thermo scientific

GM-5000 Instruction Manual

Air Quality Monitor

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Thermo Fisher SCIENTIFIC

Contents

Chapter 1
Introduction

The Thermo Scientific GM-5000 Air Quality Monitor is a real-time particulate and gas monitoring system designed for outdoor operation. The unit is designed for continuous unattended monitoring with continuous real-time data transmission to a central location and/or data logging. Its weatherproof enclosure ensures safe and effective operation under a wide range of ambient environmental conditions. Options include a tripod stand and pole-mounting hardware.

The GM-5000 incorporates laser-based particle counting for particulate measurement, and electrochemical sensing and photoionization detection for gas measurement. The instrument provides long-term, precise and low drift measurements of airborne particulate matter and priority gas pollutants using a state-of-the-art combination of optical and electrochemical sensing and data processing techniques refined over the last 25 years.

Thermo Fisher Scientific is pleased to supply this ambient pollution monitoring system. We are committed to the manufacture of instruments exhibiting high standards of quality, performance, and workmanship. Service personnel are available for assistance with any questions or problems that may arise in the use of this monitor. For more information, see Chapter 7, "Servicing".

General Description

The GM-5000 is a complete pollution monitoring system designed to provide the user with continuous measurements of airborne priority pollutants, such as ozone, carbon monoxide, nitrogen dioxide, nitric oxide, sulfur dioxide, total Volatile Organic Compounds (VOCs), and suspended particulate matter, which is reported as $PM_{2.5}$ and PM_{10}. It is a compact, rugged and totally self-contained instrument designed for rapid deployment and unattended operation, mountable on a wall, pole, or tripod.

Reference should be made to Figure 2–4 of this manual for the location and identification of various components of the GM-5000, described in this and subsequent sections of this manual.

The GM-5000 samples the air through a heated vertical inlet tube, which allows gaseous pollutants and particulate matter smaller than about 40 microns aerodynamic diameter to enter the analyzer, while excluding larger debris and water droplets. The sampled air stream then enters a laser-based Optical Particle Counter (OPC) that detects both the number of particles and the particle size distribution.

After the OPC, the sample stream passes through the sample fan and a filter and enters the gas sensor enclosure, where the concentration of gaseous pollutants is measured by the electrochemical cells and an optional photoionization detector (PID) to measure VOCs. The GM-5000 can be configured with the gas sensor enclosure, the Optical Particle Counter, or both.

After passing through the measurement system, the air exhausts into the instrument enclosure, where it mixes with air entering through the cooling inlet and is then exhausted from the enclosure by the cooling fan. Note that the cooling fan is under software control and will turn on and off to adjust the total air through the enclosure as needed based on ambient temperature.

The GM-5000 must be installed by a qualified electrician or service technician and should usually be hard-wired into the AC power line to prevent tampering or weather associated failure. The instrument accepts a universal AC power input (100–240 VAC, 50/60 Hz). The AC power is internally connected to a 24 VDC power supply which supplies all of the internal requirements.

The measured concentration of pollutants is sent to a web server running on the instrument's embedded computer and can be displayed in real time on a Windows-based PC running a standard web browser. The browser-based interface also provides the operator access to diagnostic data and the ability to adjust various operating parameters, as described in Chapter 3, "Operation" of this manual.

Measurement data is also logged internally on the GM-5000 micro-SD card for subsequent download. In addition to pollutant concentration data, the log file will contain information related to operating conditions, such as sample stream temperature and pressure, relative humidity at the gas cells, a time and date stamp and instrument status.

The GM-5000 is designed to measure priority pollutants at concentration levels that would be expected in ambient air in an urban environment anywhere in the world. Specific detection limits and other performance characteristics are listed in the specification table seen below.

Specifications

Table 1–1 lists the specifications for the GM-5000.

Table 1–1. GM-5000 Specifications

Measurement Range (maximum concentration) (other ranges available on request)	NO_2	500 ppb
	NO	500 ppb
	SO_2	500 ppb
	O_3	500 ppb
	CO	50 ppm
	t-VOC	40 ppm
	$PM_{2.5}/PM_{10}$	1500 $\mu g/m^3$
Detection Limit* (2 Sigma of noise)	NO_2	5 ppb
	NO	5 ppb
	SO_2	5 ppb
	O_3	5 ppb
	CO	.020 ppm
	t-VOC	10 ppb
	$PM_{2.5}$	<1.0 $\mu g/m^3$
	PM_{10}	<1.0 $\mu g/m^3$
Response Time (T_{90} in seconds, zero to typical span) (1-minute report period)	120 seconds all sensors	
Linearity*	2% of full scale all sensors	
Zero Drift* (Change per 24 hours)	NO_2	<10 ppb
	NO	<10 ppb
	SO_2	<10 ppb
	O_3	<10 ppb
	CO	<30 ppb
	t-VOC	<10 ppb
Span Drift* (percent change per 24 hours)	NO_2	<5% of value
	NO	<5% of value
	SO_2	<5% of value
	O_3	<5% of value
	CO	<2% of value
	t-VOC	<5% of value
Repeatability**	2% of value	
Resolution	10 ppb gases	
Flow rate range	>1.5 liters/min	
Concentration display updating interval	10 seconds	

Concentration display averaging time	120 seconds
Data logging periods	1 minute to 1 hour (average value is reported)
Total number of records that can be logged in memory	>500,000 (one year's worth of data)
Logged data	Record no., concentration, temperature, relative humidity, barometric pressure, alarms, time and date
Diagnostic data	Critical voltages, Environmental status
Readout display	Implemented through web browser
AC source	100-240 VAC 50-60 Hz
Operating environment	-10 to 45 °C (14 to 113 °F), 15 to 90% RH, non-condensing
Storage environment	-20 to 70 °C (-4 to 158 °F)
Dimensions	16 in (406 mm) H x 12 in (305 mm) W x 6 in (152 mm) D
Weight	11 lbs. (5 kg)

*All specifications measured under controlled laboratory conditions

**Measured at 80% of full-scale range

Dimensions

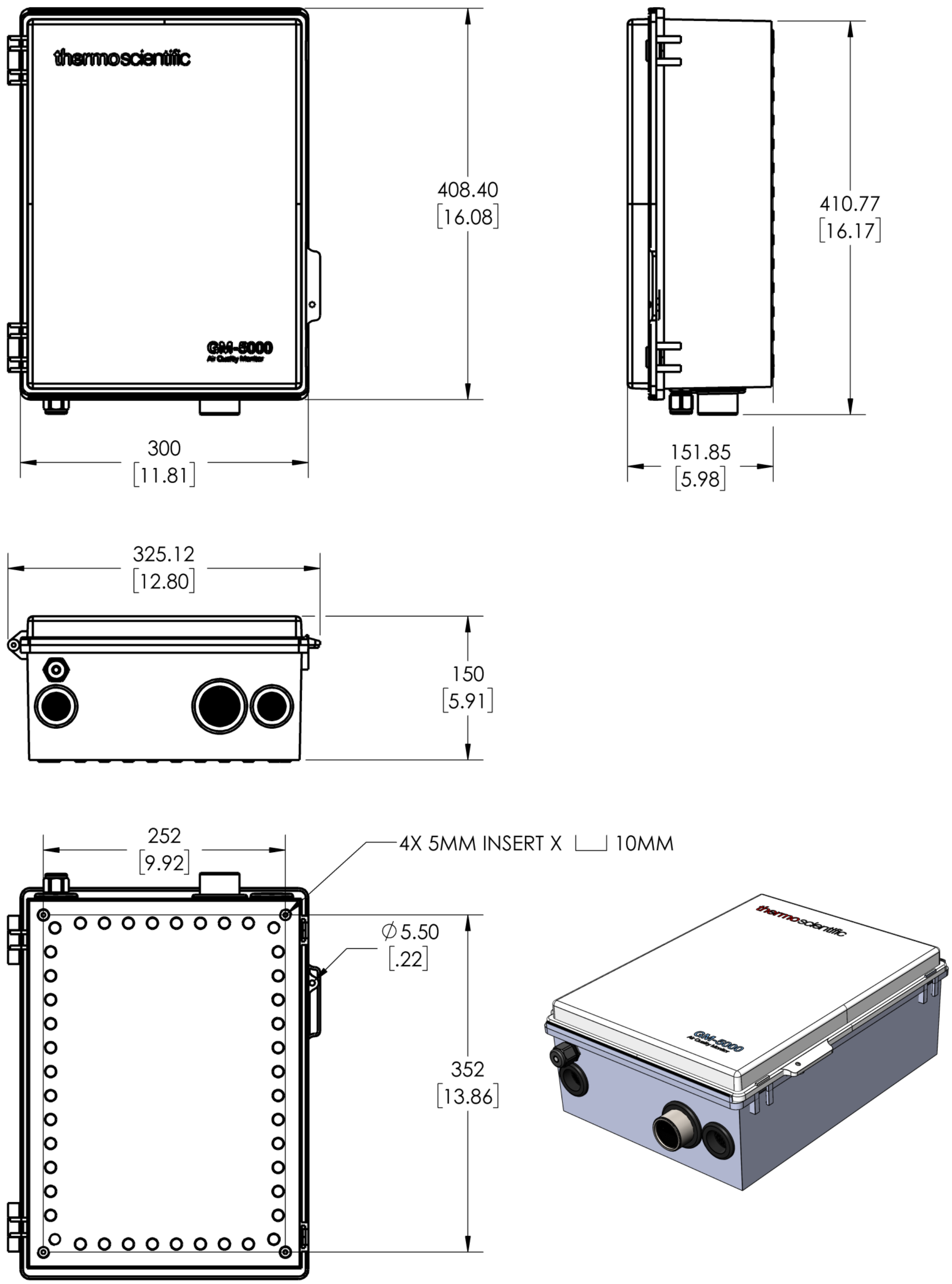


Figure 1–1. GM-5000 Appearance and Dimensions

Chapter 2
Installation and Setup

This chapter includes unpacking, positioning and handling of the instrument, instrument layout and parts identification, outdoor provisions, and computer requirements.

Unpacking the Instrument

Carefully lift the GM-5000 from the shipping box and remove the foam packing materials from the outside of the instrument. If the calibration cap assembly was ordered for the instrument, it may be found inside these packing materials. There may also be a lamp removal tool here if the total-VOC sensor was ordered. Lay the instrument down on a flat surface and then open the front panel of the enclosure and remove any internal packing materials. Next, slide the latch to the left and open the hinged door on the smaller black sensor chamber, and then remove the foam insert that is used to hold the sensors in place during shipping.

With the packing materials removed, check for loose cables and also verify that the electrochemical sensors and/or total-VOC sensor are fully seated. If they are not, press the sensors in place by the outside edge, not by the center. Use the following procedure to unpack and inspect the instrument.

Equipment Damage Do not touch the center of the electrochemical sensors, as this may cause damage. Always handle the sensors by the outside edge if necessary, not by the center. ▲

Equipment Damage Do not attempt to lift the instrument by the cover or other external fittings. ▲

Note Do not discard the packaging material. ▲

Handling

The GM-5000 is a sophisticated optical/electronic instrument and should be handled accordingly. Although the instrument is very rugged, it should not be subjected to excessive shock, vibration, temperature or humidity outside the stated specifications.

If the GM-5000 has been exposed to low temperatures during storage or transportation, care should be taken to allow the instrument to return to ambient temperature before operation. This is advisable because water vapor may condense on the interior surfaces causing temporary malfunction or erroneous readings. Once the instrument warms up to temperature, such condensation will have evaporated.

Equipment Damage Whenever the GM-5000 is shipped, it should be repackaged with the original factory provided box and packing materials. ▲

Safety

Review the following information carefully:

- Read and understand all instructions in this manual.
- Qualified Thermo Fisher Scientific personnel should perform any repair or maintenance not specifically described in this manual. Please contact the factory if any problem should arise. Do not attempt to disassemble the GM-5000, except as described in the "Maintenance" and "Servicing" chapters, otherwise voiding of instrument warranty will result.

WARNING The GM-5000 should be operated only from the type of power sources described in this manual. ▲

- The GM-5000 is normally "hard-wired" into an AC power supply and should only be installed by an electrician or other properly qualified individual.
- Shut off the GM-5000 power switch before connecting or disconnecting the AC power.

WARNING To avoid damage to the instrument, be sure the power switch is in the off position before connecting or disconnecting the AC power supply. ▲

Positioning

The GM-5000 **must be installed in a vertical position** with the sample inlet tube pointing down. This will prevent water and debris from entering the instrument. In order to collect representative data, it is important to ensure free access of the air to be monitored to the sampling inlet on the bottom of the case.

The instrument can be mounted on a wall, pole, or tripod using the four threaded inserts located on the back of the instrument. The thread size for the mounting screws is M5. See Figure 1–1 for mounting hole details. Mounting hardware can often be fabricated from standard DIN rail or optional mounting kits can be purchased from Thermo Fisher Scientific. See figures below for some suggested mounting possibilities.

Again, when mounting the GM-5000, care should be taken to ensure that the inlet is not obstructed by nearby objects. Also, be sure that the front door of the unit can be opened without hindrance, and that free access is provided to the electrical feed-through, sample inlet tube, cooling inlet, and exhaust fan on the bottom of the enclosure.

Under typical operating conditions, the door of the GM-5000 enclosure should be closed. Holes are provided on the enclosure to add a padlock to prevent unauthorized access to the interior of the unit. The door should be opened only when required for installation and/or maintenance.

⚠WARNING

WARNING Personal injury could occur when mounting the instrument. Assistance may be required. ▲

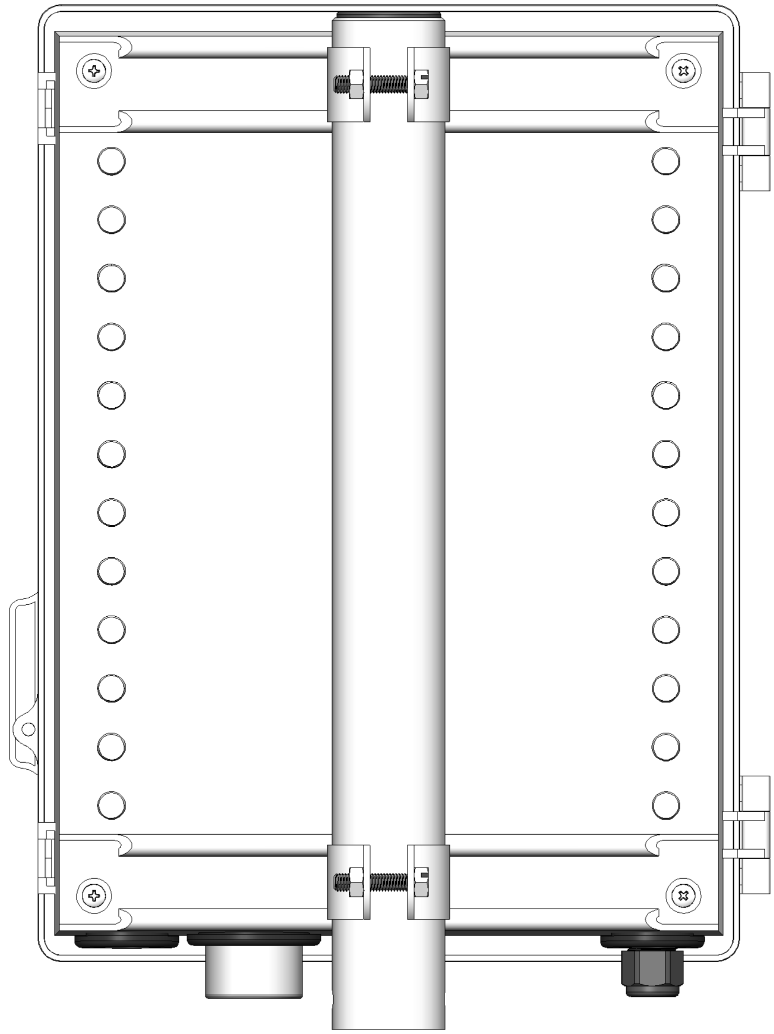


Figure 2–1. GM-5000 Pole Mount

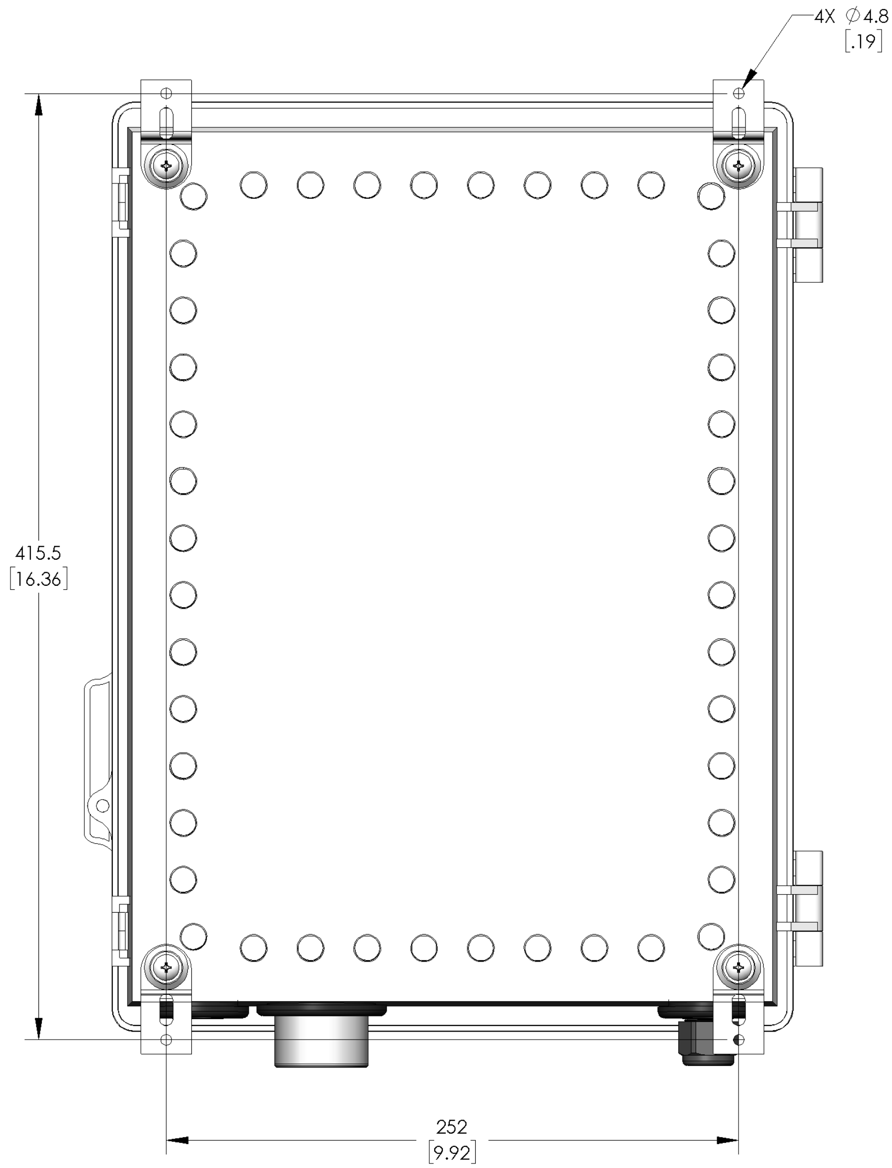


Figure 2–2. GM-5000 Wall Mount

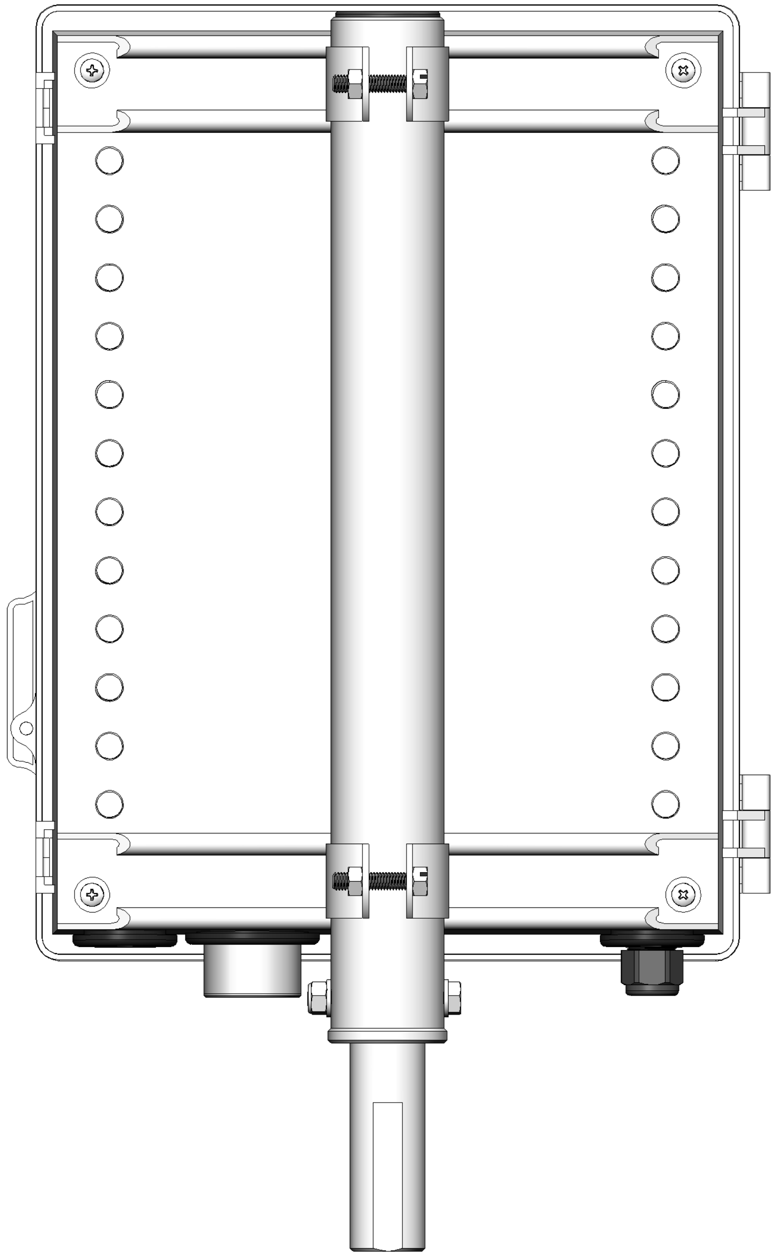


Figure 2–3. GM-5000 Tripod Mount

Instrument Layout and Parts Identification

The user should become familiar with the location and function of all internal components (Figure 2–4). Note that locking latches join the enclosure body to the front door and compress the gasket for proper sealing of the enclosure. The front door also permits the use of padlocks, if necessary.

Qualified Thermo Fisher Scientific personnel should perform any repair or maintenance not specifically described in this manual. Please contact the factory if any problems should arise. Do not attempt to disassemble the GM-5000, except as described in the "Maintenance" and "Servicing" chapters, otherwise voiding of instrument warranty will result.

