | 2500 - 4800 mV |
| Photo Flow [2] | PHOTO FLOW | 0.826 | LPM | 0.720 - 0.880 LPM | 0.720 - 0.880 LPM |
| Photo Lamp Temp | PHOTO LAMP TEMP | 58 | °C | 58 ± 0.5 °C | 58 ± 0.5 °C |
| Photo Sam Press [1,3] | PHOTO SPRESS | 29.5 | In-Hg-A | 27 - 29.9 In-Hg-A | 24 - 30 In-Hg-A |
| Photo Sample Temp | PHOTO STEMP | 40.6 | °C | 28 - 45 °C | 28 - 45 °C |
| Photo Slope | PHOTO SLOPE | 0.987 | - | 1 ± 0.03 | 1 ± 0.03 |
| Photo Offset | PHOTO OFFSET | 0.0 | PPB | 0 ± 3 PPB | 0 ± 3 PPB |
| Dark Offset | DARK OFFSET | 0.5 | mVDC | 0 ±20mV | 0 ±20mV |
| Perm Tube Flow | PERM FLOW | | LPM | 0.100 - 0.200 LPM | 0.100 - 0.200 LPM |
| Perm Tube Temp | PERM TEMP | | °C | 50 ± 0.3 °C | 50 ± 0.3 °C |

* For good instrument performance, the steadiness of this signal is more important than its absolute value (within the operating range)
** These are process control limits, and not specification limits. Items out of range do not imply the unit is out of specification.

**Statement of Calibration**

***The unit identified above has been tested with NIST measuring and test equipment using lot traceable materials. The testing is performed in accordance with ISO 9001-2015 and is traceable to NIST and industry recognized standards.***

[1] Recorded in Standby Mode, [2] Recorded in Generate O3 mode, [3] Recorded in Generate NO mode

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# Appendix F T700U Dilution Air Mass Flow Controller – Audit Calibrator

Calibration of the dilution mass flow controller in the audit calibrator must be followed by the Sensor Offset adjustment, then a verification. All air flow must go through the dilution solenoid DIL1 during the calibration / adjustment / verification procedure. **Prior to calibration / adjustment / verification of an audit calibrator, Section 4 of this SOP must be completed.**

## Appendix F.1 T700U Zero Air Mass Flow Controller (DIL1) Calibration (Audit Calibrator)

The term certification (calibration and verification) means determining the actual flow versus the flow settings for the calibration points. A table exists in the memory of the T700U for each mass flow controller that sets the output of the mass flow controller at each of 20 control points along its entire performance range. This table may be accessed in the calibrator via the DIAG> MFC CONFIGURATION submenu. For each certification point, the following is displayed:

- The drive voltage in 20 equal, incremental steps from 0.0 mV to 5000 mV.
- The expected flow rate corresponding to each drive voltage point (each equal to 1/20$^{th}$ of the full scale for the selected mass flow controller).

See Appendix A for the default Calibration point, drive voltage and corresponding flow within the calibrator menu for each mass flow controller. The table can also be used to calibrate the output of the mass flow controllers by adjusting either the control voltage of a point or its associated flow output value (See Section 7.2 of the User's Manual).