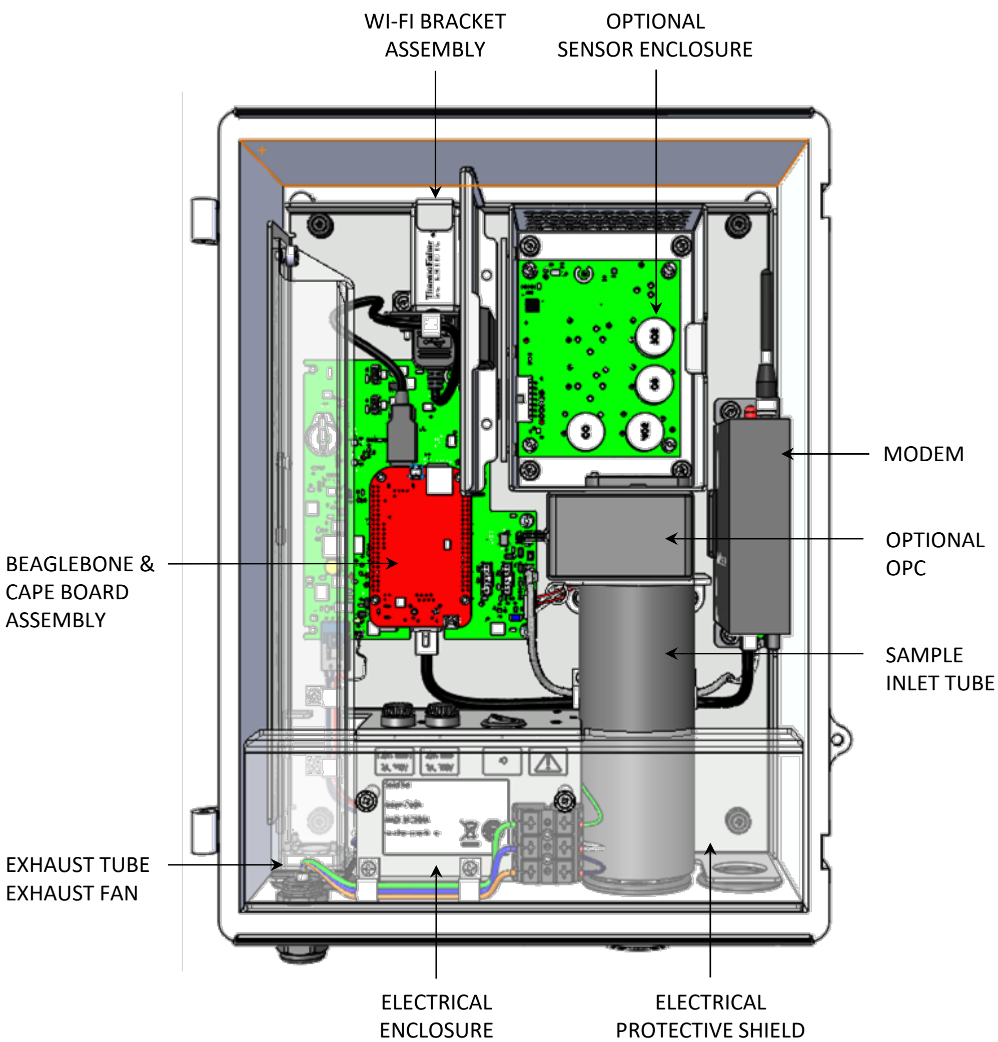


Figure 2–4. GM-5000 Front View

Instrument Bottom

There are four components on the bottom of the GM-5000; the cord grip for the AC power cord, the port for the instrument exhaust fan, the heated sample inlet tube, and the inlet port for the cooling air (Figure 2–5).

Equipment Damage Equipment damage may occur if the sample tube, inlet port or exhaust port is blocked. ▲

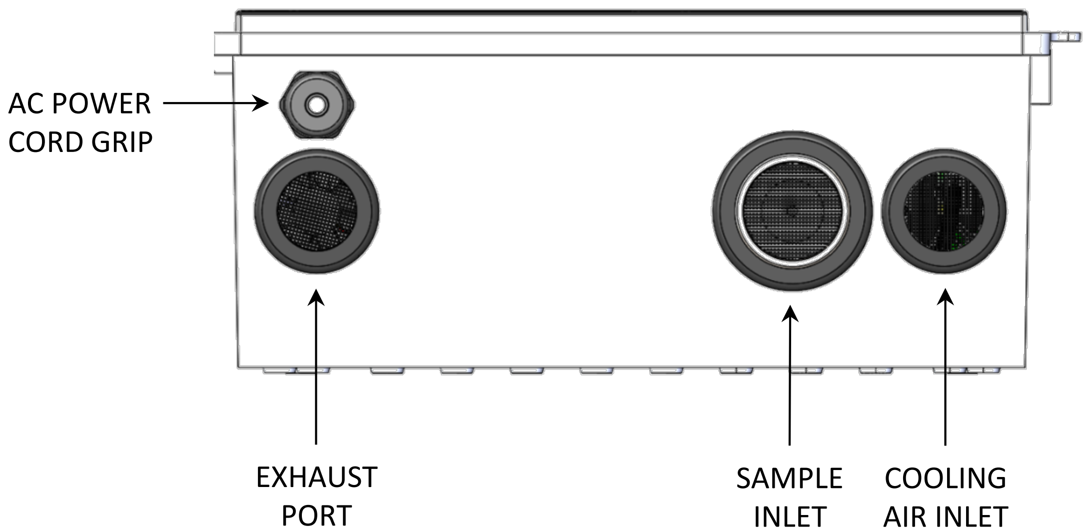


Figure 2–5. GM-5000 Instrument Bottom

Electrical Enclosure and Connections

The electrical enclosure located at the lower edge of the interior is covered by an electrical protective shield, and includes the main power switch, the fuse holders, the AC terminal block, the power supply board and the EMI filter (see Figure 2–4). The incoming AC power line is fed through the water tight gland fitting on the bottom of the case. The neutral and hot lines are then connected to the terminal block as shown in Figure 2–6. After making connections, tighten the gland to seal around the power cord and prevent water entry. The instrument's maximum current draw is 2 Amps at 110 volts, so 18 gauge or heavier power cord is most appropriate. Please consult a qualified electrician to verify proper installation.

Equipment Damage The GM-5000 can be powered from any line with a voltage between 100-240 volts AC, 50 to 60 Hz. No internal adjustments or selections need to be made for power lines with voltages and frequencies in those ranges. The internal AC-to-DC power unit performs any adjustments automatically. ▲

Equipment Damage Equipment damage may occur to instrument if power inputs or fuse type exceeds specified ranges. ▲

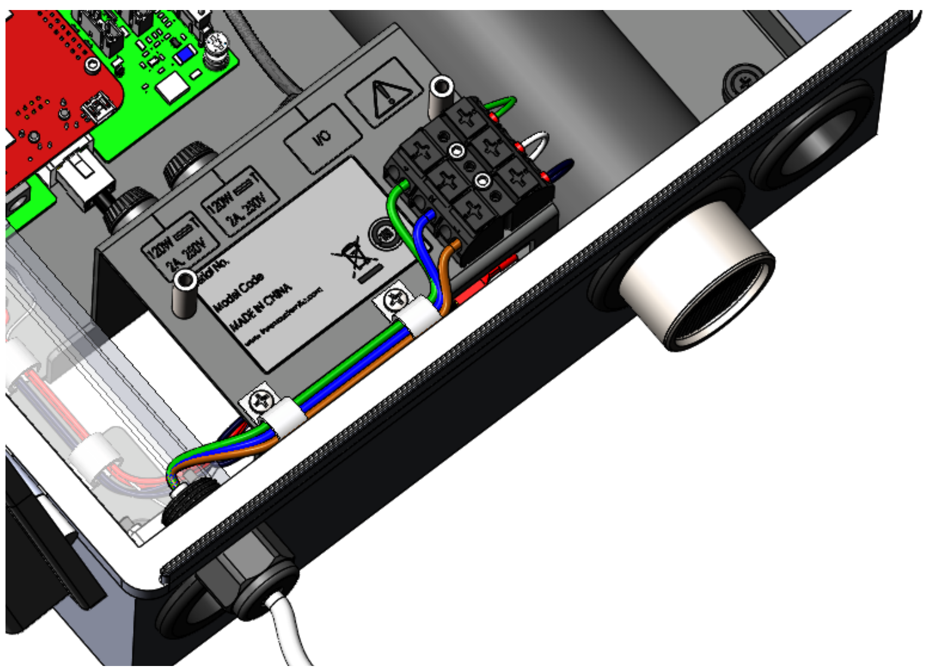


Figure 2–6. GM-5000 AC Wiring Connections

Sample Inlet Tube Assembly w/ Optional OPC

The Sample Inlet Tube Assembly protrudes through the bottom of the case and is located in the bottom right side of the GM-5000 enclosure (see Figure 2–4). The inlet is fitted with a wire screen to keep out debris. The sample inlet tube is heated to prevent condensation from forming inside the instrument, and it is sized so that particles larger than those of interest drop out and do not make it into the measuring devices. The air sample is drawn into the inlet tube by a small sample fan that is located inside of the optional Optical Particle Counter (OPC). If the OPC is not present, the sample fan is located inside of an OPC Blank, which is dimensionally equivalent to the OPC and allows the system to function the same way as if the OPC was present.

After the air sample is drawn into the sample inlet tube, it passes through the optional OPC. The OPC is a laser-based system for detecting and measuring the presence of $PM_{2.5}$ and PM_{10} particles in the air. Once the air sample passes through the OPC, or through the OPC Blank if the OPC is not present, the sample fan pushes the air into the optional Sensor Enclosure Assembly, if so equipped.

Equipment Damage Equipment damage may occur if the sample tube, inlet port or exhaust port is blocked. ▲

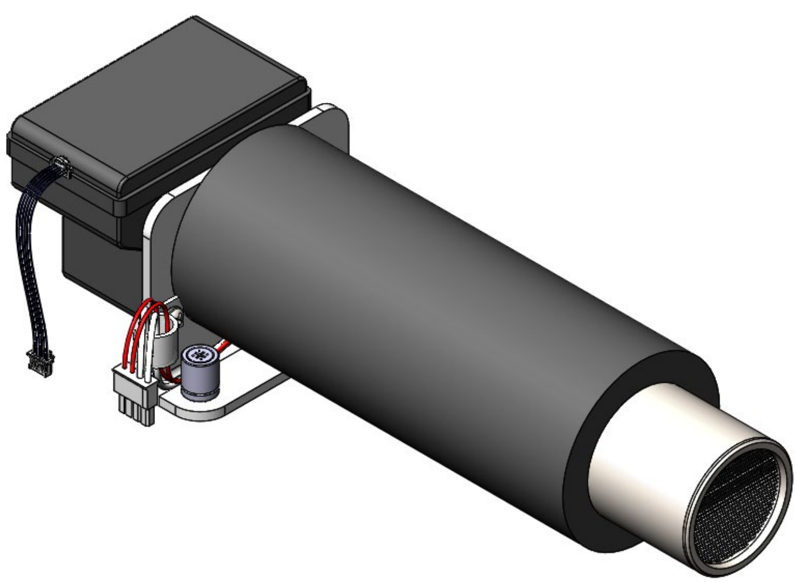


Figure 2–7. GM-5000 Sample Inlet Tube Assembly and Optional OPC

Optional Sensor Enclosure Assembly

Once the air sample passes through the OPC or OPC Blank, the sample fan pushes the air through another protective wire screen and into the optional Sensor Enclosure Assembly, if so equipped. The Sensor Enclosure Assembly is located in the top right side of the GM-5000 enclosure, and is in line with the sample inlet tube and OPC or OPC Blank (see Figure 2–4).

The Sensor Enclosure Assembly contains the sensor interface board, on which the electrochemical cells and optional photoionization detector (PID) are mounted. Depending on which sensors were ordered, these electrochemical cells provide continuous measurements of ozone, carbon monoxide, nitrogen dioxide, nitric oxide, and sulfur dioxide, while the PID measures total VOCs. The air sample fills the sensor enclosure, passes over the electrochemical sensors and PID, is measured, then exits the sensor enclosure into the main GM-5000 enclosure, where it mixes with cooling air and is exhausted into the atmosphere. (If the Sensor Enclosure Assembly is not present, the air sample passes directly from the OPC into the main GM-5000 enclosure.)

The Sensor Enclosure Assembly can be accessed for cleaning or servicing by sliding the cover latch to the left while lifting up on the cover.

Equipment Damage Do not touch the center of the electrochemical sensors, as this may cause damage. Always handle the sensors by the outside edge if necessary, not by the center. ▲

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly grounded antistatic wrist strap must be worn while handling any internal component. ▲

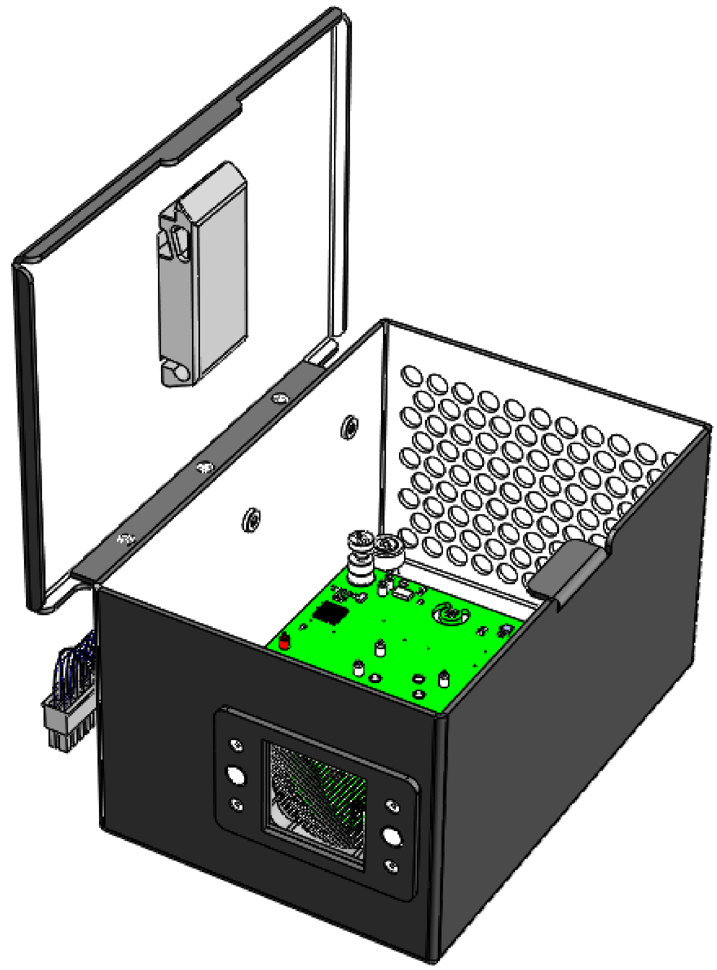


Figure 2–8. GM-5000 Optional Sensor Enclosure Assembly

Cellular VPN Router/Modem

The Router/Modem shown below is representative of the typical version provided by Thermo Fisher Scientific, but other versions of the router/modem may be utilized with the instrument. Any references made to the router/modem in this manual apply to the Thermo Fisher Scientific version.

The industrial cellular router/modem is located on the right side center of the GM-5000 enclosure (see Figure 2–4). It provides reliable 3G/4G connectivity to a cellular network and is made for use in rugged industrial applications. It allows the user to remotely download logged data from the instrument, and it also gives the user the ability to send commands, diagnose potential problems, and continuously monitor the operation of the instrument from a remote location.

Figure 2–9. Router/Modem

WiFi Bracket Assembly

The WiFi Bracket Assembly is located in the upper left corner of the GM-5000 enclosure (see Figure 2–4). The WiFi dongle provides a wireless local area network connection between the GM-5000 and a Windows-based PC. The GM-5000 is not equipped with a typical user interface that includes a display and pushbutton keys, but rather relies on the portable device's web browser to interface with the instrument. The WiFi dongle has a maximum range of approximately 20 meters.

The Graphical User Interface (GUI) is loaded onto a web server running on the instrument's embedded computer and is not accessed through the internet, providing a secure connection to the instrument. The browser-based interface displays measured concentrations of pollutants in real time, and provides the operator access to diagnostic data and the ability to adjust operating parameters. For more information on the functionality of the user interface and operation of the GM-5000, see Chapter 3, "Operation" in this manual.

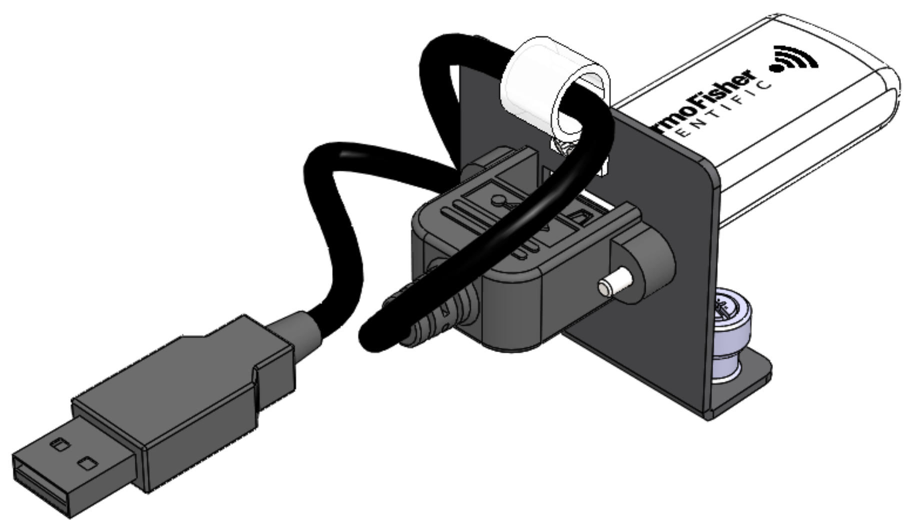


Figure 2–10. WiFi Bracket Assembly

BeagleBone Cape Board Assembly

The BeagleBone Cape Board Assembly is located on the left side center of the GM-5000 enclosure (see Figure 2–4). It contains the instrument's embedded computer that controls the function of all of the sub-components in the instrument, as well as the web server that contains the browser-based interface that provides the operator access to the instrument. It also contains the micro-SD card upon which all of the logged data is stored.

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly grounded antistatic wrist strap must be worn while handling any internal component. ▲

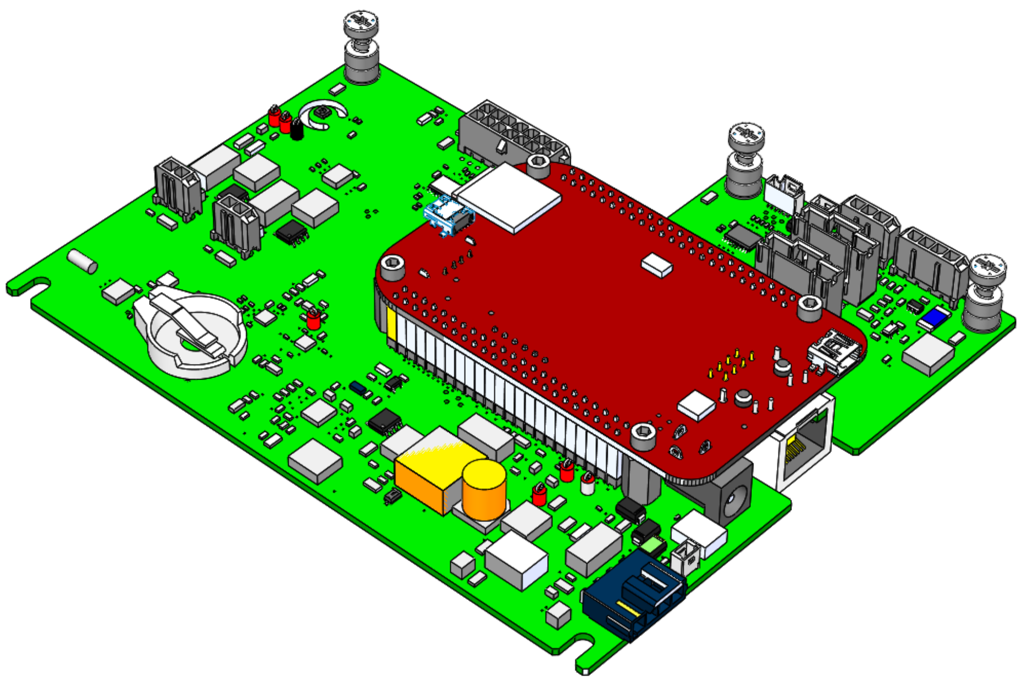


Figure 2–11. BeagleBone Cape Board

Exhaust Tube/Exhaust Fan

The exhaust tube is located along the entire left side of the GM-5000 enclosure, and the exhaust (cooling) fan is located in the lower left corner at the base of the exhaust tube (see Figure 2–4).

The exhaust fan has a higher flow rate than the sample fan, which ensures that cooling air is drawn into the instrument through the cooling air inlet port at the bottom of the enclosure. The exhaust tube directs that cooling air to flow across the electronics, where it then mixes with the analyzed air sample and is exhausted from the enclosure by the exhaust fan. Note that the exhaust/cooling fan is under software control, and will turn on and off to adjust the total air through the enclosure as needed based on ambient temperature.

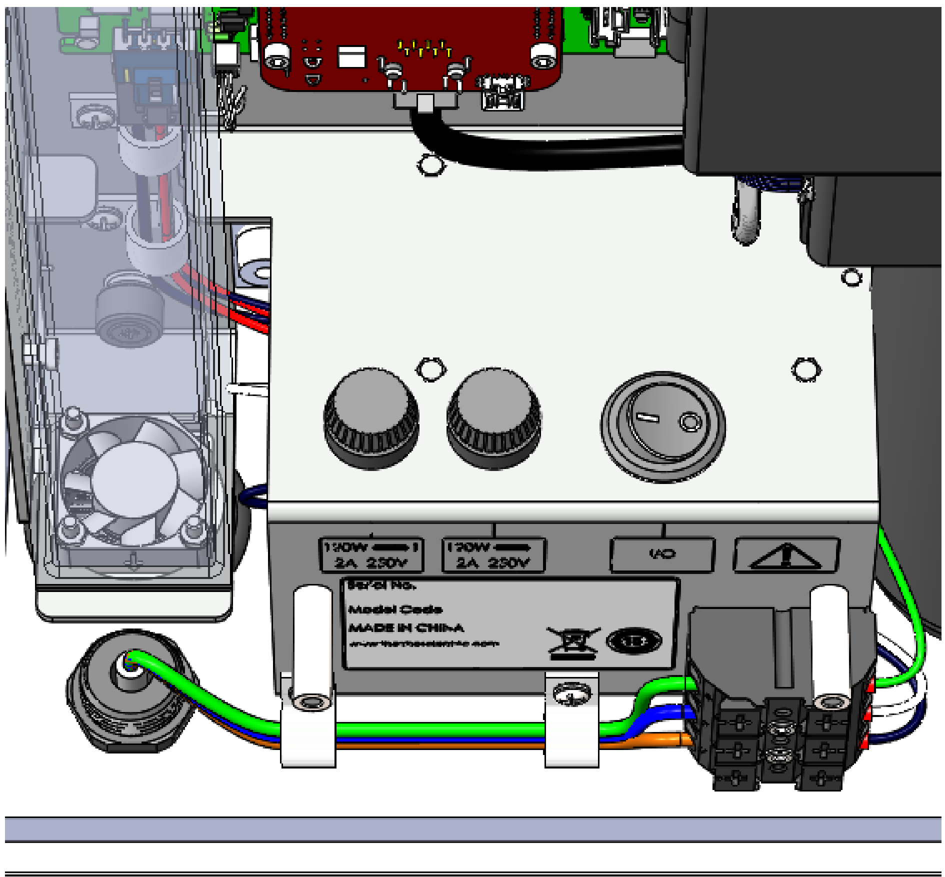


Figure 2–12. Exhaust Tube/Exhaust Fan

Preparation for Operation

To begin using the GM-5000, it must first be mounted in the proper orientation on a wall, tripod, or pole as described in the "Positioning" section earlier in this chapter.

AC Power Connection

The GM-5000 as received from the factory is not provided with an AC power cord, as the instrument is normally "hard-wired" into an AC power supply. The instrument's maximum current draw is 2 Amps at 110 volts, so 18 gauge or heavier power cord is most appropriate. Please consult a qualified electrician to verify proper installation.

Prior to connecting the AC power, the electrical protective shield must be removed. Refer to "Removing the Electrical Protective Shield" procedure (Figure 7–3) from Chapter 7, "Servicing" of this manual.

The incoming AC power line is fed through the water tight gland fitting on the bottom of the case. The neutral and hot lines are then connected to the terminal block as shown in Figure 2–13. After making connections, tighten the gland to seal around the power cord and prevent water entry.

Equipment Damage It should be noted that the GM-5000 can be powered from any line with a voltage between 100-240 volts AC, 50 to 60 Hz. No internal adjustments or selections need to be made for power lines with voltages and frequencies in those ranges. The internal AC-to-DC power unit performs any adjustments automatically. ▲

WARNING

WARNING To avoid damage to the instrument, be sure the power switch is in the off position before connecting or disconnecting the AC power supply. ▲

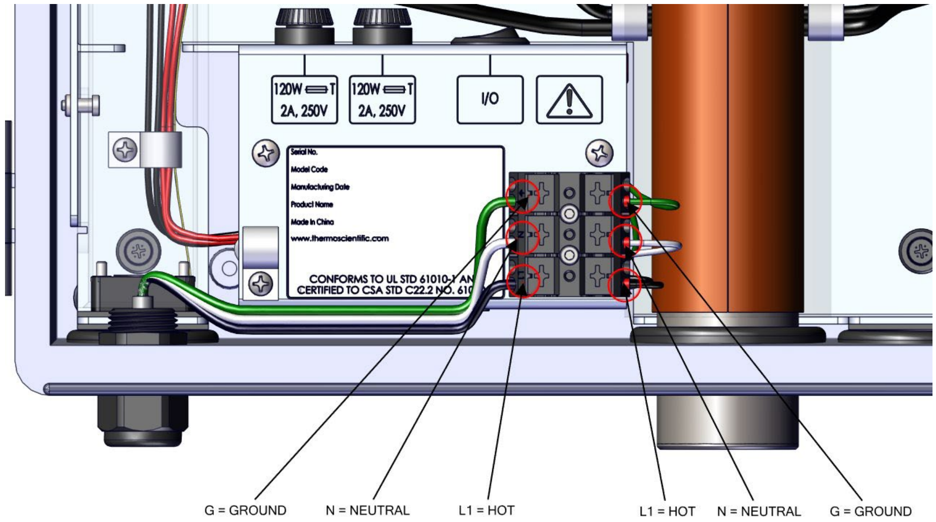


Figure 2–13. AC Power Connection

Communication between GM-5000 and Computer

The GM-5000 user interface is loaded onto a web server running on the instrument's embedded computer and is accessed through WiFi from a Windows-based PC.

Use the following procedure to establish a WiFi connection between the GM-5000 and the computer.

1. Turn the GM-5000 power switch on.

2. After about 2 minutes, you will see that a blue LED on the lower edge of the underside on the GM-5000 computer board is flashing with a steady "heartbeat" pattern. This indicates that the system is operating normally.

3. Open the window showing available wireless connections by clicking the bar symbol in the lower right corner of the Windows PC screen.

4. Find the device that matches the GM-5000 host name, which will appear as "thermo-grid-xxxx", where the "xxxx" is a series of numbers and letters, and click "Connect."

5. You will be asked for a password. The default password is "thermo-grid".

6. After entering the password, you should get a message indicating that the device is connected. If you get a yellow warning message indicating there is no internet connection, that message can be ignored.

7. If the connection fails completely, it is best to shut off the GM-5000, wait 10 seconds and then turn the power back on. Note that only one user or device can be connected to the GM-5000 WiFi at any given time.

8. Once a connection is established, open a browser window (Chrome or Firefox is suggested.)

9. Go to the IP address line and enter 192.168.4.1. The user interface should open within approximately 10 seconds.

Chapter 3
Operation

This chapter describes the functionality of the user interface.

User Interface

The User Interface consists of a Navigation Bar, an Active Area, and a Status Bar. The Navigation Bar, located at the top, includes the Home button and Title Field. The Active Area, located in the middle, is where the Home Screen and all other screens are accessed. The Home Screen has three Main Menu buttons, located on the left side, which include Calibration, Data, and Service, while the main data table to the right of the buttons displays the current concentration readings from the instrument sensors. The Status Bar, located at the bottom, includes the Back button, Mode Field, Status Symbol, and Date/Time.

Home Screen

The User Interface contains the following information:

- Navigation Bar:
  - *Home button:* This button appears on every page and always returns the user to the Home Screen. If the Home Screen is already displayed, this button just refreshes the display.
  - *Title Field:* This is a text box that appears in every screen and displays the instrument model number and the name of the current page. In some cases, it also displays the instrument identifier or name, which can be edited in the setup menu.
- Active Area:
  - *Control buttons:* A set of three action buttons appears in the active area of the Home Screen. Each button is a hyperlink to one of the three main menus: Calibration, Data, and Service.
  - *Main Data Table*: The main data table is used to display the current concentration readings from the instrument sensors. This table will always have three columns. The left most column shows the parameter being measured or reported. The center column is a "live" display of measurement results. This column is updated or refreshed once every 10 seconds. The far-right column shows the concentration units for each parameter. The number of lines in the table will vary depending on the type of sensors that are installed.
- Status Bar:
  - *Back button:* Moves the display back one step to the previously displayed screen.
  - *Mode Field:* This is a text box that displays the current operating mode of the instrument. The operating mode is also included in each data record and is used by the instrument operator during post-processing or analysis of downloaded records. Possible values to be displayed in the Mode Field are Run and Service. Note that the exhaust/cooling fan and the sample fan both turn off any time the instrument is in Service Mode.
  - *Status Symbol:* This field shows one of two possible symbols that indicate instrument status. The symbol is a green "check" if there are no errors and is a red  if errors have been detected.
  - *Time Stamp Field:* This is a text box that appears on every screen and displays the current date and time.

Main Menu

The Main Menu buttons, located on the Home Screen, contain three submenus. Each submenu contains related instrument settings, actions, or information. This chapter describes each submenu and screen in detail. Refer to the appropriate sections for more information.

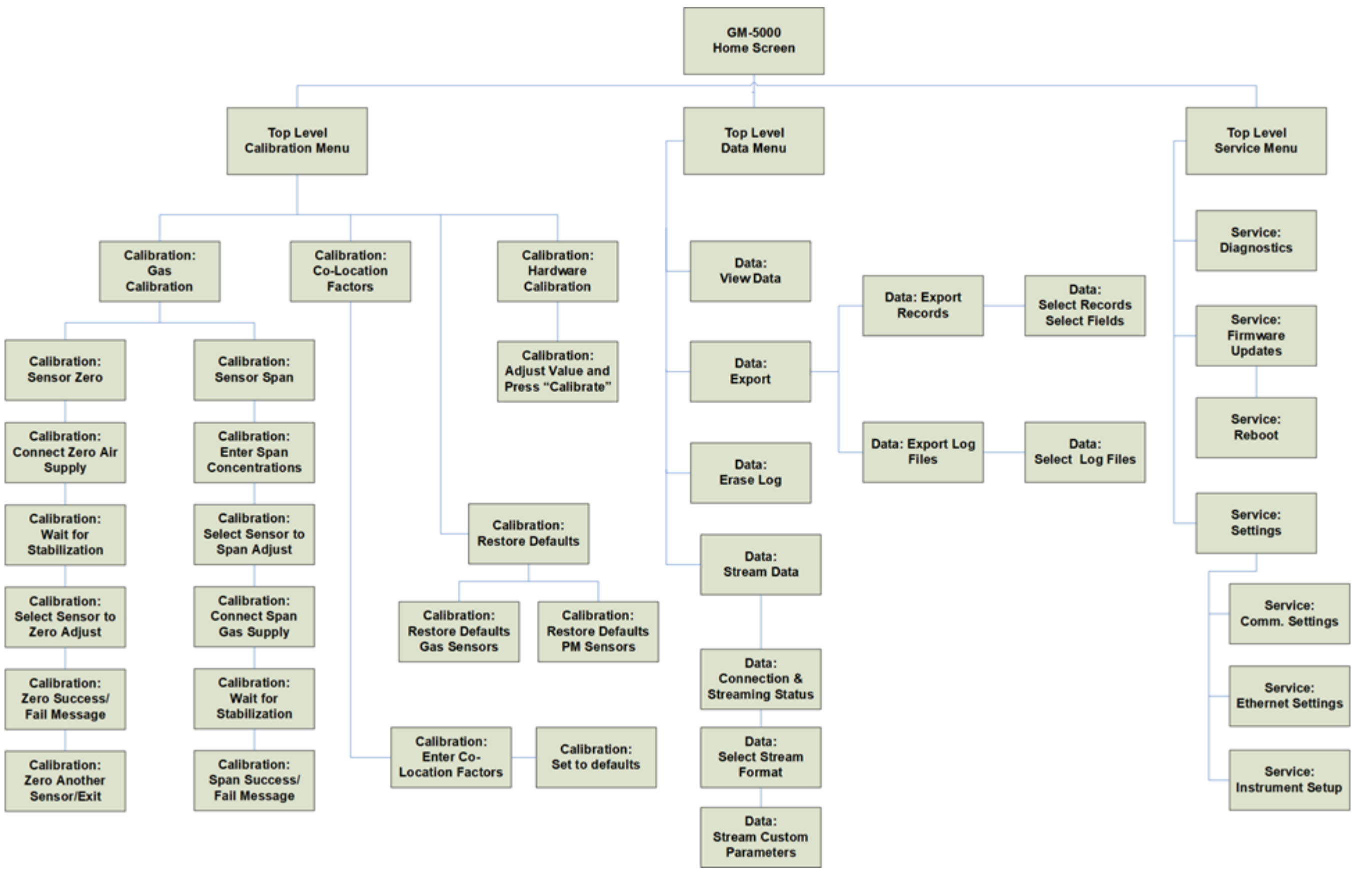
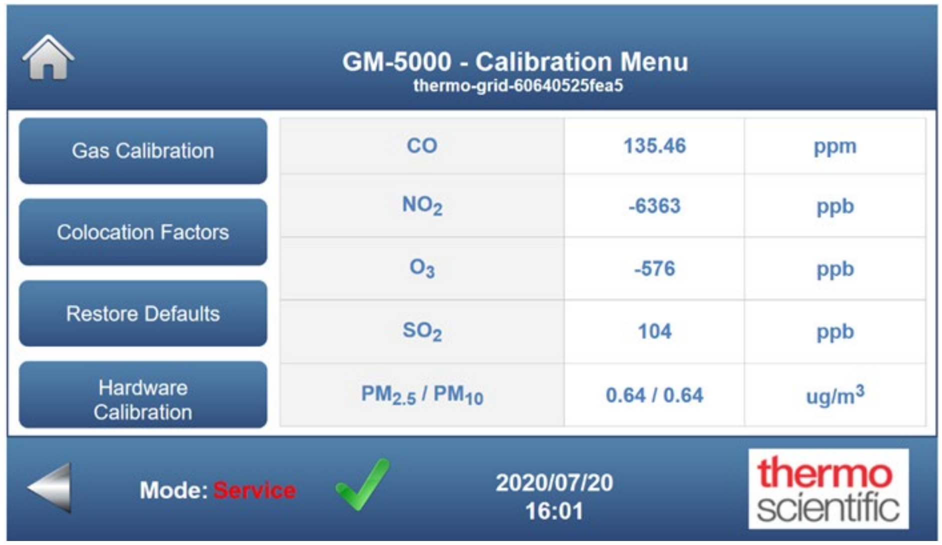


Figure 3–14. GM-5000 Main Menu Structure

Calibration

The Calibration screen allows the user to calibrate the air quality sensors using a zero and span gas supply, to manually adjust the intercept and slope using a colocation process, to restore the original factory calibration default values, or to calibrate “hardware”, meaning the sensors for temperature, relative humidity and pressure. See Chapter 4 “Calibration” for further instructions on how to perform a calibration.

Home Screen>Calibration



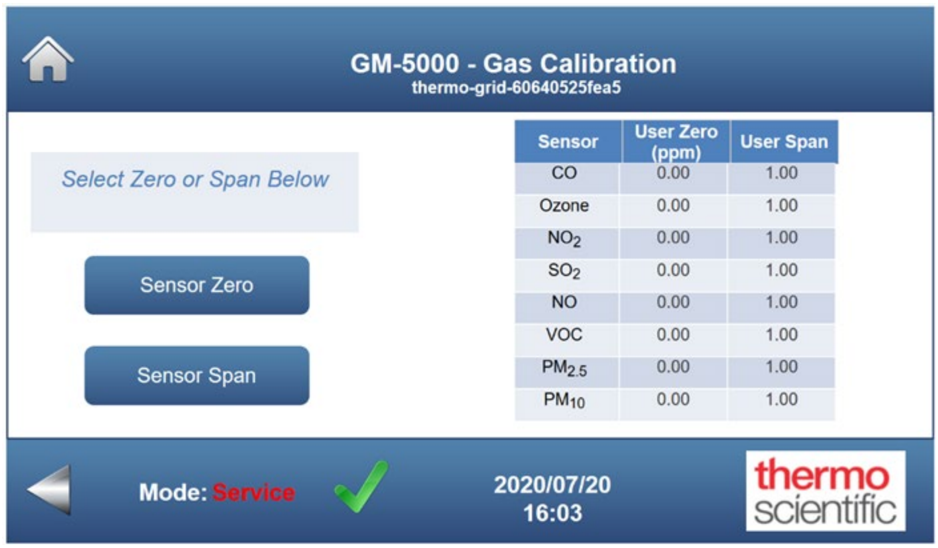
The Calibration screen contains the following information:

- *Gas Calibration:* Allows the user to calibrate the air quality sensors by utilizing zero air and span gas.
- *Colocation Factors:* Allows the user to manually enter calibration factors that are calculated off-line using colocation data that can be generated by running the GM-5000 in a “side by side” configuration with certified reference analyzers.
- *Restore Defaults:* Allows the user to restore the calibration coefficients to the original factory default values.
- *Hardware Calibration:* Allows the user to calibrate “hardware”, meaning the sensors for temperature, relative humidity and pressure.

Gas Calibration

The Gas Calibration screen is used to initiate a calibration of the air quality sensors by introducing a supply of either zero air or span gas. The operator selects either Sensor Zero to zero-adjust any of the gas sensors or particulate sensors, or selects Sensor Span to span-adjust any of the gas sensors. For more information on performing a gas calibration, see Chapter 4, “Calibration”.

Home Screen>Calibration>Gas Calibration



The Gas Calibration screen contains the following information:

- *Sensor Zero:* Allows the user to adjust the zero reading of the air quality sensors.
- *Sensor Span:* Allows the user to initiate a span calibration of the gas sensors (the particulate sensors cannot be span-adjusted).
- *Current ValuesTable:* This read-only table shows the current “User zero” and “User span” values for all sensors. The zero values are expressed in terms of concentration and the span values are unitless multiplication factors.

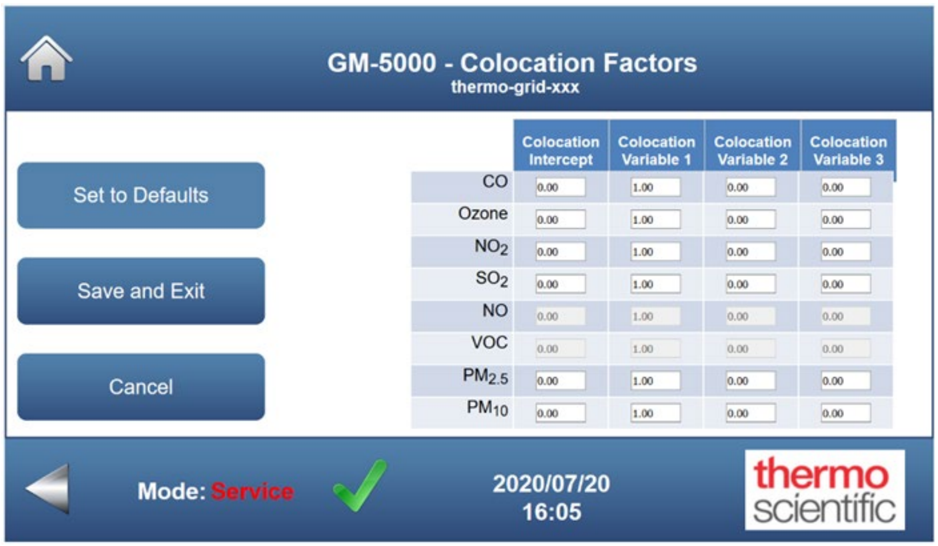
Colocation Factors

The Colocation Factors screen is used to manually enter intercepts and regression coefficients that are calculated off-line during a calibration by colocation. That is, calibration against a known reference instrument.

Default values when the instrument is shipped from the factory are as shown below. Note that these values can also be adjusted from a remote server as described later in this chapter.

For more information on calibration by colocation, see Chapter 4, "Calibration".

Home Screen>Calibration>Colocation Factors



The Co-Location Factors screen contains the following information:

- *Set to Defaults:* Allows the user to clear colocation values, setting Intercept, Variable2 and Variable3 to zero and Variable1 to one. This essentially disables colocation.
- *Save and Exit:* Allows the user to save and utilize any changes to the colocation factors as described above, then exit and return to the main Calibration screen.
- *Cancel:* Allows the user to exit this screen without making any changes to the colocation factors and return to the main Calibration screen.

Restore Defaults

The Restore Defaults screen is used to restore the gas calibration coefficients and the colocation coefficients back to the original factory default values. Any calibration data stored in the instrument from a user calibration will be deleted. The calibration values revert back to those that were originally set at the factory until a new user calibration is performed. For more information on restoring defaults, see Chapter 4, "Calibration".

Home Screen>Calibration>Restore Defaults

The Restore Defaults screen contains the following information:

- *Restore Default Calibration - Gas Sensors:* Allows the user to restore the original factory calibration for the gas sensors only.
- *Restore Default Calibration - PM Sensors:* Allows the user to restore the original factory calibration for the particulate sensors only.
- *Cancel:* Allows the user to abort the restoring defaults process without making any changes to the existing calibration.

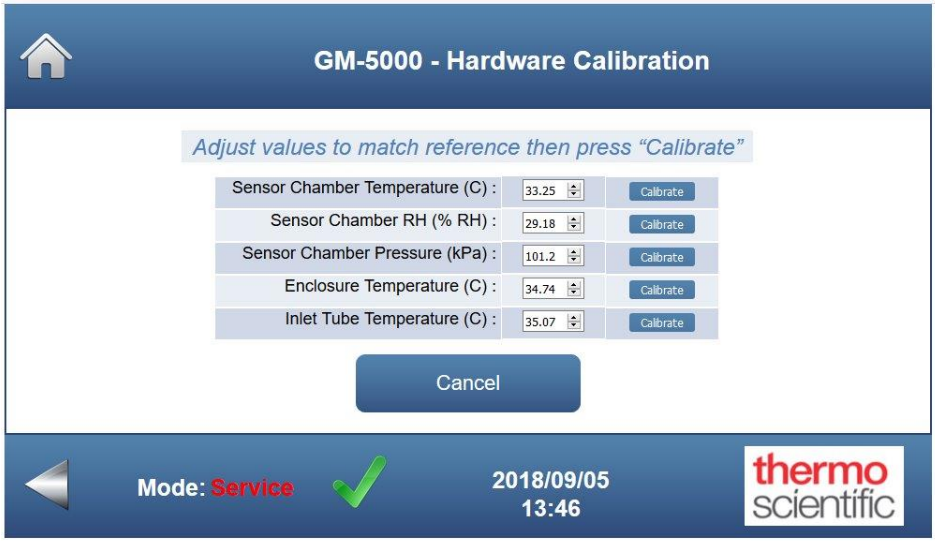
Hardware Calibration

The Hardware Calibration screen is used to calibrate the temperature, humidity and pressure sensors. The screen includes five text boxes with an action button associated with each test box.

All five sensors are calibrated by entering a reference value taken with a known "good" instrument that is co-located with the GM-5000. For example, to calibrate the GM-5000 pressure sensor, the operator would take an atmospheric pressure reading with a high quality, calibrated reference manometer. The manometer value is then entered in the appropriate text box. Clicking the associated "Calibrate," or action button, transmits the known true pressure reading back to the application program which then calculates a span adjustment value that can be applied to correct the GM-5000 pressure sensor.

These hardware calibrations are initially performed at the factory and generally do not need to be repeated unless there is a malfunction or hardware replacement.

Home Screen>Calibration>Hardware Calibration



The Hardware Calibration screen contains the following information:

- *Sensor Chamber Temperature:* Allows the user to adjust the sensor chamber temperature reading to match a reference value.
- *Sensor Chamber RH:* Allows the user to adjust the sensor chamber relative humidity reading to match a reference value.
- *Sensor Chamber Pressure:* Allows the user to adjust the sensor chamber pressure reading to match a reference value.

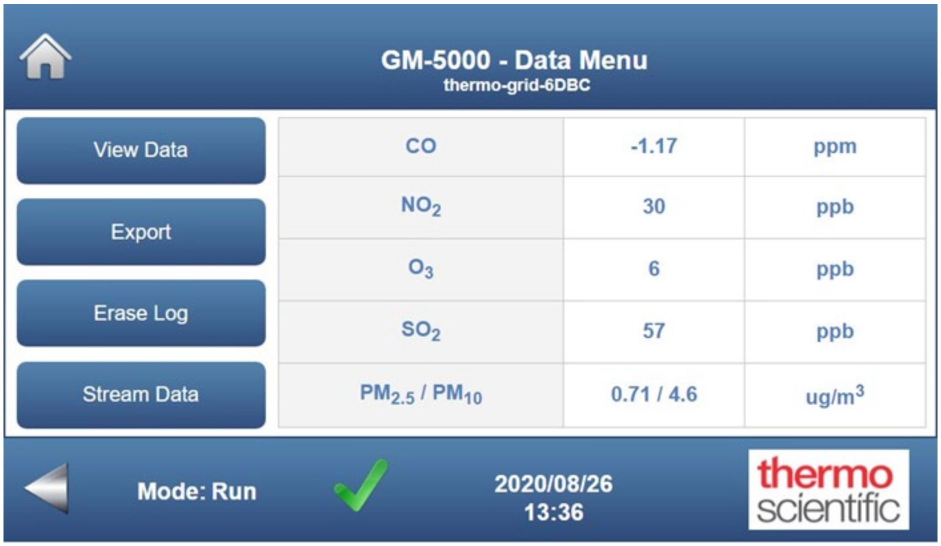
- *Enclosure Temperature:* Allows the user to adjust the enclosure temperature reading to match a reference value.
- *Inlet Tube Temperature:* Allows the user to adjust the sample inlet tube temperature sensor reading to match a reference value.

Note This hardware calibration adjusts the reported readings to match a reference instrument, but does not change or set the actual temperatures, pressure or relative humidity. ▲

Data

The Data screen is used to view and record concentrations and instrument data. Users can view the data in tabular format, export the data to a file, or stream the data in real time to an external server. Various log files can also be exported to a file, which may be used for diagnostic purposes.

Home Screen>Data



The Data screen contains the following information:

- *View Data:* Allows the user to view the logged data, with the most recent data being at the top of the table.
- *Export:* Allows the user to export all the logged data or a specified subset of the logged data to a file in CSV format. The user can also export GUI (graphical user interface), system, application, or histogram log files, which may be used for diagnostic purposes.
- *Erase Log:* Allows the user to erase all logged data from the database.
- *Stream Data:* Allows the user to stream the real time data to a remote server at an IP address specified by the user.

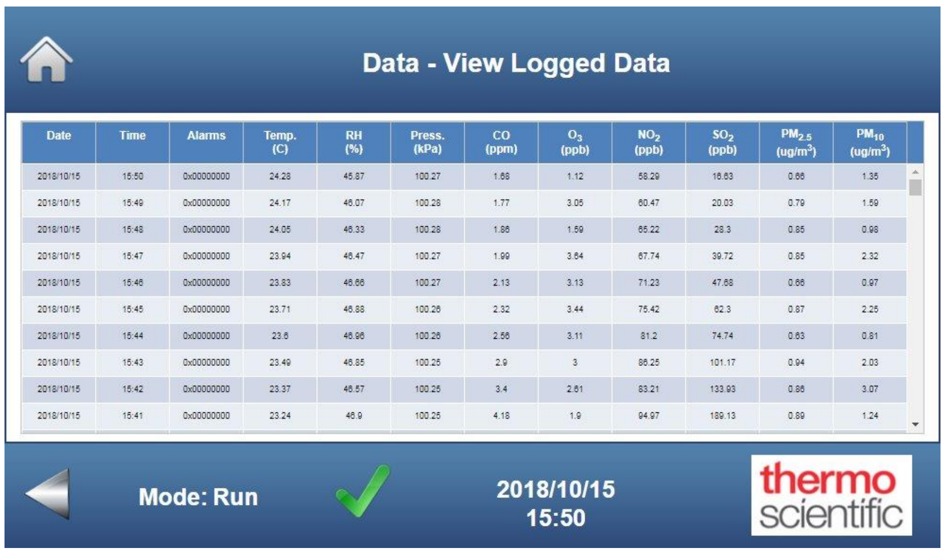
View Data

The View Data screen allows the user to retrieve and view measurement data that has been stored in the instrument's database. This is a read only table where each row represents a database record.