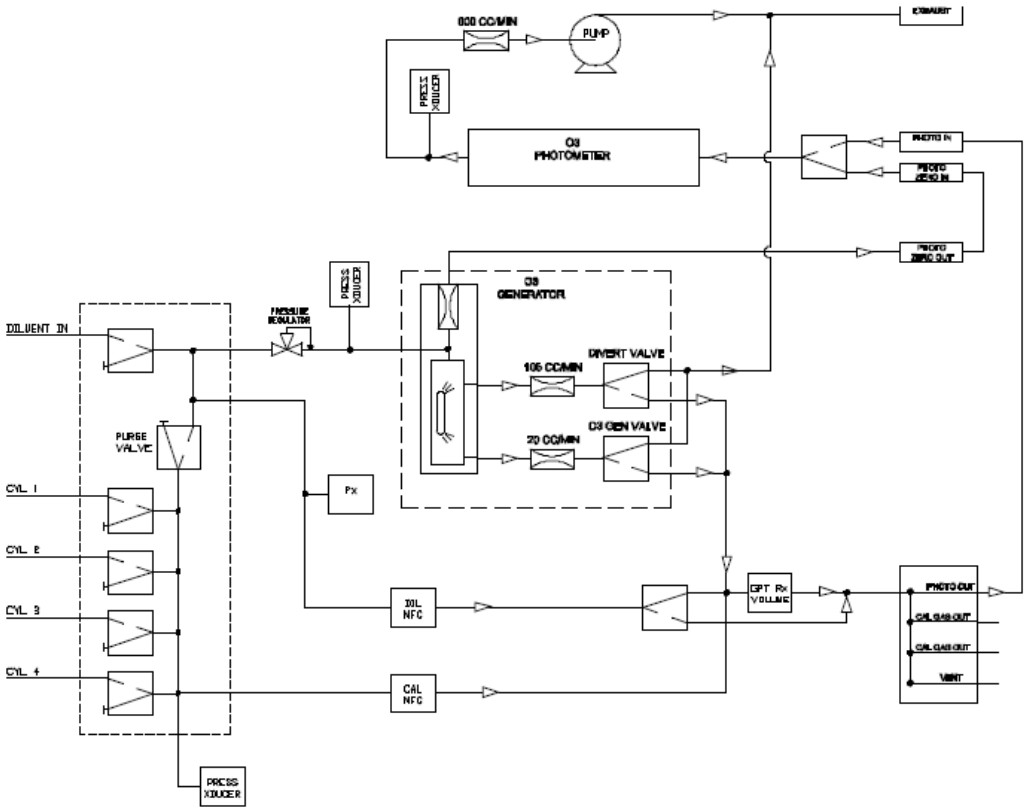


**Figure F.1 T700U MFC Layout**

1. Confirm the T700U is connected to a suitable zero air source, set to deliver 30 psi of air.
2. Confirm the MFC flow points were defaulted (See Section 4.5 of this SOP) using the DIAG menu as follows:
    - DIL1 = 20.000 LPM
    - CAL1 = 0.100 LPM (100 cc/min)
    - CAL2 = 0.050 LPM (50 cc/min)

***NOTE: There is only one dilution mass flow controller in the audit calibrator, and it is referred to as DIL1 also.***

3. Connect power to the Alicat mass flow meter being used and allow the instrument to stabilize (~ 5 minutes)
4. If using a data collection system (DAS, data logger, etc.) connect both the Alicat and the Calibrator to the data collection system.
5. Using the Alicat mass flow meter, perform an initial flow tare by pressing the button labeled "TARE" for approximately 5 seconds (*see Figure 5.2*). This action tares the flow meter and provides it with a reference point for zero flow. (Appendix D provides the manufacturer's instructions for taring the device.)

**NOTE:** It is a good practice to "TARE" the Alicat mass flow meter each time it is powered up. It is critical to have a stable tare before starting any flow certification procedure. If the flow reading varies significantly from zero after an initial TARE (10/20 LPM mass flow meter = 3 cc/min) allow more time for the instrument to warm up then repeat the TARE process.

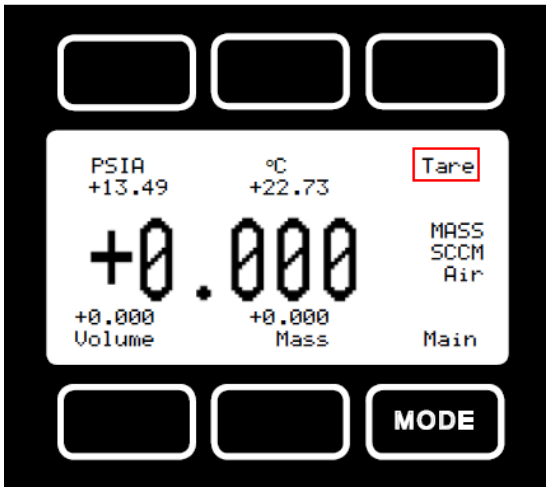


**Figure F.2 Alicat Mode Screen**

6. When the Alicat TARE is stable, remove the cap and connect the Alicat to the T700U calibrator mass flow controller being certified, observing the correct flow direction.
7. Using the front panel of the calibrator or *APIcom* select SETUP> MORE> DIAG> 929 (password) ENTR > press NEXT> until MFC CONFIGURATION is displayed on the Param Ribbon, then press ENTR>.
8. Press EDIT> SET> until DIL1 Table is displayed in the Param Ribbon, then press EDIT> NEXT> DIL1[1] DRV = 250 FLW = 1.000 is displayed, then press ON to initiate flow through the mass flow controller. (Pressing OFF will turn the flow ON) ***NOTE:*** *there is a delay (up to 1 minute) for the mass flow controller in use to deliver flow when the flow controller is turned ON initially during this procedure.*
9. Once the flow has stabilized (~10 min) record the 5-minute average value using the Excel workbook.
10. Using the front panel of the calibrator or *APIcom* click NEXT> to advance to the next pre-set drive voltage/flow in the calibration points table. See Appendix A for the default mass flow controller calibration points specific for each mass flow controller. Once the flow has stabilized (~10 min) record the 5-minute

average values using the Excel Workbook, DIL1 20 SLPM MFC tab. Repeat this step for all 20 drive voltage settings and recording average values.