Records are displayed in the order collected, with the newest record at the top. A scroll bar allows the operator to scroll down to view older records.

The format and content of each record is fixed, with each record containing approximately 12 data fields as shown in the sample "View Logged Data" screen below. The exact number of fields may vary depending on what sensors are installed.

Home Screen>Data>View Data



Date	Time	Alarms	Temp. (C)	RH (%)	Press. (kPa)	CO (ppm)	O_3 (ppb)	NO_2 (ppb)	SO_2 (ppb)	$PM_{2.5}$ (ug/m^3)	PM_{10} (ug/m^3)
2018/10/15	15:50	0x00000000	24.28	45.87	100.27	1.68	1.12	58.29	16.63	0.66	1.35
2018/10/15	15:49	0x00000000	24.17	46.07	100.28	1.77	3.05	60.47	20.03	0.79	1.59
2018/10/15	15:48	0x00000000	24.05	46.33	100.28	1.86	1.59	65.22	28.3	0.85	0.98
2018/10/15	15:47	0x00000000	23.94	46.47	100.27	1.99	3.64	67.74	39.72	0.85	2.32
2018/10/15	15:46	0x00000000	23.83	46.66	100.27	2.13	3.13	71.23	47.68	0.66	0.97
2018/10/15	15:45	0x00000000	23.71	46.88	100.26	2.32	3.44	75.42	62.3	0.87	2.25
2018/10/15	15:44	0x00000000	23.6	46.96	100.26	2.56	3.11	81.2	74.74	0.63	0.81
2018/10/15	15:43	0x00000000	23.49	46.85	100.25	2.9	3	86.25	101.17	0.94	2.03
2018/10/15	15:42	0x00000000	23.37	46.57	100.25	3.4	2.61	83.21	133.93	0.86	3.07
2018/10/15	15:41	0x00000000	23.24	46.9	100.25	4.18	1.9	94.97	189.13	0.89	1.24

The View Data screen contains the following information:

- Across:
  - Date: YYYY/MM/DD
  - Time: 24 hour format
  - Alarms: Displays digits that encode instrument mode and any alarms that are present. These digits will be highlighted in yellow if the instrument is in Service Mode and will be highlighted in red if there are alarms.
  - Temp.: Sensor chamber temperature, reported in degrees C
  - RH: Sensor chamber relative humidity in "%"
  - Press: Sensor chamber atmospheric pressure, reported in kPa

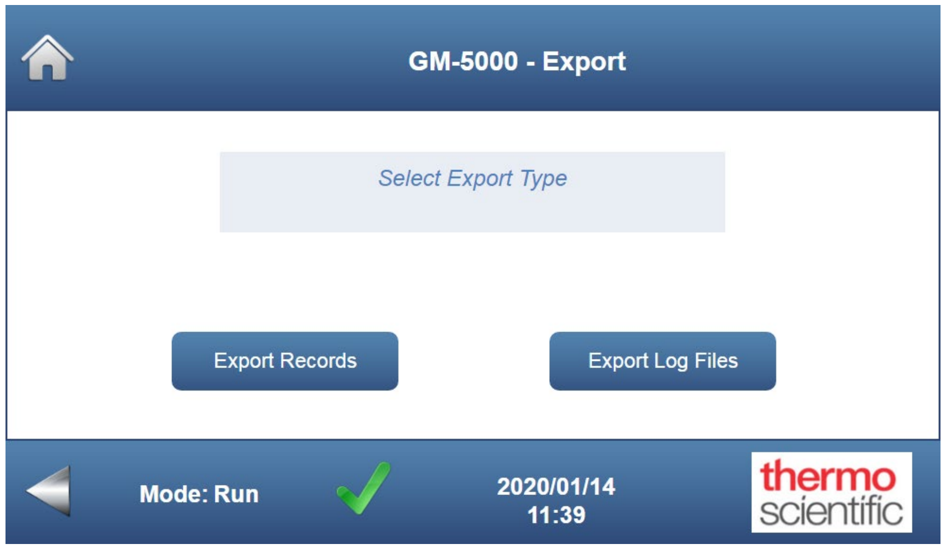
- CO: Carbon monoxide reading in ppm
- O_3: Ozone reading in ppb
- NO_2: Nitrogen dioxide reading in ppb
- SO_2: Sulfur dioxide reading in ppb
- NO: Nitric oxide reading in ppb
- VOC: Total VOC reading in ppm
- $PM_{2.5}$: Particulate matter reading in $\mu g/m^3$, less than 2.5 microns
- PM_{10}: Particulate matter reading in $\mu g/m^3$, less than 10 microns

Note The temperature, RH, and pressure reflect conditions inside the sensor chamber, not the ambient environment. Pollutants displayed will vary depending on instrument configuration. ▲

Export

The Export screen allows the user to select the type of information to be downloaded to a PC, either data records or log files that contain various types of diagnostic data. Once a selection is made, another screen is opened where the user can further specify what information will be exported to the file.

Home Screen>Data>Export



The Export screen contains the following information:

- *Export Records***:** Allows the user to export all the logged data records or a specified subset of the logged data to a file in Comma Separated Value (CSV) format that can be easily imported to Microsoft Excel or other data analysis programs.
- *Export Log Files:* Allows the user to export the GUI log files, system log files, application log files, histogram log files, or a set of all log files, which may be used for diagnostic or trouble-shooting purposes.

Export Records

The Export Records screen allows the user to download measurement records from the database and save to a personal computer (PC) or similar device in CSV format. When the operator navigates to this screen, they are presented with "radio button" type controls that allow them to select which records they intend to download and what information is contained in those records.

Home Screen>Data>Export>Export Records

The Export Records screen contains the following information:

- *Export all records:* Downloads all the logged data records from the database to a file.
- *Export new records:* Downloads any records that have not been previously downloaded.
- *Export selected number of records:* Downloads the specified number of records, starting with the most recent and counting backwards.
- *Export selected date range:* Downloads all records that were saved within a stated range of dates and times.
- *Standard Fields:* Allows the user to select the standard data set as the information to be contained in the downloaded records. Standard data fields include date and time, all gas sensor and particulate sensor measurement concentrations, temperatures and pressures, and any alarms present.
- *Expanded Fields:* Allows the user to download records that contain more information than would be included in the standard fields.

Expanded data fields include all the information found in the standard data fields, plus gas sensor voltage readings that may be used for diagnostic purposes.

- *Calibration Data:* Allows the user to download records that contain the calibration history of the instrument. This data can be used by service technicians for diagnostic purposes. None of the information from standard or expanded fields is included here.

If the user has selected "Export all records" or "Export new records," clicking the "Enter" button downloads the data file to the PC. If the operator has selected either the "Number of Records" or "Date Range" option, the number of records or date range should be entered in an additional screen. Pressing the "Export Data" button will then download the specified data to the PC. Data files are usually saved in the "Download" folder, although the file location can vary depending on the browser used and the PC operating system.

Export Selected Number of Records

The Export Selected Number of Records screen allows the user to enter the number of records to export, starting with the most recent and counting backwards.

Home Screen>Data>Export>Export Records>Export Selected Number of Records

The Export Selected Number of Records screen contains the following information:

- *Number of Records Back from Latest*: Allows the user to enter the number of records to be exported to a file, starting with the most recent.
- *Export Data*: Clicking on this button exports the selected logged data to a file on the PC.

Export Selected Date Range

The Export Selected Date Range screen allows the user to select a subset of logged data to download that was taken over a specified time period.

Home Screen>Data>Export>Export Records>Export Selected Date Range

The Export Selected Date Range screen contains the following information:

- *Data Start Date/Time*: Allows the user to enter the starting point of the logged data to be exported.
- *Data End Date/Time*: Allows the user to enter the ending point of the logged date to be exported.
- *Export Data:* Clicking this button exports the selected logged data to a file on the PC.

Export Log Files

The Export Log Files screen allows the user to download instrument log files and save them to a PC. These are text files that are exported in a compressed format. After uncompressing, they can be viewed with Microsoft WordPad or an equivalent program. Log files are used for diagnostic purposes in the event that any problems arise with the instrument. Once downloaded to a PC, the log files can be emailed to a service center.

When the operator navigates to this screen, they are presented with “radio button” type controls that allow them to select which log files they intend to download. Once the enter button is pressed, the log files are exported to the PC. Files are in a zip format and are usually saved in the “Download” folder, although the file location can vary depending on the browser used and the PC operating system.

Home Screen>Data>Export>Export Log Files

The Export Log Files screen contains the following information:

- *Export all log files*: Downloads all four types of log files together in the same folder.
- *Export GUI log files:* Downloads a folder of log files that contains errors related to the operation of the GUI (graphical user interface).
- *Export system log files:* Downloads a folder of log files that contains errors generated by the operating system.
- *Export application log files:* Downloads a folder of log files that contains GM-5000 specific information, such as alarms, errors, updates, and status changes.

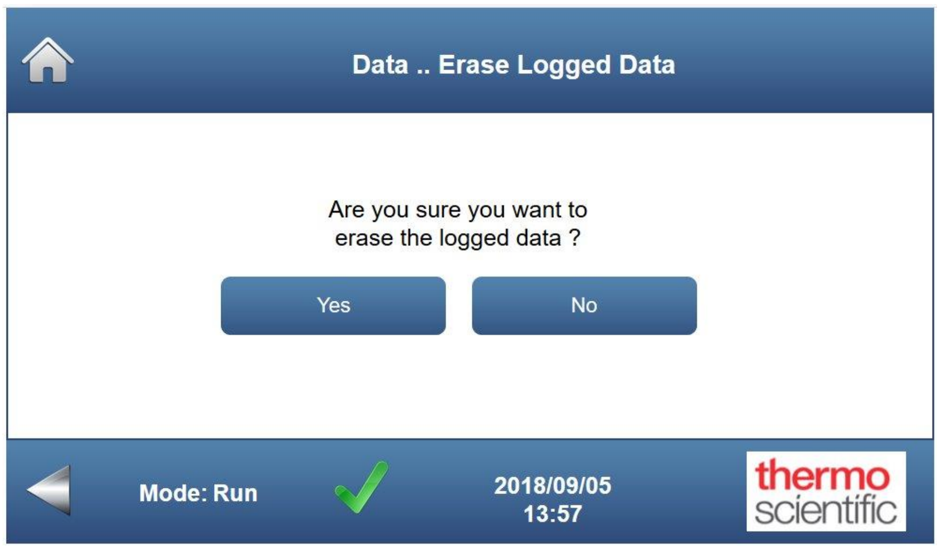
- *Export histogram log files:* Downloads a folder of log files that contain detailed particle size distribution data and diagnostics generated by the Optical Particle Counter (OPC). These log files may be useful in understanding any performance errors generated by the particle counter.

Erase Log

The Erase Log screen is a simple 2-button screen that allows the user to erase all logged measurement data from the database or to cancel the operation. The operator can also cancel out of this operation by selecting the "Back" button or the "Home" button. Only measurement data is deleted, not log files that contain diagnostics.

The GM-5000 has a large memory capacity, so it is rarely necessary to erase the data log. Also, please be aware that an erased file cannot be recovered, so any data that might have value should be downloaded to a PC before erasing the log file.

Home Screen>Data>Erase Log



The Erase Logged Data screen contains the following information:

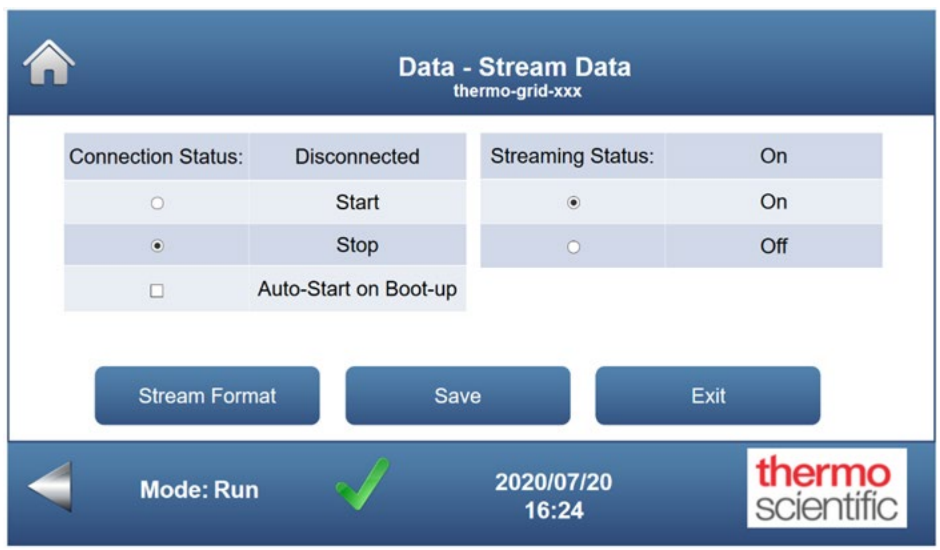
- *Yes*: Confirms user decision to erase all data stored in the GM-5000 data log file. Clicking "Yes" will permanently delete all saved measurement data.
- *No:* Cancels the deletion and returns the user to the previous screen.

Stream Data

The Stream Data screen allows the user to see the current connection status, to initialize or break a connection, and to turn the data streaming function on and off. When the streamer is "on" the instrument sends a line of data to the remote server at the end of each sampling period. In order to establish a connection and stream data, the Server Name/Address and TCP Port needs to be entered on the Communication Settings screen, which is located under the Service Menu. For more information on setting up streaming data, refer to Appendix C, "Connectivity".

The Reporting Interval, which is the frequency of data point logging and streaming to the server, can be set on the Instrument Set-Up screen, also under the Service Menu. The default value is once every 5 minutes. Refer to the Service section later in the chapter for more information on those two screens.

Home Screen>Data>Stream Data



The Stream Data screen contains the following information:

- *Connection Status***:** The connection status field displays the current state of the connection between the GM-5000 and the remote server. The status will be either "Connected," "Disconnected", or "Trying to Connect". The "Start" and "Stop" radio buttons are used to initiate or break a connection with the remote server. Note that the radio button selection only takes effect when the "Save" button has been clicked. For example, to break an existing connection, select the "Stop" radio button and then click "Save." If "Auto-Start on boot up" is checked, the GM-5000 will automatically try to establish a connection to the remote server on power-up. If data streaming is being used, the Auto-

Start box should be checked so that instrument will automatically reconnect to the server after a power outage or other interruption of service.

- *Streaming Status***:** The streaming status field is used to turn automatic data streaming on and off and to display the current setting. Again, a change in the radio button selection only takes effect after the "Save" button has been clicked. So, for example, to stop the instrument from automatically streaming data, select the "Stop" radio button and then click "Save." The GM-5000 streaming status will be automatically "held" in the case of a power outage. So, for example, if Streaming is set to "On", it will still be "On" after a power outage or reboot. Note that in most installations, the connection status will be "Connected" and the streaming will be set to "On." However, there are some situations in which the GM-5000 may have a connection to the remote server, but the operator will want the Streaming Status set to the "Off" position. This is typically done in order to allow the remote server to poll for data or to allow the server and GM-5000 to exchange data in a two-way "conversation" without the possibility of interruption from a new data record. For more information on communicating with a remote server, refer to Appendix C, "Connectivity".
- *Stream format:* This button opens another screen where the operator can select the format/contents of the data string, or packet, that will be sent to the remote server by the streaming function.
- *Save:* Commits any changes made to this screen.
- *Exit:* Cancels any changes and takes the user back to the previous screen without committing the changes.

Stream Format

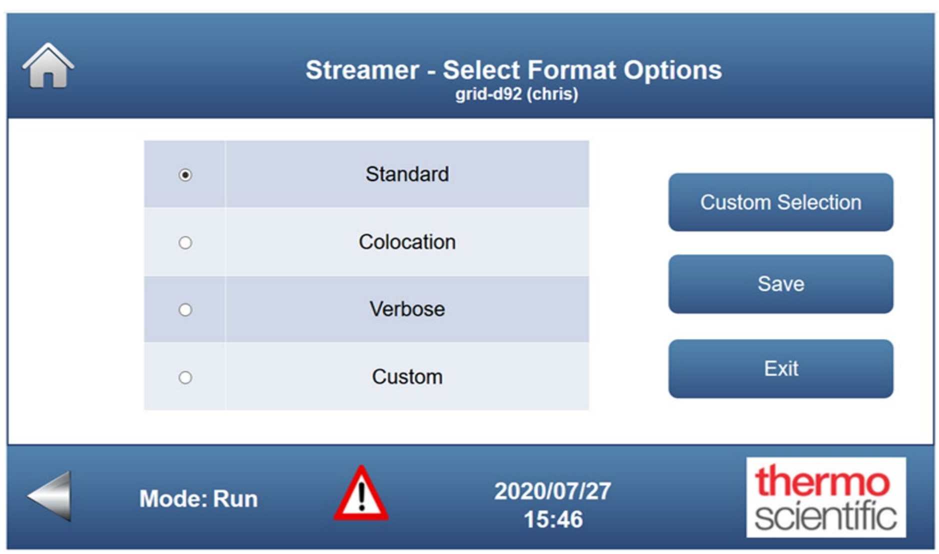
The Stream Format/Select Format Options screen provides a "radio button" selection list that allows the operator to select the desired contents for the streamed data records, or data packets. There are three options for pre-defined data formats as described below. The operator also has the option to create a custom data record that includes only fields that are specified during the setup.

Standard records include the date, time, instrument name, all temperature readings, RH, pressure, alarms, and all sensor readings reported in units of concentration. Each data point is preceded by a label and fields are separated by commas.

Colocation records include all the same fields as the standard records, but they also include additional concentration readings called "actuals" that reflect the values that the instrument would have reported if colocation calibration had been shut off. These are essentially the concentrations that are calculated from sensor voltages using just the factory calibration values. The "actuals" are valuable information because they can be compared to reference data and used in regression analysis to calculate colocation coefficients, as described in Chapter 4, "Calibration".

Verbose records include all the data fields that are included in the colocation records, plus the gas sensor voltage readings. These voltage readings are sometimes useful for diagnostics and troubleshooting, or they can be used by some cloud computing systems for off-line calculation of pollutant concentrations using alternate algorithms.

Home Screen>Data>Stream Data>Stream Format



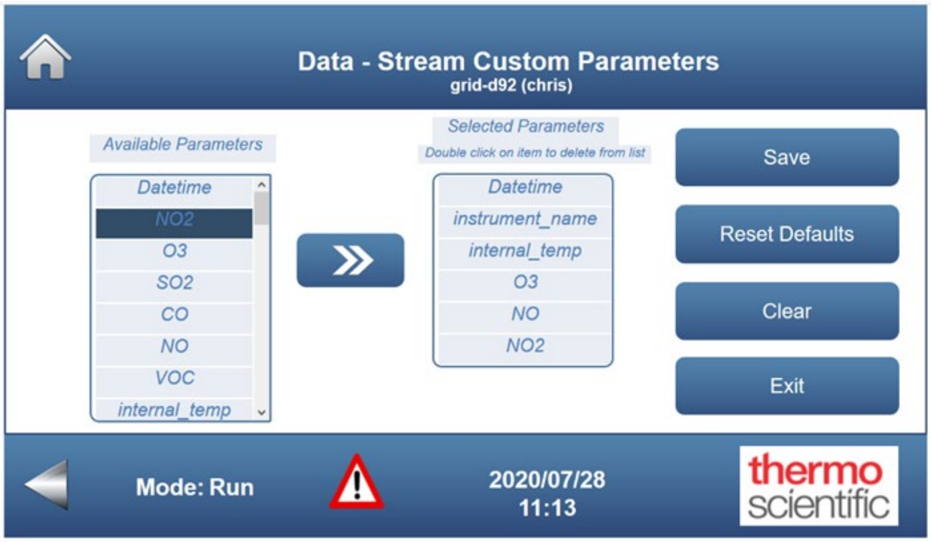
The Stream Format screen contains the following information:

- *Radio Button Checklist***:** When the screen is opened, the currently active format will be "checked", or selected. To change the data stream format, select the desired option and then click the "Save" button.
- *Custom Selection***:** This button opens another screen that allows the user to create a customized version of the data packet that will be used by the data streaming function.
- *Save***:** This button registers, or commits, a change in the radio button selection and also closes this screen.
- *Exit***:** This button cancels any changes and closes the screen.

Data Stream Custom Parameters

The Custom Parameters screen allows the operator to create a data stream that includes just the specific parameters that are required for that particular application. In the example below, the operator has created a custom format that will include just the date and time, the instrument name, the internal temperature, and then the ozone, NO and NO_2 concentration readings. Readings from other sensors will still be logged in the GM-5000 internal data base but will not be included in the streaming data. By reducing the parameter set to just those items that are required, the operator can minimize cellular data usage and may simplify data processing.

Home Screen>Data>Stream Data>Stream Format>Custom Selection



The Custom Parameters screen contains the following information:

- *Available Parameters*: This scroll box contains a list of all parameters that are available for inclusion in the streaming data.
- *Selected Parameters*: This scroll box contains a list of all parameters that have been selected for inclusion in the streaming data. A new parameter can be added by highlighting the required item in the "Available Parameters" list and then clicking the double arrow (>>) symbol.
- *Save*: The "Save" button registers, or commits, changes made in the "Selected Parameters" list and the Custom Parameters screen will be closed. If you Exit without saving, the list will revert to the version that existed when the screen was opened.
- *Reset Defaults*: This button sets the "Selected Parameters" list to include all available parameters. It then asks the user to confirm that selection.

If the user confirms the selection, the list will be saved and the Custom Parameters screen will be closed.

- *Clear*: This button will delete all the entries in the Selected Parameters list, giving the operator a chance to create a new list.
- *Exit*: This button will close the Custom Parameters screen without saving the Selected Parameters list. Any changes that have been made and not saved will be lost.

Service

The Service screen allows the user to view diagnostic information such as voltages and temperatures, set parameters for WiFi and cellular communications, load new firmware updates onto the instrument, set the date and time, and set the reporting interval for logging and streaming data.

Home Screen>Service

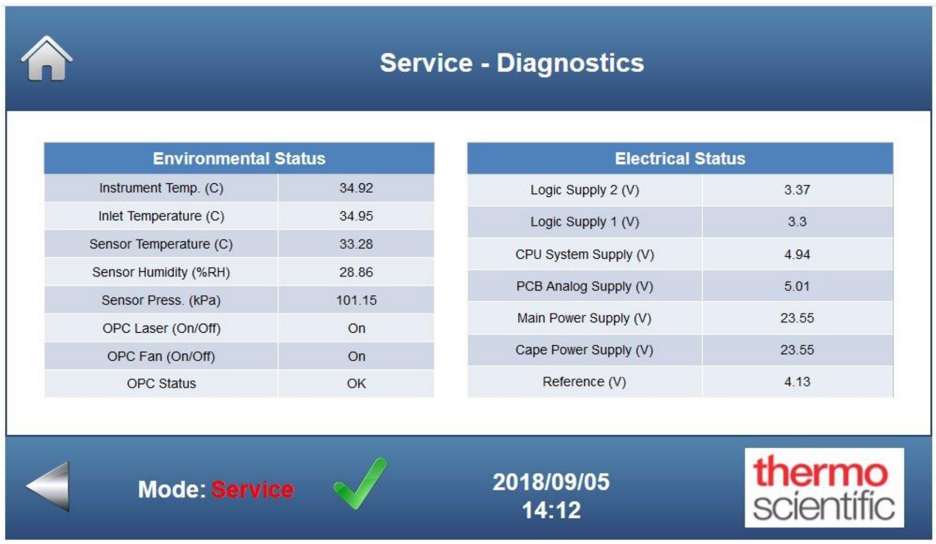
The Service screen contains the following information:

- *Diagnostics:* Provides the user with various environmental and electrical diagnostic information, including temperature, relative humidity, and pressure readings, as well as voltage measurements taken from critical circuits. If any of these parameters are outside of predetermined factory alarm limits, they will be highlighted in red.
- *Firmware Update:* Allows the user to load new firmware over the WiFi connection, Ethernet, or remotely, using a VPN with the cellular modem.
- *Settings:* Provides access to additional service screens that can be used to configure communications, set a static Ethernet address or adjust instrument settings.

Diagnostics

The Diagnostics screen, shown below, includes two "read-only" tables that provide information on instrument operating conditions, including various environmental and electrical diagnostic information. If any of these parameters are outside of the predetermined factory alarm limits, they will be highlighted in red. Because the screen may contain more information than most others, the format is altered somewhat with small fonts and multiple tables on one screen.

Home Screen>Service>Diagnostics



The Diagnostics screen contains the following information:

- *Environmental Status:* Shows real-time measurements taken with different types of sensors that are located on various analyzer components.
  - *Instrument Temp.:* Displays the current temperature inside the instrument enclosure in degrees C.
  - *Inlet Temperature:* Displays the current sample inlet temperature in degrees C.
  - *Sensor Temperature:* Displays the current sensor chamber temperature in degrees C.
  - *Sensor Humidity:* Displays the current sensor chamber relative humidity.
  - *Sensor Press:* Displays the current sensor chamber pressure in kPa.
  - *OPC Laser:* Displays the current OPC laser state as either On or Off.

- *OPC Fan:* Displays the current OPC fan state as either On or Off.
- *OPC Status:* Displays the current OPC operational status as either OK or Fail.

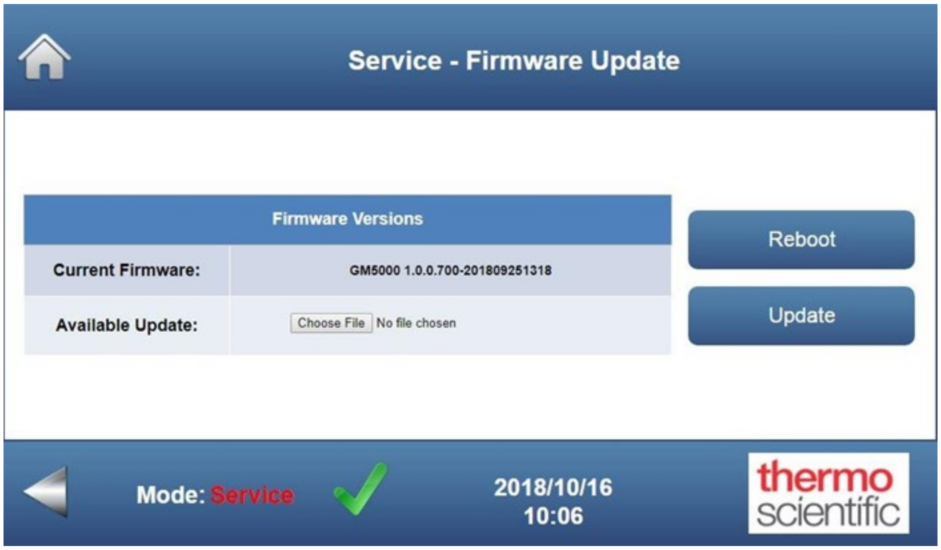
- *Electrical Status:* Shows a table of real-time voltage measurements taken from the critical circuits within the analyzer. If any of these voltages are outside of the acceptable range, they will be highlighted in red. This information can be used for diagnostic purposes.

Firmware Update

The Firmware Update screen is used to load the latest firmware version onto the instrument. Updated versions of firmware can be found on the Thermo Fisher Scientific website and downloaded to a PC. The user must then select “Choose File” on the Available Update line and select the file containing the updated firmware. The user then clicks on the “Update” button to begin the installation process. When the file transfer from the PC to the GM-5000 is complete, a pop-up window may briefly appear notifying the user that the transfer has finished. The user will need to follow any on-screen prompts. The instrument will then reboot itself to install and activate the new firmware. Although it may not be obvious while looking at the GUI, connection to the instrument may be lost two times. The entire update process will take a minimum of 10 minutes to complete. It is very important to not turn off power to the analyzer or otherwise interrupt this process.

Note Firmware updates can take at least 10 minutes to complete and should not be interrupted after starting the process. It is very important to not turn off power to the analyzer during this process. Connection to the analyzer can be re-established only after the firmware update process is complete. ▲

Home Screen>Service>Firmware Updates



The Firmware Update screen contains the following information:

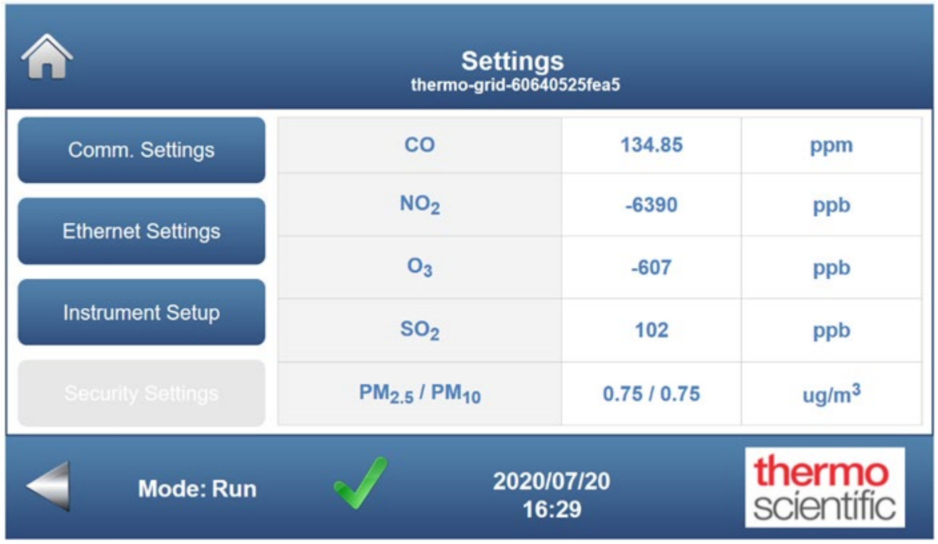
- *Firmware Versions:*

  - *Current Firmware:* Displays the current firmware version number installed in the instrument.
  - *Available Update:* Displays the version number of the firmware that will be loaded during the update after the file containing the new firmware is chosen.
- *Reboot:* Allows the user to reload the operating system without turning off the instrument. This is sometimes required after a firmware update or after changing communication settings.
- *Update:* Starts the update and installation of the new firmware version.

Settings

The Settings screen provides access to three additional screens that allow the operator to adjust communications settings, Ethernet parameters and other controls that affect the GM-5000 configuration and operation.

Home Screen>Service>Settings



The Settings screen contains the following information:

- *Comm. Settings:* This button opens a data entry screen that allows the operator to configure the local WiFi connection and the HTP connection to a remote server.
- *Ethernet Settings:* The Ethernet settings button opens a data entry screen that allows the operator to set a static IP address on the GM-5000's Ethernet connection. This screen is not used in a typical installation, but it allows the instrument to join an existing network in cases where that is required. Note that there is only one Ethernet port in the instrument, so it is not possible to connect both the internal modem/router and an Ethernet network without additional hardware.
- *Instrument Settings:* The Instrument Setup button provides access to an additional setup screen that allows the user to assign the instrument a name and location, set the reporting interval for logging or streaming data, set the local time zone, and set the current date and time.

Communication Settings

The Communication Settings screen allows the user to set various parameters that configure communications with the GM-5000. An operator can connect with the GM-5000 through WiFi, over an Ethernet cable, or over the internet using a wireless 3G/4G router that connects to an Internet Service Provider (ISP). For more information on setting up the router/modem, refer to Appendix C, "Connectivity".

For "local" operation, the operator will usually connect a PC or similar device to the GM-5000 using WiFi. When used in this mode, the GM-5000 acts as the server and creates its own local network that the operator can join by selecting the appropriate SSID number from the list of available WiFi connections that shows up in the computer's WiFi list. Only one device is allowed to connect to the GM-5000 server at any given time, so the GM-5000 and PC are essentially creating a private 1:1 network that gives the PC access to instrument settings and data.

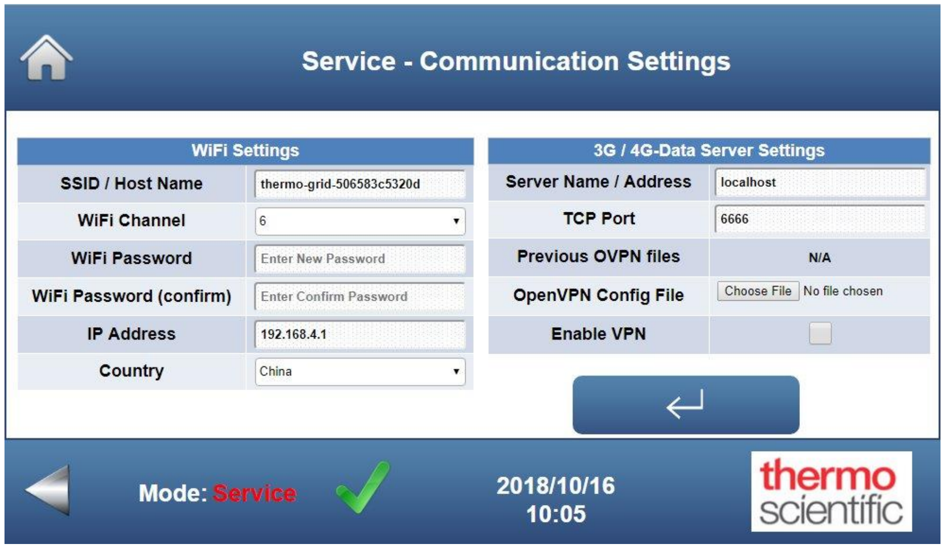
When connecting over the internet, a remote server can be utilized in two ways. A simple HTP connection can be used to stream data to the remote server, or a Virtual Private Network (VPN) can be used to provide a secure connection. The GM-5000 is equipped with an Open-VPN client, so if a VPN connection is required, the remote server must be running the Open-VPN server program. Other VPN systems are not supported at this time.

When used in streaming mode, the GM-5000 sends the unencrypted data directly to the server, where it can be formatted and put into a text file. Use of streaming data requires that only the Server Name/Address and TCP Port fields be filled in under the Data Server Settings column. It should be noted that a simple HTP connection does allow some limited 2-way communication between the server and the GM-5000. The command set for 2-way communication is described in Appendix C, "Connectivity".

When the VPN is enabled, it allows remote access to the user interface in the same manner as connecting through WiFi, only the connection is made to the server over the cellular modem. Use of a VPN requires that all fields be filled in under the Data Server Settings column.

If any changes are made to this Communications Settings screen, an instrument reboot is required after the user has pressed the "Enter" button. A reboot can be initiated using the "Reboot" button located on the Firmware Update screen described in the next section.

Home Screen>Service>Settings>Comm. Settings



The Communication Settings screen contains the following information:

- *WiFi Settings:*
  - *SSID/Host Name:* The current SSID/host name is displayed in the text box and the user is allowed to enter a new SSID/host name. If a new SSID/host name is assigned, the user will be prompted to enter and confirm the existing password or create a new WiFi password. Be careful when changing passwords. There is no way to recover a lost password from a remote connection. Note that in the GM-5000, the SSID, or WiFi name, is the same as the host name, or node name. This is not typical of most network systems.
  - *WiFi Channel:* Allows the user to select the WiFi channel from a drop down list. Note that not all WiFi channels will work with all systems or in all countries.
  - *WiFi Password:* Allows the user to create a new WiFi password for the SSID/host name. Note that the SSID/host name password and the WiFi password are always the same.
  - *WiFi Password (confirm):* User re-enters the new password to confirm. Be careful when changing passwords. There is no way to recover a lost password over a remote connection.
  - *IP Address:* The current IP address of the GUI is displayed. Allows the user to enter a new IP address. This may be necessary in some circumstances, but it is not recommended.
  - *Country:* Allows the user to select the country where the GM-5000 is located from a drop down list.

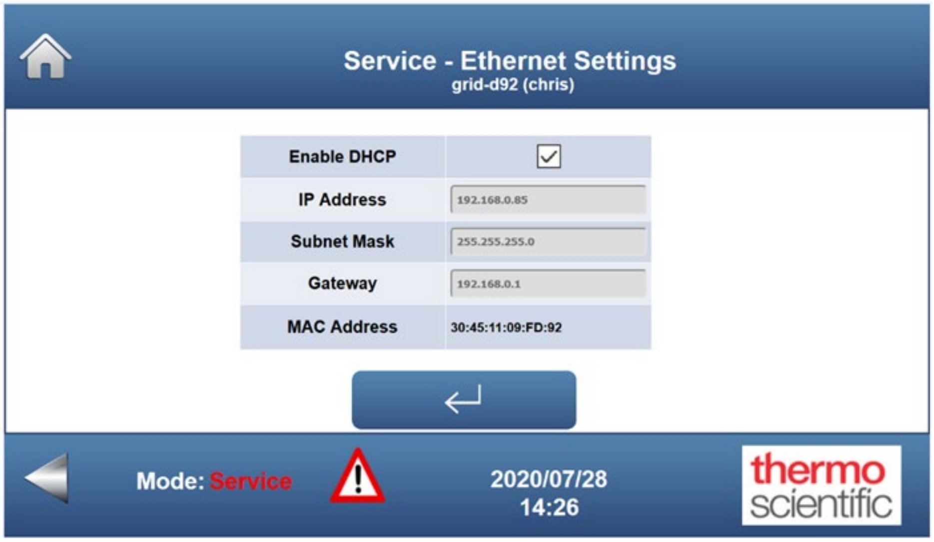
- *3G/4G – Data Server Settings:*
  - *Server Name / Address:* User enters the domain name or IP address of the remote server.
  - *TCP Port:* User enters the TCP port of the remote server.
  - *Previous OVPN files:* Displays the name of the last OVPN file that was loaded. The OVPN file contains the Open-VPN credentials that are needed to join a specific Open-VPN network. If the VPN has never been set up, the field will display “NA”.
  - *OpenVPN Config File:* The button allows the user to browse to a PC and select an OVPN file to load on the GM-5000. The OVPN file must be generated by the Open-VPN server and essentially configures the GM-5000 for connection to that specific server. The user will be prompted to select the configuration file from the connected PC.
  - *Enable VPN:* User checks this box to enable a connection to the VPN.

Important Once the user has entered or changed any of these settings, the user must click the “Enter” button to accept (commit) the new settings. After clicking the “Enter” button, an instrument reboot is required. The “Reboot” button is located on the Firmware Update screen of this Service Menu. ▲

Ethernet Settings

The Ethernet Settings Screen is used to assign a static IP address to the GM-5000. For most installations this is not necessary, but it can be used in applications where the operator needs to have the GM-5000 join an existing network with a pre-defined IP address.

Home Screen>Service>Settings>Ethernet Settings



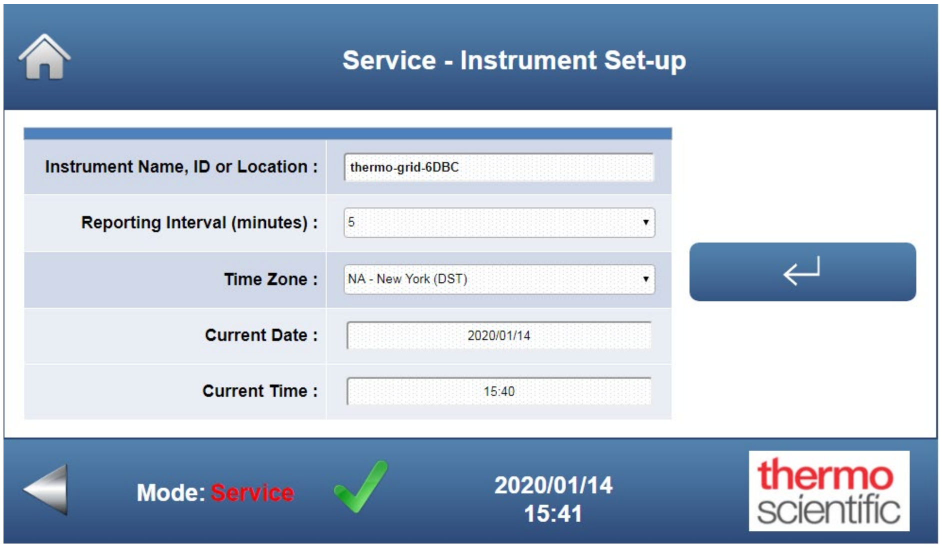
The Ethernet Settings screen contains the following information:

- *Enable DHCP:* This check box enables or disables Dynamic Host Configuration Protocol (DHCP). When DHCP is enabled, the GM-5000 will allow the network or router to assign an IP address. This is the "normal" or usual configuration. If DHCP is disabled, then the text boxes below the check box must be populated with the correct information to assign the desired IP address to the GM-5000.
- *IP Address:* This text box allows the user to enter the static IP address that will be used when the GM-5000 joins the local network without DHCP.
- *Subnet Mask:* This test box allows the user to manually set the subnet mask that will be applied on the local network.
- *Gateway:* This text box allows the user to manually enter the IP address of the gateway device that will provide access to the internet.
- *MAC Address:* This is a noneditable text box that displays the hardware's Media Access Control address (MAC address). This is a unique identifier that is commonly used in various networking technologies, including the GM-5000 Ethernet and Wi-Fi systems.

Instrument Setup

The Instrument Setup screen allows the user to assign the instrument a name, ID, or location, set the reporting interval for logging and streaming data, set the local time zone, and set the current date and time.

Home Screen>Service>Settings>Instrument Setup



The Instrument Setup screen contains the following information:

- *Instrument Name, ID or Location:* User enters an instrument name, ID or Location. Any printable character except a comma ","can be used. This name will appear on each line of the data file.
- *Reporting Interval (minutes):* Allows the user to select the reporting interval in minutes, which is the frequency in which data is logged in internal memory or streamed to an external server. Choices are from once per minute up to once per hour. The default setting is once every 5 minutes. Reported data is coordinated with clock time, so for example, a 5 minute interval will report at 1:00, 1:05, 1:10, etc. Note that the average value is reported over this time period for all concentration readings, as well as for sensor chamber temperature, relative humidity, and pressure.
- *Time Zone:* User selects the time zone from a drop down list.
- *Current Date (YYYY:MM:DD):* User sets the current date.
- *Current Time (HH:MM):* User sets the current time (24 hour format).

Once the user has entered all required information, clicking the "Enter" button accepts that information.

Chapter 4
Calibration

This chapter describes the procedures and options for calibrating the GM-5000 air quality sensors and for calibrating the hardware sensors that report temperature, relative humidity and pressure.

Like all air quality monitors, the GM-5000 requires initial and periodic calibration of the air quality sensors. Accurate calibration is essential to ensure that correct readings are obtained from the gas and particulate sensors, while incorrect or improper calibration can impair performance. Frequency of calibration is dependent on the needs of the air monitoring program and on factors such as changing weather conditions at the test site. As a general guideline, calibration will be required at the time of initial installation and then once every two to three months. Dependent on climate and accuracy requirements, the frequency of re-calibration may be increased or reduced over time based on the operator's observations regarding signal stability.

In addition to the gas and particulate sensors, the GM-5000 also features sensors for temperature, humidity and air pressure. Those sensors are calibrated against reference instruments at the factory and typically do not require any adjustment or periodic maintenance. However, this chapter does include instructions for adjusting the readings of those sensors in case this should ever become necessary.

Air Quality Sensor Calibration

The GM-5000 gas sensors have been tested for proper operation at the factory using contaminant free zero air and a series of test gases containing known concentrations of ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide and other test gases. The quantitative response of sensors to each test gas has been verified and recorded in the analyzer's non-volatile memory. The Particulate Matter (PM) sensor is also calibrated at the time of manufacture using an aerosol of polystyrene beads and a NIST traceable aerosol reference analyzer.

Although the instrument response has been validated at the factory, Thermo Fisher Scientific recommends that periodic calibrations should be conducted by the operator to ensure optimal performance. The exact calibration method and frequency will depend on availability of equipment and staff and on the user's expectations regarding accuracy, precision and resolution of air quality data. In some cases, adequate data quality may be achieved with a very limited calibration program, while other applications may require more frequent and extensive calibration efforts.

Types of Calibration

There are two generally accepted approaches to calibration of the air quality sensors used in the GM-5000.

The first method is calibration with certified standards. Calibration with certified, or reference, gas cylinders is the accepted method of calibration that is used by most traditional, regulatory air quality monitoring programs. For gas sensors, this involves challenging the GM-5000 with contaminant free "zero-air," then with a series of span gases containing known levels of pollutant. In many cases, the span gases are mixed from standards that can be traced to the US National Institute for Standards and Technology (NIST) or to another organization that can certify their accuracy. For the PM sensors, the approach is slightly different. When calibrating particulate sensors, the instrument is challenged with particulate free zero air, but there is no span adjustment step. At the time of this writing, it is not possible to include a span adjustment step for the PM sensors because there is no practical method for generating a known concentration of test aerosol in the field.

The second method of calibration is by colocation. In a colocation program, the GM-5000 is run in close proximity to a trusted set of reference analyzers for an extended period of time, sometimes called the "learning period." The learning period can last as much as one month, but typically runs for about two weeks. Data collected from the reference analyzers and GM-5000 is post-processed to determine the relationship between raw sensor readings and the true pollutant concentrations, as reported by the colocated reference instruments. This analysis can also take into account the effects of other factors such as temperature and humidity that might affect sensor readings. In the case of the GM-5000, the colocation analysis is done using simple multiple regression tools found in common spreadsheet programs and/or other data analysis software. The regression analysis generates a set of calibration coefficients that can be loaded into the GM-5000 through the software interface or can be uploaded programmatically by a remote server through the HTP interface. After calibration, the instrument or instruments are then re-located to the intended test site, and the analyzer's embedded software uses the saved calibration coefficients to interpret sensor outputs and calculate the concentration of each pollutant. For a program that is running a large number of grid monitors, colocation is a more efficient method of calibration versus use of gas cylinders because it allows multiple units to be calibrated in parallel.

The choice of which calibration method will be used is generally dependent on the availability of equipment, consideration of the time required, and on the knowledge and experience of the operator.

When operating a small network of just a few instruments, either method of calibration can produce good quality data with about the same level of effort and investment. However, if operating a larger network, calibration by colocation may be preferred because it requires less time per unit and fewer resources. Calibration by colocation also has the advantage that it allows the operator to routinely calibrate the PM sensors against a known and trusted reference device and it may also do a better job of compensating for the effects of changing temperature and humidity. On the other hand, calibration with certified gases provides more information regarding actual sensitivity of the sensors, improves traceability, and includes automatic adjustment for cross interferences.

In some cases, it may be advisable to use a combination of both calibration approaches. For example, running a gas calibration in a lab or service center to validate the initial setup and then running a colocation in the field at the time of deployment. Note however, that if using both types of calibration, the gas calibration must be run first. Running a gas calibration after colocation will invalidate the calibration factors generated by colocation.

When relying on colocation, it is strongly recommended that at least one GM-5000 should be permanently installed at the site of the reference analyzers to serve as a surrogate, or control, for units that are deployed to remote locations. If the readings provided by the control unit start to deviate from those taken with the reference analyzers due to changes in weather, it can be assumed that other GM-5000 units that are subject to the same weather patterns will exhibit similar behavior.

Calibration Procedure using Certified Standards

Use the following procedure to calibrate the GM-5000 air quality sensors with certified reference gas cylinders.

Calibration by standards follows a process very similar to that used in calibration of reference grade air quality monitors. The instrument is powered on and allowed to warm-up and fully stabilize for a period of 12 to 24 hours. The instrument is then presented with a series of standard gas mixtures, starting with contaminant free zero air, followed by one or more "span" gases that contain known concentrations of each gas that will be monitored. As the analyzer responds to each standard gas, the response is recorded and/or adjusted as necessary to bring the reading to the expected value.