11. Once completed, turn OFF the flow then EXIT>.
12. Manually enter the recorded flow values into the DIL1 table stored in the calibrator, beginning with DIL1 FLOW [20] > ENTR> then press PREV> until all flows have been edited, making sure the drive voltages correspond with the measured flows. Press EXIT> and Y> at the prompt to save the changes.

## Appendix F.2 T700U Zero Air Mass Flow Controller (DIL1) Sensor Offset Adjustment (Audit Calibrator)

Sensor Offset adjustment is a procedure used to adjust the actual flow to the target flow. The procedure compares the Calibrator flow to the actual Alicat flow. Values are averaged across the collected flow readings and converted into a millivoltage.

1. Using the front panel of the calibrator or *APIcom* select SETUP> GAS> CYL> PRT1> ENTR>.
2. The NO cylinder concentration will be displayed.
3. Press EDIT> press the "NO" key and scroll through the gas choices displayed until USR1 is displayed, then press ENTR> then EXIT>.
4. With the Alicat still connected to the DIL1 mass flow controller, cap the ends and TARE the device until a stable TARE is achieved, then remove caps. (Appendix D provides the manufacturer's instructions for taring the device.)
5. Using the front panel of the calibrator or *APIcom* select GEN> MAN> using left most key select "USR1" press ENTR>.
6. Set CAL gas flow to any value between 10 and 150 cc/min (75 cc/min is recommended)
7. Set Diluent Flow = 3000 cc ENTR>.
8. Leave O3 Gen mode OFF and press ENTR>.
9. Using <TST> key scroll through until A-DIL (actual dilution flow) is displayed on the Param Ribbon.
10. When stable, record the calibrator and Alicat flow readings using the Excel Workbook on the DIL1 Sensor Offset Adjustment tab.
11. Using the front panel of the calibrator or *APIcom* advance to the next target Dilution flow setting GEN> MAN USR1> ENTR>, leaving the CAL gas flow unchanged, and setting the target Dilution flow to 6000 cc/min and again leaving the O3 Gen mode OFF and press ENTR>.
12. When stable, record the calibrator and the Alicat flow readings using the calibrator spreadsheet.
13. Repeat for flow settings at 9000 cc/min, 12000 cc/min and 15000 cc/min, always leaving the CAL gas unchanged and the O3 Gen mode OFF.
14. Enter the values into the Excel Workbook, DIL1 Sensor Offset Adjustment tab to determine the DIL1 Sensor Offset value in millivolts.
15. Enter the DIL1 Sensor Offset value into the calibrator SETUP> MORE> DIAG> 929 (password) ENTR>.press NEXT> until MFC CONFIGURATION appears in the Param Ribbon then press ENTR>.
16. Scroll until the correct mass flow controller can be selected, press EDIT>, then press the SET> key until DI1 SENSOR OFFSET can be selected then press EDIT>.
17. Enter the DIL1 SENSOR OFFSET value (from Excel workbook) then press ENTR> then EXIT> until the value is saved. (The message "storing MFC properties will appear briefly on the Param Ribbon.) **Make sure the DIL1 Sensor Offset is being edited and *NOT* the DIL1 Offset.**
18. Once completed, turn OFF the flow then EXIT>.

## Appendix F.3 T700U Zero Air Mass Flow Controller (DIL1) Verification (Audit Calibrator)

1. With the Alicat still connected to the DIL1 mass flow controller, cap the output and TARE the device until a stable TARE is achieved, then remove cap. (Appendix D provides the manufacturer's instructions for taring the device.)
2. Using the front panel of the calibrator or *APIcom* select GEN> MAN> USR1> ENTR> set gas flow to 3000 cc ENTR> leave O3 Gen mode OFF and diluent flow unchanged then press ENTR>.
3. Using < TST > key scroll through until A-DIL (actual dilution flow) is displayed on the Param Ribbon.
4. When stable, record the calibrator and Alicat flow readings using the calibrator spreadsheet.
5. Using *APIcom* advance to the next target flow setting GEN> MAN> USR1> ENTR> setting the target flow to 6000 cc/min.
6. Repeat for flow settings at 9000 cc/min, 12000 cc/min and 15000 cc/min.
7. Enter the values into the certification Excel workbook DIL1 Sensor Offset Adjust to determine the percent error between the calibrator and the Alicat for each point. The percent error between each point should be less than 2% difference.
8. Once completed, turn OFF the flow then EXIT>.

When the following steps have been completed for the audit calibrator mass flow controller:

- T700U Zero Air Mass Flow Controller (DIL1) Calibration (Audit Calibrator)
- T700U Zero Air Mass Flow Controller (DIL1) Sensor Offset Adjustment (Audit Calibrator)
- T7000U Zero Air Mass Flow Controller (DIL1) Verification (Audit Calibrator)

Return to Section 6.0 of this SOP and continue as written.