When calibrating with standard gases, please be aware that use of dry zero air and span gas that is typically used with reference analyzers, will not produce good results. The electrochemical sensors used in the GM-5000 are very sensitive to sudden changes in humidity and they require at least some humidity to be present in the sample or calibration gas to function correctly. In order to get good calibration results, the zero air and span gas should be presented to the analyzer at an RH level similar to current ambient conditions.

Equipment Required

The following equipment is required for calibrating the GM-5000 air sensors.

- A zero air delivery system, such as the Thermo Scientific 111iQ, that is capable of delivering at least 10 LPM of clean zero air that is free of contaminants that would cause a detectable response on the installed sensors. Gas must be delivered at atmospheric temperature and relative humidity.
- A span gas dilution and delivery system with an ozone generator, such as the Thermo Scientific 146iQ Dynamic Gas Calibrator. The required ozone concentration is 100 to 300 ppb at 5 to 10 LPM.
- Compressed gas cylinders containing known concentrations of appropriate gases, dependent on what sensors are installed. Typical span supplies are: CO in air balance, SO_2 in air balance, NO_2 in air balance, NO in nitrogen balance and isobutylene in air balance. Isobutylene is the preferred calibration gas for the photoionization technology used by the total-VOC sensor. The cylinder gas concentrations must be appropriately matched to the span delivery system so that the span gases can be delivered to the analyzer at the following concentrations: 2 to 20 ppm CO, 100 to 300 ppb NO_2, 100 to 500 ppb SO_2, 100 to 500 ppb NO, and 1 to 5 ppm isobutylene.
- 6 mm OD PTFE tubing.
- The GM-5000 Calibration Cap Assembly, p/n 118625-00, which includes a Nafion moisture exchanger to add humidity to the calibration gas. (This accessory can be ordered from Thermo Fisher Scientific as separate line item with the GM-5000.)

Calibration Flow System

In order to calibrate the GM-5000 with reference gases, it will first be necessary to deliver 5 to 10 LPM of clean, particulate and contaminant free “zero air” to the instrument’s sample intake for a period of approximately 15 minutes to allow the instrument to purge and stabilize.

Once the analyzer is fully stabilized, the sensor zero, or background readings, can be set by following the step by step instructions presented later in this chapter. In order to avoid erroneous readings that can result from sudden changes in humidity and/or temperature, the zero air must be delivered at a temperature and humidity that matches current ambient conditions. This can be accomplished by using a Nafion based humidity stabilization tube in the gas delivery system. Nafion is a modified Teflon polymer that is highly permeable to water but is generally impermeable to other common components of the atmosphere. A Nafion tube of this type is available from Thermo Fisher Scientific as part of the Calibration Cap Assembly mentioned earlier in the “Equipment Required” section.

After the zero, or background, reading is established for all gas and PM sensors, the gas sensor spans will be set by adding known amounts of CO, SO_2, NO_2, NO, isobutylene, and ozone to the zero air stream. To the extent possible, the flow rate of span gases should match the flow rate of the zero air. As in the zero adjustment, it is important to maintain the gas stream at ambient temperature and humidity.

A suggested design for a calibration gas delivery system is presented in Figure 4–1 below. Components for building a system of this type are available from Thermo Fisher Scientific.

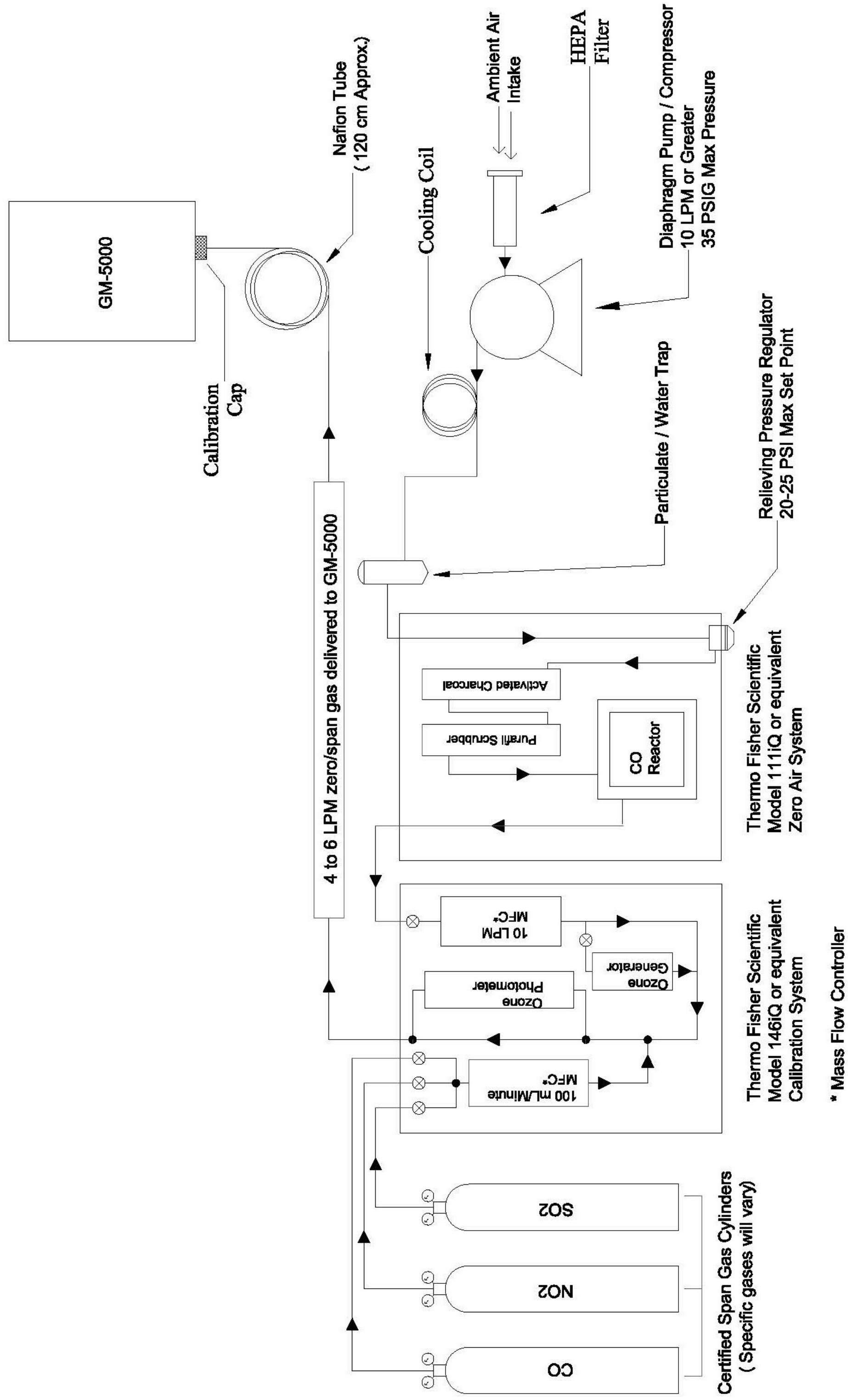


Figure 4–1. Calibration Flow Diagram

Connect to the Instrument

Connect the calibration equipment to the GM-5000 as shown in Figure 4–1. Run the PTFE tubing from the gas delivery system to the fitting on the moisture exchanger coil part of the Calibration Cap Assembly. Slide the Calibration Cap over the Sample Inlet Tube Assembly as far as it can go. The Calibration Cap contains an internal O-ring that will hold it in place without the need for tools or fasteners.

Initiate gas flow from the gas delivery system and ensure that there is flow. A minimum flow rate of 5 l/min is required. Note that there is no atmospheric vent, so the full 5 LPM of gas will flow into the analyzer.

Figure 4–2. Calibration Cap Installed

Operation in Service Mode

It should be noted that under "normal" operating conditions, ambient air enters the GM-5000 through two ports, the sample inlet and the cooling air inlet. Air that enters through the cooling inlet is allowed to mix with the sample stream in the gas sensing chamber. In order to prevent this type of mixing during calibration with zero and span gases, the GM-5000 must be operated in "Service Mode" as indicated by the Status Bar at the bottom of the user screen. In this case, "Service Mode" is initiated by clicking on the Calibration button on the Home Screen. As long as the user remains in the Calibration Menu, the instrument remains in "Service Mode".

When the instrument is placed in Service Mode, the sampling fan and cooling fan will both shut off, which increases the residence time of the calibration gases in the sensor chamber and prevents mixing of calibration gases with ambient air. Since the sampling fan will be shut off during calibration, the calibration gases must be fed to the sample inlet under conditions of positive flow and pressure. That is, the calibration system must **not** include an ambient pressure vent or dump, as is typical with instruments that use pumps for sampling. Also, be aware that if calibration gases are supplied from a dilution calibrator, such as the Thermo Fisher Scientific Model 146, there will usually be an atmospheric pressure vent on the back of the calibration unit that must be capped when used with the GM-5000 (Figure 4–3).

The instrument should not be taken out of Service Mode (i.e. the Calibration Menu) at any point during calibration, or when running experiments such as calibration checks or linearity tests. If the instrument is taken out of Service Mode during calibration or testing, please allow 15 minutes for stabilization after re-entering Service Mode.

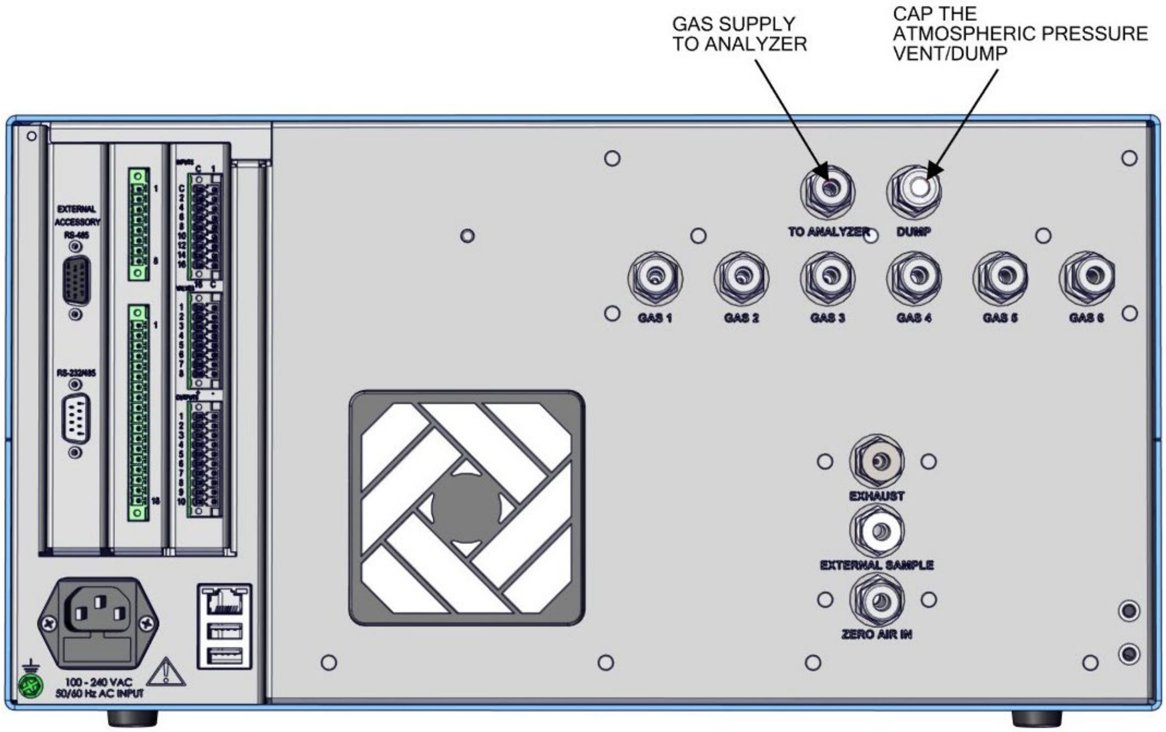
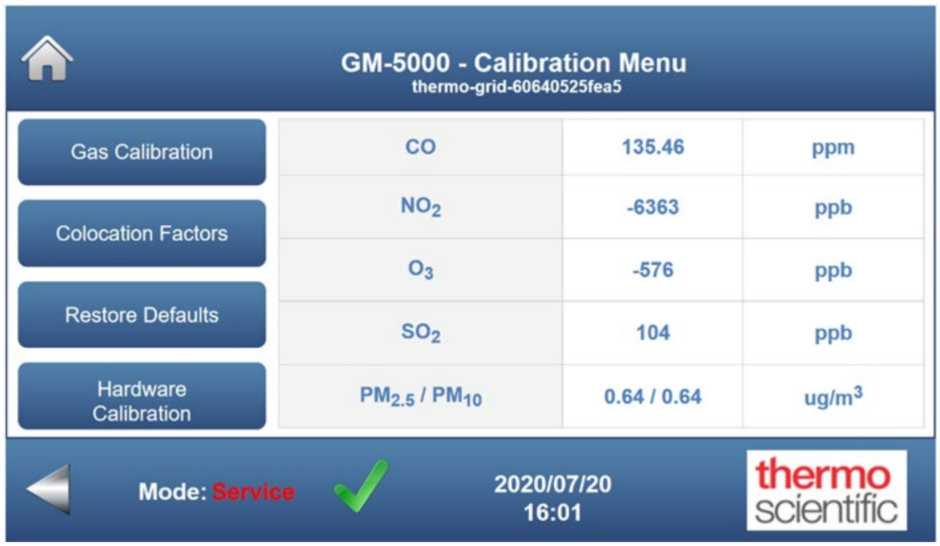


Figure 4–3. Properly Capped Atmospheric Pressure Vent on back of Dilution Calibrator

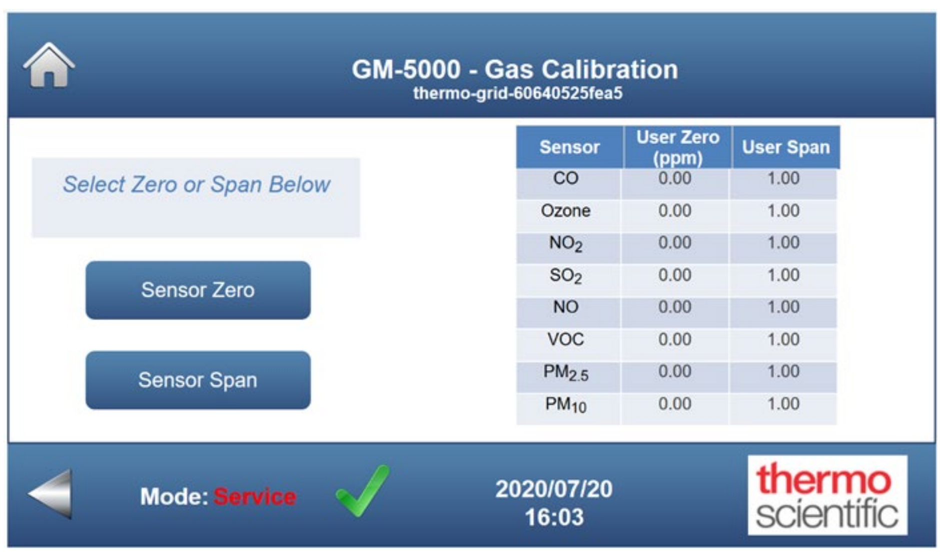
Zero Air Sensors

Use the following procedure to adjust the air sensor readings to zero. Note that once the contaminant free zero air is supplied, each sensor must be zeroed one at a time.

1. From the Home Screen, choose **Calibration>Gas Calibration**. You will see a warning screen reminding you that running a gas calibration will invalidate any colocation coefficients, and you will be given a choice to continue or cancel.

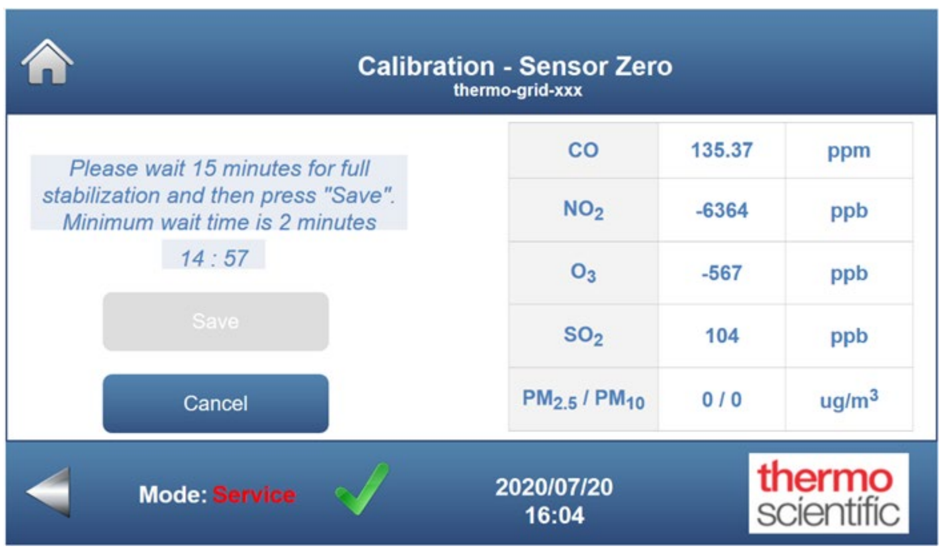


2. From the Gas Calibration screen, choose **Sensor Zero**.

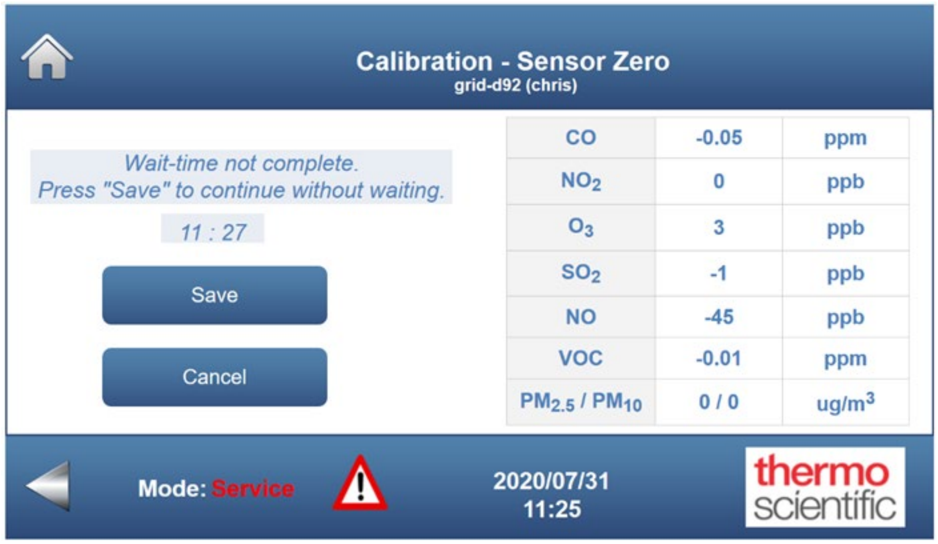


3. The user is then prompted to connect a contaminant free zero air supply. Once that is complete, choose **Ready**.

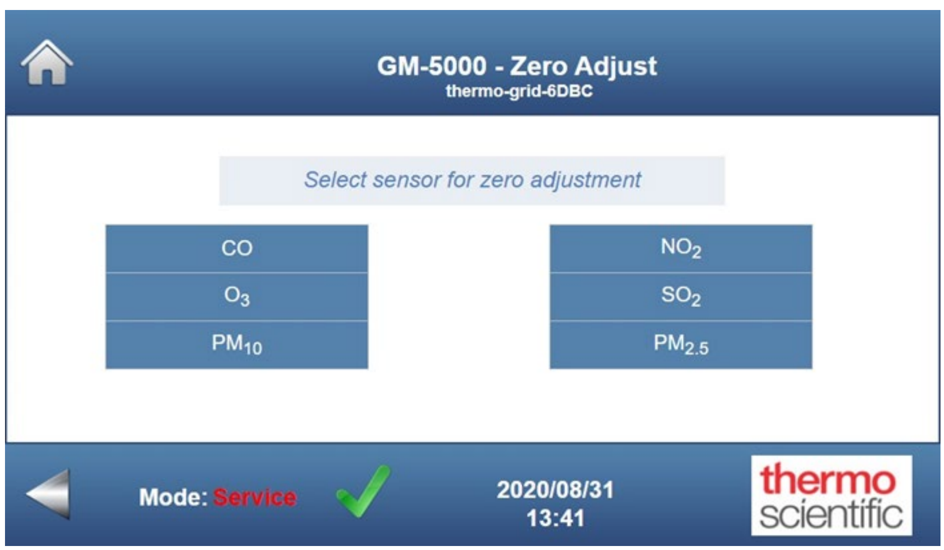
4. The user is then prompted to wait 15 minutes for the instrument to stabilize while a countdown timer is displayed. After 15 minutes, choose **Save**.



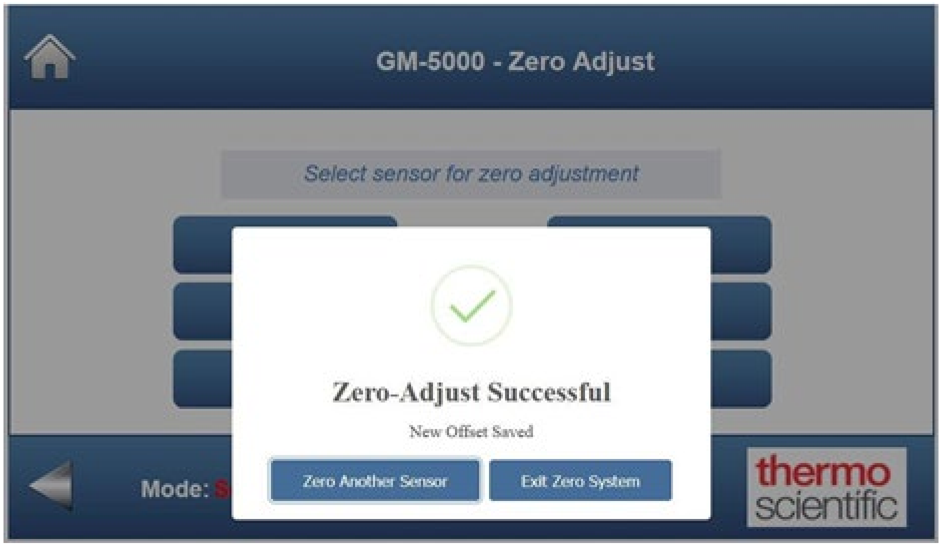
If the user does not wait the full 15 minutes before choosing Save, another screen appears displaying a message that the wait time has not been completed and the countdown timer continues. If at least 2 minutes has elapsed, the "Save" button is active and the user will have the option to Save without waiting the full 15 minutes, but this is not recommended as it may negatively impact the quality of the calibration. After the full 15 minutes, choose **Save**.



5. Select which sensor to set to zero. Note that the buttons will vary depending on instrument configuration.



6. The user is then notified whether the calibration has been successful or whether it has failed. Then choose to **Zero Another Sensor** or to **Exit Zero System** to the Calibration Menu.

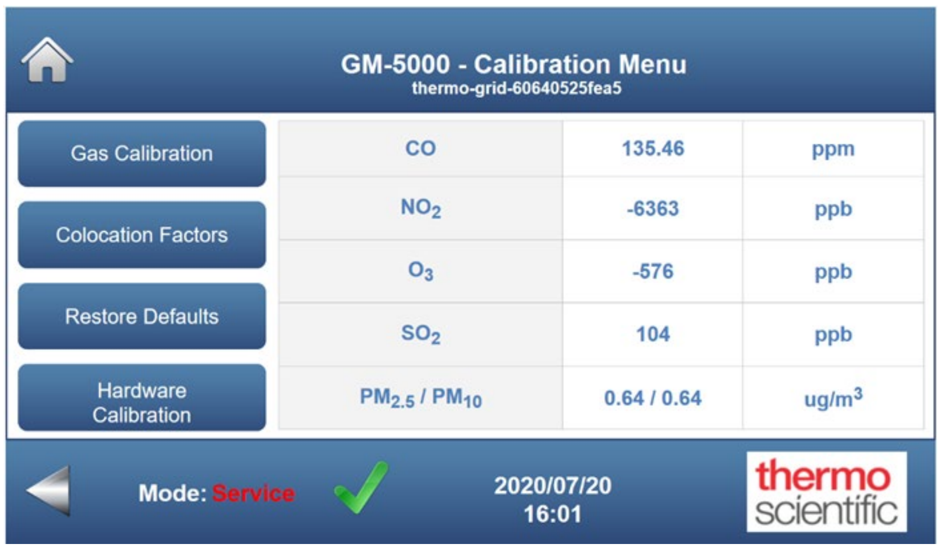


Span Gas Sensors

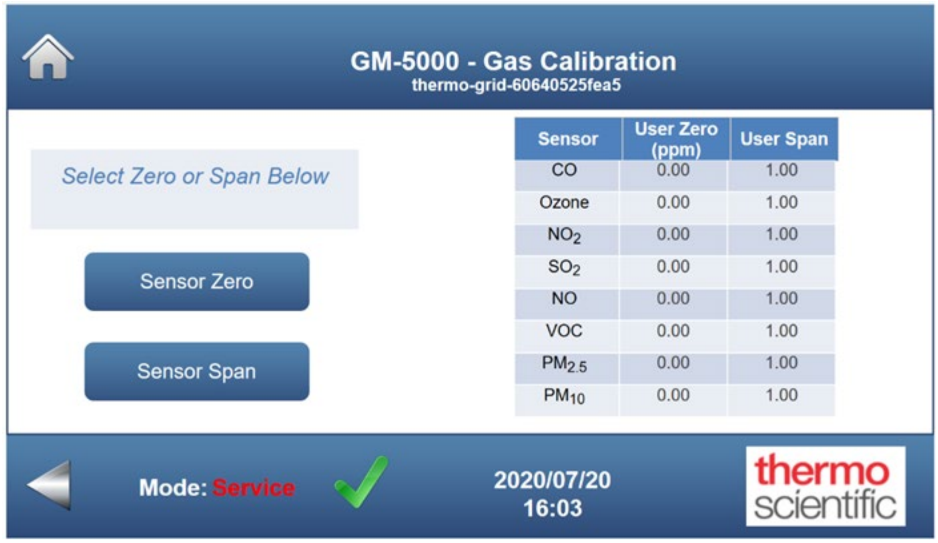
Use the following procedure to adjust the gas sensor readings to match the entered span gas concentrations.

Note Each of the gas sensors must be spanned separately, and the particulate (PM) sensors cannot be spanned. Span screens will vary depending on instrument configuration. ▲

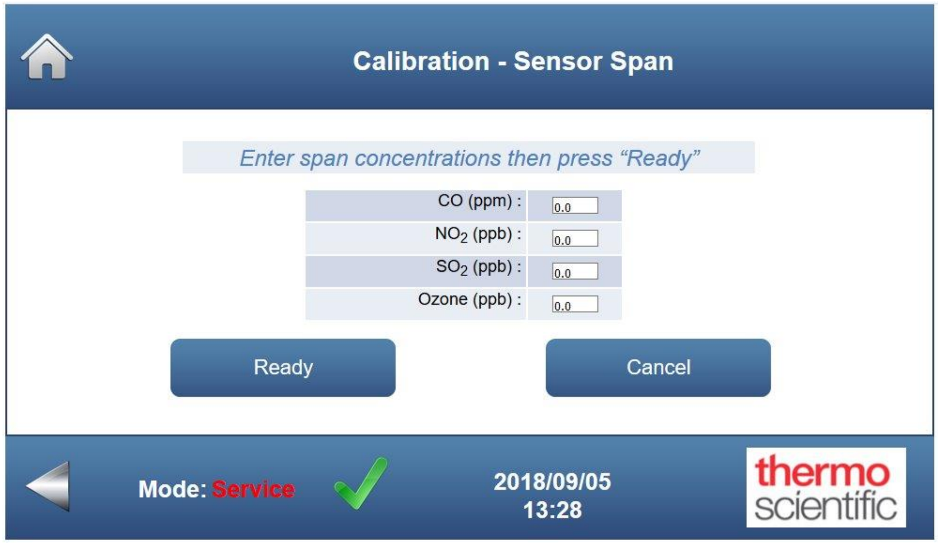
1. From the Home Screen, choose **Calibration>Gas Calibration**. You will see a warning screen reminding you that running a gas calibration will invalidate any colocation coefficients, and you will be given a choice to continue or cancel.



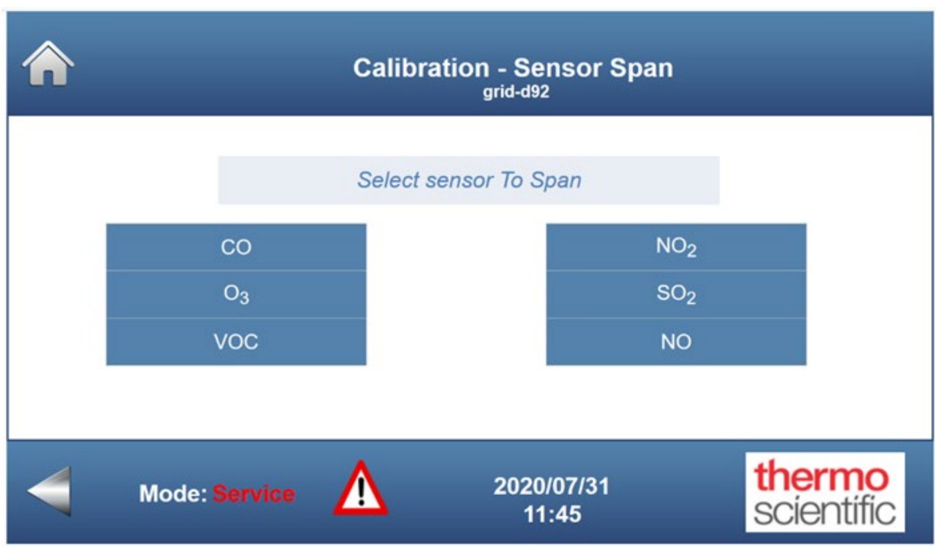
2. From the Gas Calibration screen, choose **Sensor Span**.


GM-5000 - Gas Calibration
thermo-grid-60640525fea5
Select Zero or Span Below
Sensor Zero
Sensor Span
Sensor
User Zero (ppm)
User Span
CO 0.00 1.00
Ozone 0.00 1.00
NO2 0.00 1.00
SO2 0.00 1.00
NO 0.00 1.00
VOC 0.00 1.00
PM2.5 0.00 1.00
PM10 0.00 1.00
Mode: Service
2020/07/20
16:03
thermo scientific

3. Enter the span concentrations of all gases in the displayed table. The span concentrations only need to be entered if they have changed since the previous calibration. Choose **Ready** once the span concentrations have been entered.

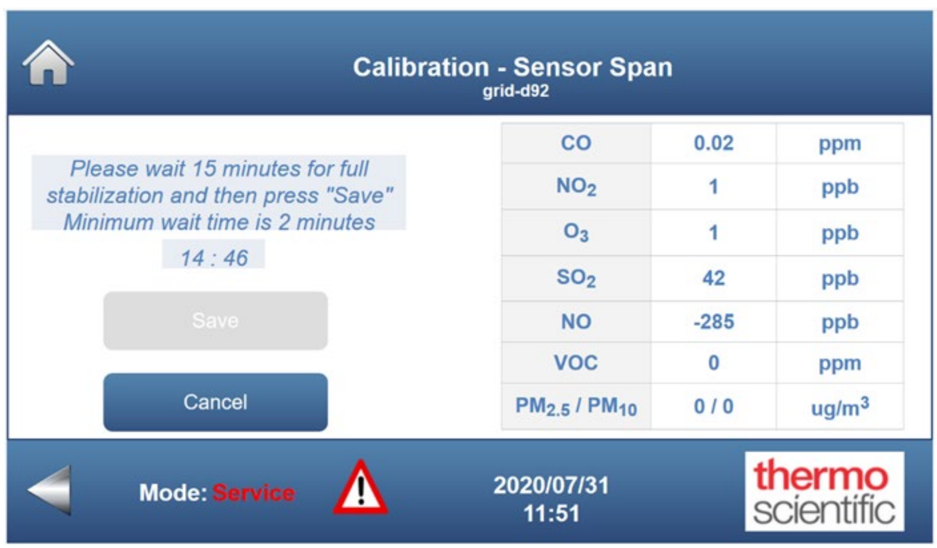


4. Next, choose **CO, NO_2, SO_2**, **NO**, **VOC** or **Ozone**, depending on which sensor is being adjusted.

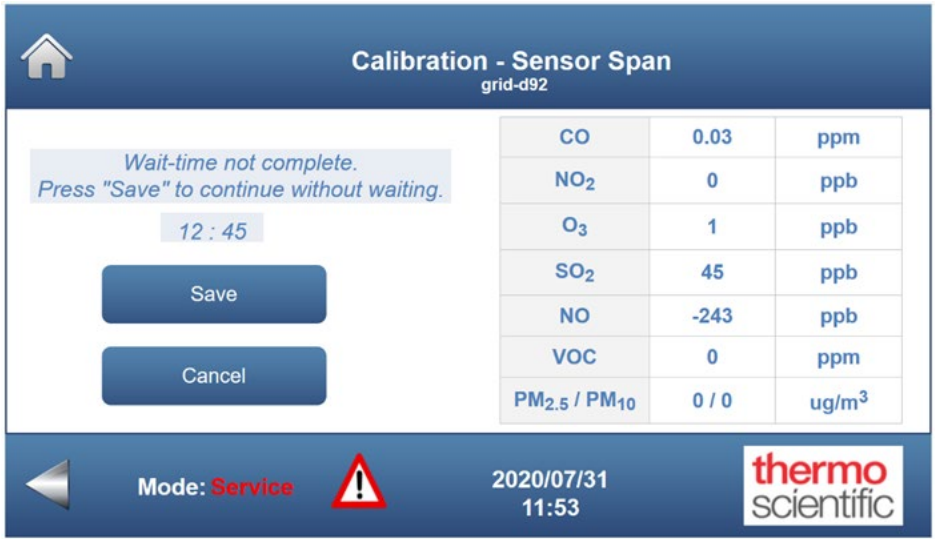


5. The user is then prompted to connect the span gas supply for the selected gas sensor. Once that is complete, choose **Ready**.

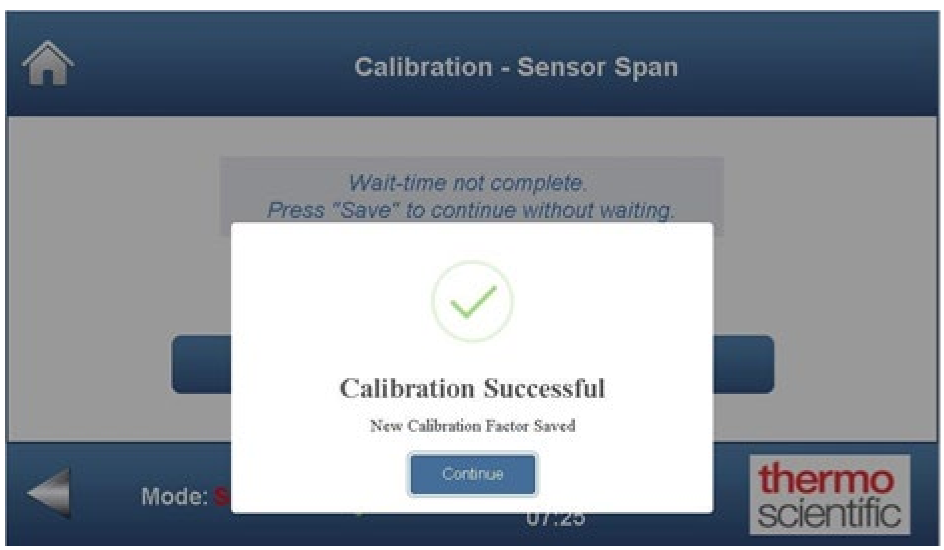
6. The user is then prompted to wait 15 minutes for the instrument to stabilize while a countdown timer is displayed. After 15 minutes, choose **Save**.



If the user does not wait the full 15 minutes before choosing Save, another screen appears displaying a message that the wait time has not been completed and the countdown timer continues. The user can still Save without waiting the full 15 minutes, but this is not recommended as it may negatively impact the quality of the calibration. After the full 15 minutes, choose **Save**.



7. The user is then notified whether the calibration has been successful or whether it has failed. Then choose **Continue** to return to the top-level Calibration menu.



Calibration Procedure using Colocation

As already described, calibration by colocation involves simultaneously collecting data with the GM-5000 and with a known reference device over a long period of time that is referred to as the learning period. After the learning period is complete, the saved data is used to develop a mathematical model that describes the relationship between sensor readings and the "true" concentrations, as determined by the reference instruments. Ideally, data collected during the learning period will include many variations in pollution levels, temperature and humidity, so that the impact of sampling conditions can be included as part of the analysis.

Once a valid mathematical model is developed, it can be used as a type of calibration system that will "predict" accurate concentration levels of each pollutant based on the raw sensor data, the temperature and the humidity. As long as the sensor is stable, and as long as conditions are similar to those experienced during the learning period, that model should improve the accuracy of the sensor readings going forward.

For a large network of monitors, calibration by colocation is more efficient than calibration with reference gases. Calibration by colocation may also provide better accuracy because the calibration calculations will be based on a large data set that will likely include measurements taken at a range of temperatures, humidity levels and pollutant concentrations.

Disadvantages to colocation include the need for expertise in "off-line" data analysis, the requirement for access to a reference grade air quality monitoring station, and the need for up to several weeks of data collection before the instruments can be deployed. Updating calibration by use of colocation can also present logistical challenges, since each GM-5000 would need to be taken out of service, transported to the site of the reference analyzers, calibrated, and then returned to the monitoring location.

Among professionals using colocation for air monitoring, there are many different approaches to developing the calibration model that converts a raw sensor reading to a final concentration reading. Some customers, such as those who are integrating the GM-5000 into an existing cloud-computing system, may wish to collect raw sensor data and apply their own machine learning or other analytical tools to derive calibration relationships. For those users, sensor voltage readings are made available in the GM-5000 expanded records export file, or they can be obtained with data-streaming by selecting the "verbose" data stream format.

The following discussion and instructions are written assuming that the operator will be using the multiple linear regression calibration model that is built into the GM-5000 firmware. If an alternate calibration model is required, please contact Thermo Fisher Scientific for guidance.

Site Selection

In order for colocation to work effectively, the calibration site must be carefully selected and set up. The learning period must be executed under environmental conditions that will be similar to those that will be experienced by the GM-5000 during normal operation.

As a practical matter, the choice of locations will usually be limited to a small set of established air quality monitoring sites with a full set of reference instruments. If multiple sites are available, the operator should select a site that is in the same general geographic area and air shed as the intended GM-5000 monitoring sites.

Relative to the arrangement of instruments at the calibration site, it is advantageous to keep the calibration area free of large obstructions, to locate the GM-5000 analyzers as close as possible to the reference analyzer intake, and to mount the GM analyzer intakes at least 1.5 meters above the surface. Instruments should not be placed near the side of buildings because unpredictable air currents that occur around buildings will disrupt sampling and pollutant distribution, especially for the PM measurement. Typically, a large flat roof-top makes a good location for an air sampling and calibration station.

Calibration Duration and Frequency

There is no specific set of rules that can be applied to calculate the correct duration for the learning period. Typical durations might range from one week to one month, with most calibrations requiring at least two weeks of data collection. Since air quality sensors are affected by temperature, humidity and cross interferences, the learning period should include a variety of pollutant levels, temperatures and humidity. Changes in weather, wind direction and pollution levels will generally result in better calibrations, but obviously cannot be planned.

From the above, it should be understood that colocation calibration factors that are established during one season may under perform in another part of the year. So, for example, if the last calibration was done in mid-summer, the instrument's readings will probably be inaccurate in mid-winter and vice versa. If the monitoring program will rely exclusively on calibration by colocation, the calibration process should usually be repeated every three to four months, or even more frequently if the location is subject to seasonal extremes.

If frequent recalibration is not possible due to cost or logistical limitations, it may be possible to keep one or two GM-5000 analyzers permanently colocated at the reference site. These units can be used as a surrogate to provide guidance about how other GM-5000 analyzers in the network will respond to changes in weather. For example, if a GM-5000 that is permanently located at the reference site starts to give higher readings than the reference following a sudden change in weather, it is likely that other GM-5000 units installed in the same general region will be doing the same.

Instrument Configuration

The reference monitoring system must include an analyzer for each parameter that will be measured with the GM-5000. The calibration accuracy will only be as good as the reference data, so the reference instruments should be the highest quality available, must be fully maintained, and should be calibrated in accordance with manufacturer guidance and any applicable regulations. Any calibration activity or measurement issues that arise with reference instruments during the learning period should be noted, so that suspect data can be excluded from the analysis.

Be sure that the GM-5000 clock and time zone are set to match the reference instruments and that the clocks are synchronized. To maintain data synchronization, the averaging time on the reference instruments must be set to match the GM-5000 configuration. Since the concentration values reported by the GM-5000 at the end of each report period represent the average value taken over that time, the reference instrument averaging time should be set to match the GM-5000 report period.

The recommended report period during the learning period is 5 to 15 minutes. Report periods longer than 15 minutes tend to obscure details that can help provide a more accurate calibration but using a report period of less than 5 minutes generates large data sets that require more memory and work to process and does not provide any significant performance advantage. If the report period or averaging time on the reference analyzers cannot be altered, the GM-5000 report period can be changed to match the reference.

In many cases, different reference analyzers running at the same AQMS site may have different report periods. For example, 5 minute reporting for gases and 15 minute reporting for particulate matter is common. In this situation, the GM-5000 should be configured to match the shortest sampling period among the reference analyzers, 5 minutes in this example. The data from the GM-5000 can then be post-processed using averaging or other techniques to match the slower sampling rate used by the PM analyzers, and to bring the data sources into temporal alignment.

If the colocation data is going to be collected by streaming to a remote server, be sure the GM-5000 streamer is configured to send out "Colocation" or "Verbose" records. The "Standard" format does not include the estimated concentration readings (labeled as "Actuals") that are needed for the colocation analysis. "Actuals" reflect the values that the instrument would have reported if colocation calibration had been shut off. To state it another way, the concentration readings labeled as "Actual" are the estimated concentration values that are calculated using calibration factors loaded at the factory and any calibration adjustments that were created using the “gas calibration” procedure described earlier in this chapter.

A final point to consider during colocation setup is measurement units. The GM-5000 measurement units are parts per million (ppm) for CO and VOC, parts per billion (ppb) for SO_2, NO_2, NO, and O_3, and micrograms per cubic meter (µg/m^3) for particulate matter. The GM-5000 units cannot be changed, so if the reference analyzers report in different units, the reference measurements must be converted to match the GM-5000 before calculating calibration coefficients.

As described elsewhere, data records stored in the GM-5000 on-board memory can be downloaded using the GUI “Data - Export” menu. The records can be exported in either standard format or in an expanded format. The standard format only includes the final concentration readings, time stamps and basic environmental data, so is not appropriate for use in a calibration. The expanded format includes sensor voltages, estimated concentrations, called “actuals”, and other information that is needed for colocation calibration. When the data is exported from the GUI, it will be automatically saved in the “CSV” file format that can be easily opened in Excel. The exported data file will contain approximately 30 columns with labels in the top row and one row of data for each report period.

The GM-5000 data collected during the learning period can also be captured using the data streaming function. The data streaming function sends a report to an external server, typically connected over the internet, at the end of each measurement period. Streamed data records can be sent in four different formats designated as standard, verbose, colocation, and custom. The standard format is intended for normal routine operation and does not include data required for calibration. The colocation and verbose formats both include the information needed for setting up the standard colocation calibration, while the verbose format adds additional information, such as sensor voltage readings. The actual file format for streamed records will depend on how the server is set up, so streamed records may or may not be easily imported by Excel.

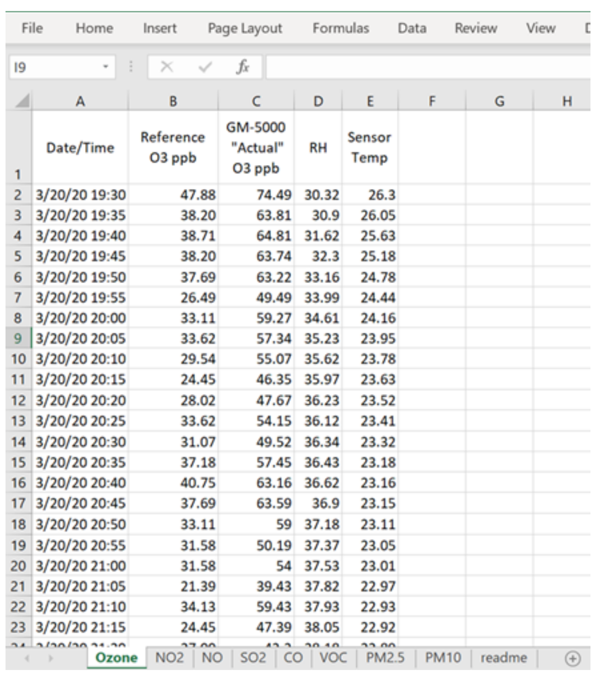
When operating only a few instruments it will be easier to work with data that is downloaded from the GM-5000 memory through the GUI. The following instructions are written based on that approach.

The exact procedure for downloading the reference data will vary depending on the manufacturer of the instruments and/or data logger that is being used. Follow the manufacturer’s instructions to download the reference data and save in a CSV or text-based file that can be imported by Excel. Be sure that the data files from the reference instrument include the date and time stamps so that the data sets from the reference analyzer and GM-5000 can be aligned.

Data Validation and Clean-Up

Before running any correlation analysis, it is important to validate the data sets to ensure that the time stamps on the reference data match the data from the GM-5000 and to be sure that each column contains the same number of data points. In order to run an accurate analysis, the start and end times and the total number of points in the reference data set and the GM-5000 file must be an exact match. It is also important to scan through both sets of data to make sure there are no missing or duplicate records. Any reference data that is "flagged" as part of a calibration, or a calibration check, should be removed along with the corresponding records from the GM-5000. Any data flagged with an error code should be examined and corrected or removed before continuing. The regression analysis function in Excel will not execute if columns contain blanks or non-numeric data so be sure to check carefully for any such problems.

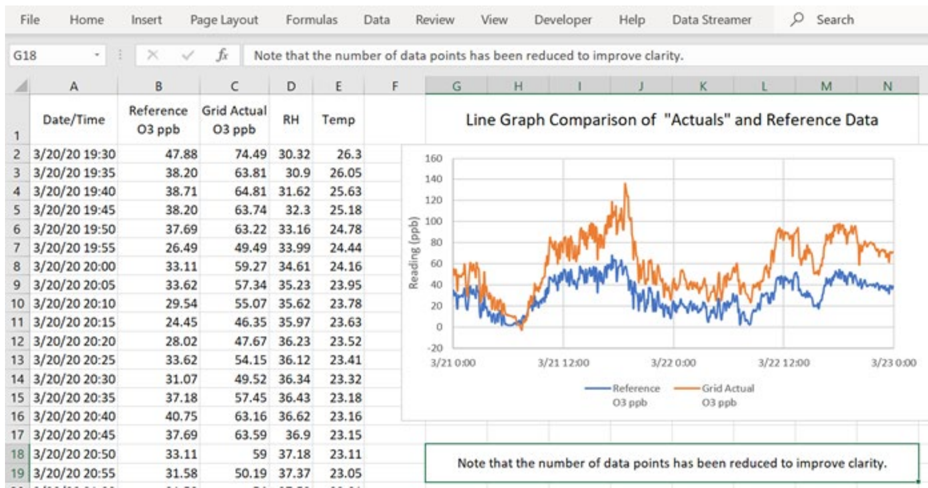
Once the data sets are validated, data for each measurement parameter should be loaded into a separate worksheet to help keep things organized. For the analysis to work correctly, the data columns must be organized in a specific order. We suggest putting the time and date stamps in column A, the reference concentrations in column B, GM-5000 "actuals" in Column C, GM-5000 sensor temperatures in Column D and GM-5000 RH data in Column E. A sample spreadsheet showing the suggested organization of data for one sensor is shown below in Figure 4–4. An identical worksheet, or tab, will be set up for each measurement parameter.



Date/Time	Reference O3 ppb	GM-5000 "Actual" O3 ppb	RH	Sensor Temp
3/20/20 19:30	47.88	74.49	30.32	26.3
3/20/20 19:35	38.20	63.81	30.9	26.05
3/20/20 19:40	38.71	64.81	31.62	25.63
3/20/20 19:45	38.20	63.74	32.3	25.18
3/20/20 19:50	37.69	63.22	33.16	24.78
3/20/20 19:55	26.49	49.49	33.99	24.44
3/20/20 20:00	33.11	59.27	34.61	24.16
3/20/20 20:05	33.62	57.34	35.23	23.95
3/20/20 20:10	29.54	55.07	35.62	23.78
3/20/20 20:15	24.45	46.35	35.97	23.63
3/20/20 20:20	28.02	47.67	36.23	23.52
3/20/20 20:25	33.62	54.15	36.12	23.41
3/20/20 20:30	31.07	49.52	36.34	23.32
3/20/20 20:35	37.18	57.45	36.43	23.18
3/20/20 20:40	40.75	63.16	36.62	23.16
3/20/20 20:45	37.69	63.59	36.9	23.15
3/20/20 20:50	33.11	59	37.18	23.11
3/20/20 20:55	31.58	50.19	37.37	23.05
3/20/20 21:00	31.58	54	37.53	23.01
3/20/20 21:05	21.39	39.43	37.82	22.97
3/20/20 21:10	34.13	59.43	37.93	22.93
3/20/20 21:15	24.45	47.39	38.05	22.92

Figure 4–4. Suggested data layout for regression analysis in Excel

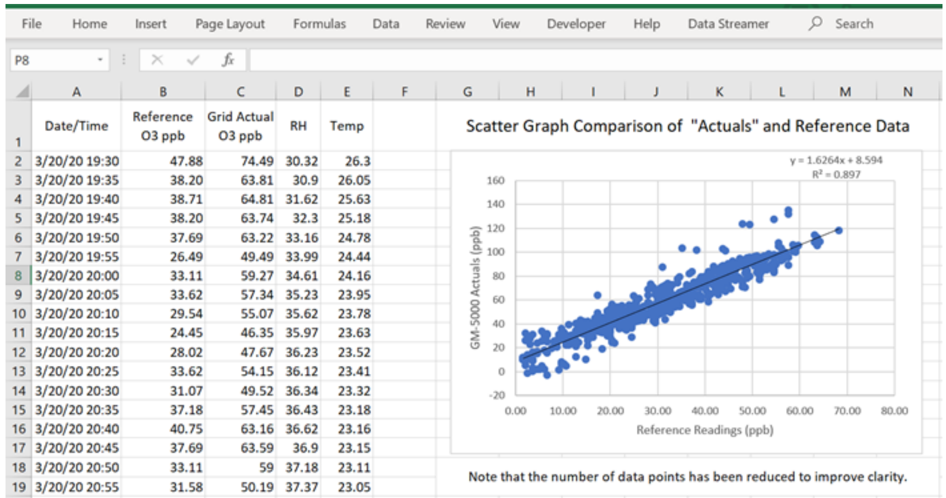
Once worksheets that contain both the reference and GM-5000 "actual" data are set up, it is useful to create charts showing the relationship between those two data sets. The GM-5000 "actual" values are generated using factory calibration data and, if everything is working correctly, there should be an obvious correlation between the two data sets, even before colocation calibration is applied. One simple approach to visualizing the data is to create a line chart showing the reference data and GM-5000 "actuals" overlaid on top of each other. As in the figure below, the two lines should show similar shapes with peaks and valleys tracking each other. If the two lines are not at least similar in shape, it suggests that there is a problem in the data set.



Date/Time	Reference O3 ppb	Grid Actual O3 ppb	RH	Temp
3/20/20 19:30	47.88	74.49	30.32	26.3
3/20/20 19:35	38.20	63.81	30.9	26.05
3/20/20 19:40	38.71	64.81	31.62	25.63
3/20/20 19:45	38.20	63.74	32.3	25.18
3/20/20 19:50	37.69	63.22	33.16	24.78
3/20/20 19:55	26.49	49.49	33.99	24.44
3/20/20 20:00	33.11	59.27	34.61	24.16
3/20/20 20:05	33.62	57.34	35.23	23.95
3/20/20 20:10	29.54	55.07	35.62	23.78
3/20/20 20:15	24.45	46.35	35.97	23.63
3/20/20 20:20	28.02	47.67	36.23	23.52
3/20/20 20:25	33.62	54.15	36.12	23.41
3/20/20 20:30	31.07	49.52	36.34	23.32
3/20/20 20:35	37.18	57.45	36.43	23.18
3/20/20 20:40	40.75	63.16	36.62	23.16
3/20/20 20:45	37.69	63.59	36.9	23.15
3/20/20 20:50	33.11	59	37.18	23.11
3/20/20 20:55	31.58	50.19	37.37	23.05

Figure 4–5. Line chart overlaying GM-5000 "actuals" with reference measurements

A more quantitative understanding of the raw data set can also be obtained by generating a scatter chart with the reference data on the horizontal (X) axis and with the GM-5000 actuals on the vertical (Y) axis, as shown below. Adding a linear trend-line and best-fit equation will help the operator to visualize how the GM-5000 is performing based on the factory calibration alone. A slope of 1.0 would theoretically indicate a "perfect" span setting and an intercept of 0.0 would indicate a "perfect" zero setting. In the case shown here, the slope of about 1.6 indicates that the GM-5000 is over-responding to ozone and the intercept of 8.6 shows that the GM-5000 would give a small positive reading even if there is no ozone present. The R-Square value, or correlation coefficient, and visible scatter around the trend line provide some insight into how much influence factors such as temperature, RH and cross interference might be exerting on the GM-5000 readings. While not strictly correct, the R-Square value of just under 0.90 suggests that about 90% of the variation in GM-5000 readings can be attributed to actual changes in the concentration of the target pollutant and that about 10% of the variation is coming from interferences. If temperature and RH variations are a significant interference, the multiple regression calibration should improve this value.



	Date/Time	Reference O3 ppb	Grid Actual O3 ppb	RH	Temp
2	3/20/20 19:30	47.88	74.49	30.32	26.3
3	3/20/20 19:35	38.20	63.81	30.9	26.05
4	3/20/20 19:40	38.71	64.81	31.62	25.63
5	3/20/20 19:45	38.20	63.74	32.3	25.18
6	3/20/20 19:50	37.69	63.22	33.16	24.78
7	3/20/20 19:55	26.49	49.49	33.99	24.44
8	3/20/20 20:00	33.11	59.27	34.61	24.16
9	3/20/20 20:05	33.62	57.34	35.23	23.95
10	3/20/20 20:10	29.54	55.07	35.62	23.78
11	3/20/20 20:15	24.45	46.35	35.97	23.63
12	3/20/20 20:20	28.02	47.67	36.23	23.52
13	3/20/20 20:25	33.62	54.15	36.12	23.41
14	3/20/20 20:30	31.07	49.52	36.34	23.32
15	3/20/20 20:35	37.18	57.45	36.43	23.18
16	3/20/20 20:40	40.75	63.16	36.62	23.16
17	3/20/20 20:45	37.69	63.59	36.9	23.15
18	3/20/20 20:50	33.11	59	37.18	23.11
19	3/20/20 20:55	31.58	50.19	37.37	23.05

Figure 4–6. Scatter chart showing correlation of GM-5000 "actuals" with reference measurements

Special Considerations Regarding PM Data

When setting up a calibration by colocation, the $PM_{2.5}$ and PM_{10} channels are slightly different from the setups used for the gas measurement channels. The GM-5000 database does not include a field called "actuals" for the PM data. In place of "actuals", each PM channel includes a field called "raw data" that contains the estimated PM concentrations as reported by the embedded AlphaSense optical particle counter. When calculating calibration coefficients for the PM sensor, it is important to use these "raw data" values. These values will be located in the last two columns of the exported data file.

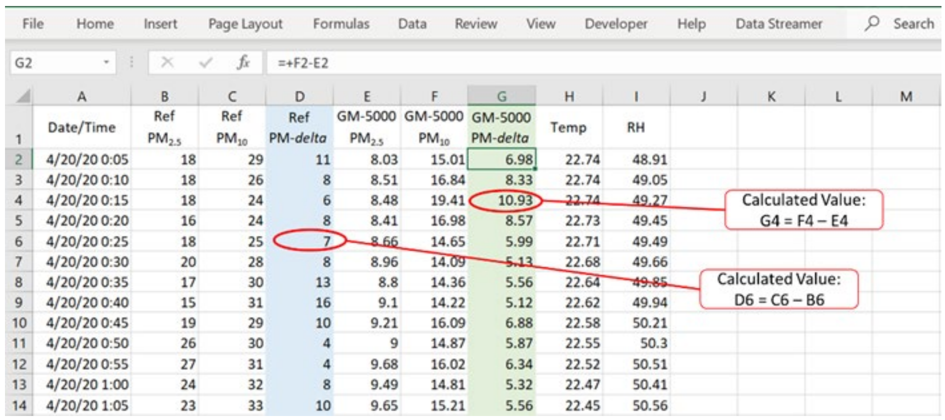
Other than the use of "raw data" in place of "actuals", the spreadsheet setup and regression calculations for $PM_{2.5}$ are the same as those used with the gas sensors.

Calibration of the PM_{10} channel proceeds in a similar manner, but it requires one additional step. Rather than using the raw PM_{10} data in the calibration calculations, it is necessary to calculate a new parameter that we refer to as the PM_{delta}. The PM_{delta} represents the concentration of particulate matter with diameters between 2.5 and 10 microns. Note that by accepted definition, PM_{10} includes all particles with mean aerodynamic diameters ranging from zero to 10 microns. To improve calibration accuracy, the GM-5000 calibration procedure applies one set of calibration coefficients to particles with diameters ranging from zero to 2.5, and a second set of calibration coefficients for particles with diameters ranging from 2.5 to 10 microns, which we refer to here as PM_{delta}.

To calculate the PM_{delta} values, create a new column that subtracts the $PM_{2.5}$ data column from the PM_{10} data column. This calculation must be done for both the GM-5000 and for the reference analyzer. You will then use the PM_{delta} data in place of the PM_{10} data for the regression analysis that follows.

Note that the term PM_{delta} is not generally recognized in the air quality community but is used here to emphasize that we are working with data that represents the difference between $PM_{2.5}$ and PM_{10}.

A sample spreadsheet showing typical calibration data set-up for the PM_{10} measurement channel is shown below. Note that the highlighted columns are filled with calculated values representing the difference (delta) between the $PM_{2.5}$ and PM_{10} concentrations at that time.



	A	B	C	D	E	F	G	H	I
1	Date/Time	Ref $PM_{2.5}$	Ref PM_{10}	Ref PM-*delta*	GM-5000 $PM_{2.5}$	GM-5000 PM_{10}	GM-5000 PM-*delta*	Temp	RH
2	4/20/20 0:05	18	29	11	8.03	15.01	6.98	22.74	48.91
3	4/20/20 0:10	18	26	8	8.51	16.84	8.33	22.74	49.05
4	4/20/20 0:15	18	24	6	8.48	19.41	10.93	22.74	49.27
5	4/20/20 0:20	16	24	8	8.41	16.98	8.57	22.73	49.45
6	4/20/20 0:25	18	25	7	8.66	14.65	5.99	22.71	49.49
7	4/20/20 0:30	20	28	8	8.96	14.09	5.13	22.68	49.66
8	4/20/20 0:35	17	30	13	8.8	14.36	5.56	22.64	49.85
9	4/20/20 0:40	15	31	16	9.1	14.22	5.12	22.62	49.94
10	4/20/20 0:45	19	29	10	9.21	16.09	6.88	22.58	50.21
11	4/20/20 0:50	26	30	4	9	14.87	5.87	22.55	50.3
12	4/20/20 0:55	27	31	4	9.68	16.02	6.34	22.52	50.51
13	4/20/20 1:00	24	32	8	9.49	14.81	5.32	22.47	50.41
14	4/20/20 1:05	23	33	10	9.65	15.21	5.56	22.45	50.56

Figure 4–7. Excel layout for PM_{10} data showing calculation of PM_{delta} values by subtraction

Creating a Test Set

When performing regression analysis or other types of statistical modeling, it is quite common to randomly split the data set into two groups or sub-sets. The larger data set, called the training set, usually contains eighty to eighty-five per cent of the total data and is used for model development. The smaller sub-set, called the test set, is held aside and used as test data to validate the model before it is deployed. Although this is common practice for some types of modeling, it is not generally useful for time-series data and is not recommended in this case. If a test data set is desired, we suggest extending the colocation period by a few extra days and setting aside the last two or three days of data to be used as a test set.

Regression Analysis

After the GM-5000 and reference data is validated and organized, the colocation factors can be determined using Excel's regression analysis function which is available in the data "Analysis Tool Pack." To locate the regression function, select the Data menu, then the Data Analysis sub-menu and then scroll down to "Regression" as shown in the figure below.

If "Data Analysis" does not appear in the top-level Data menu, then the "Analysis Tool Pack" will need to be installed. The "Analysis Tool Pack" is an Add-In that can be found in Excel's File-Options menu but is not loaded during typical installation. Please refer to the Microsoft Excel Help system or the Microsoft web site for further information about installing optional "Add-Ins".

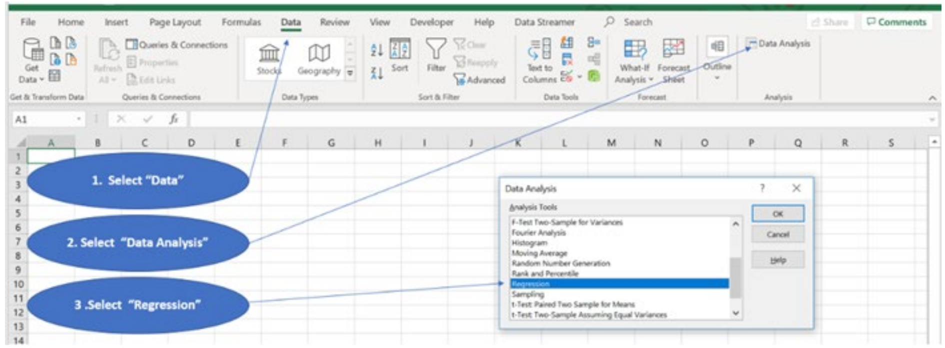


Figure 4–8. Locating the Excel regression analysis function

When you select "Regression" under the Data Analysis menu, you will be presented with a dialog box similar to the one shown in Figures 4-9 and 4-10 below. The reference data (Column B in our example) is the dependent variable and should be selected as the "Input Y-Range". The "actual" sensor readings, the sensor temperature, and sensor RH (Columns C, D, and E) are the independent variables and should be selected as the "Input X-Range". Be sure to leave the "Constant is Zero" box unchecked.

Under "Output Options", we suggest checking the "Output Range" box and then selecting a cell off to the right of your data. The regression output will be pasted into the cells below and to the right of the one you select for the "Output Range". It is generally not necessary to print or plot the residuals or the normal probability, although the residual plots sometimes provide useful diagnostics.

Once the Input and Output box is properly filled out, click the "OK" button and Excel will perform the regression analysis.

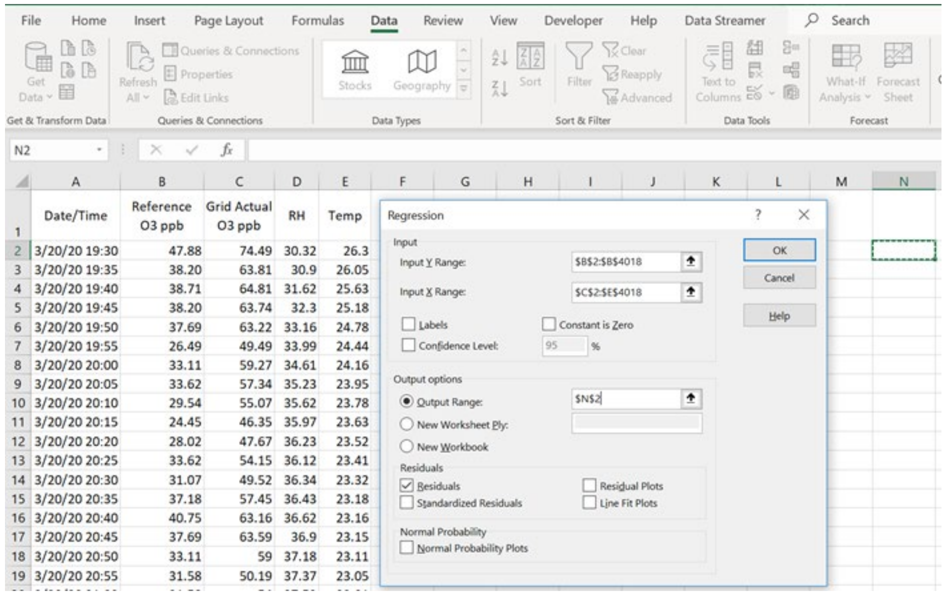


Figure 4–9. Recommended setup for performing multiple linear regression analysis on GM-5000 gas sensor data

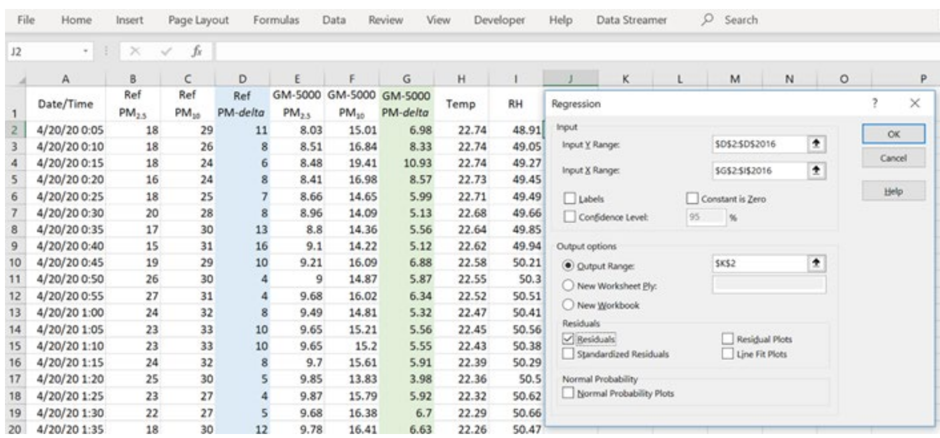


Figure 4–10. Recommended setup for performing multiple linear regression analysis using the PM_{delta} readings that are calculated from $PM_{2.5}$ and PM_{10} "raw" values

When the regression calculation is complete, which may take several seconds, Excel will provide an output table as shown in Figure 4-11. This includes the intercept and the three coefficients. Variable 1(Var_1) corresponds to the "actual" sensor reading, Variable 2 (Var_2) corresponds to the temperature and Variable 3 (Var_3) corresponds to the RH. These variables should be transferred to the GM-5000 "Calibration-Colocation Factors" menu as shown in Figure 4-12. Note that the coefficients calculated using PM_{delta} values will be used in the line labeled PM_{10}. For more information on using the Colocation Factors screen, see Chapter 3, "Operation".

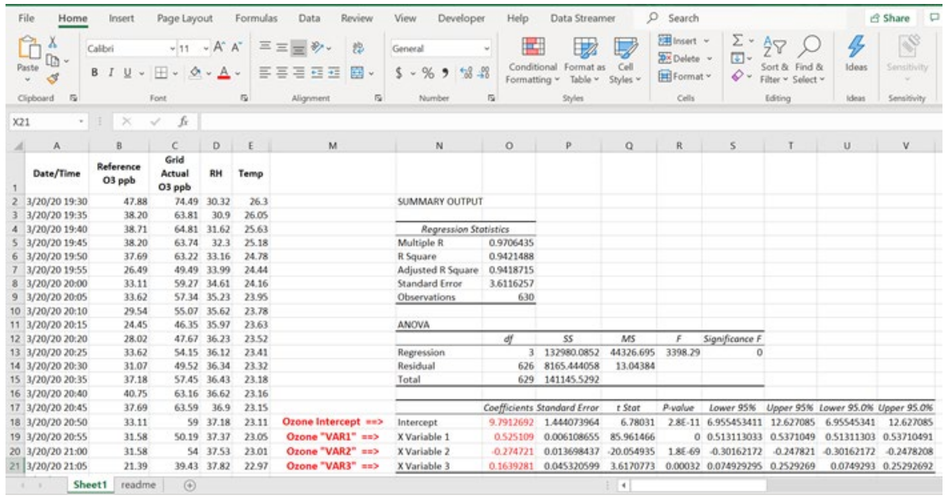


Figure 4–11. Standard regression output showing the location of coefficients that will be transferred to the GM-5000

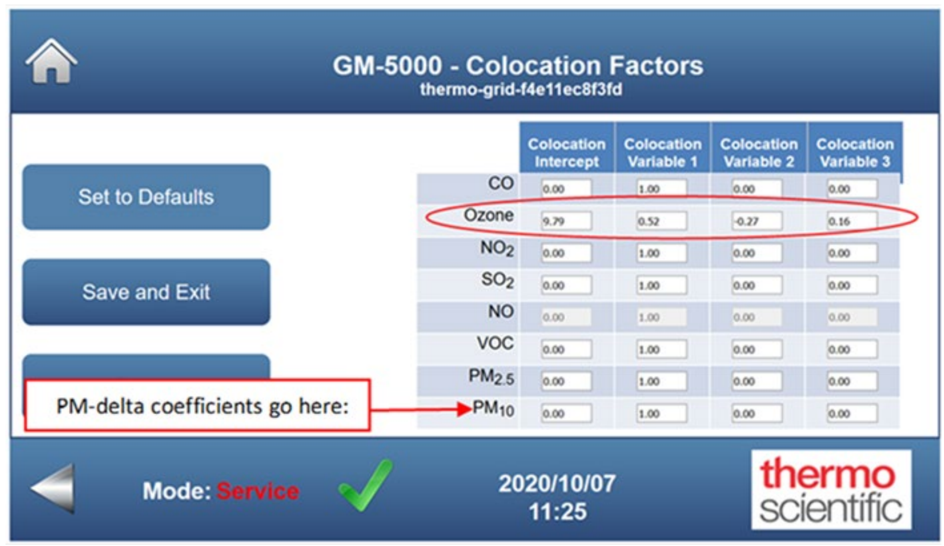


Figure 4–12. GM-5000 GUI colocation screen with multiple regression coefficients highlighted. Note that the PM_{delta} coefficients are entered in the line labeled "PM_{10}"

Checking Quality of Fit for the Regression Model

Once the regression analysis is complete, it is good practice to go back and verify the quality of the model by looking at Excel's "Regression Statistics" box and to also generate a new "corrected" data set using the original "actuals," temperature, RH and the coefficients. If everything went well, the "corrected" data column should be a close match to the original reference data.

Addressing the regression statistics first, the R-Square value (coefficient of determination) explains the degree to which your input variables (actuals, temperature and RH) explain the variation in your output (reference data). As noted above, if R-Square is 0.8, it means 80% of the variation in the output variable is explained by the input variables. So, the higher the R-Square is, the more variation is explained by your input variables and the better the model. The "multiple R" also shown in the Excel output is the correlation coefficient and is simply the square root of the R-Square.

One problem with the R-Square statistic is that it will generally increase with addition of more variables, even if those variables do not have an actual influence on the output variables. Unlike the standard R-Square, the adjusted R-Square introduces a penalty for adding variables that do not improve the fit of the existing model. Since the colocation calibration uses multiple variables, it is suggested that you use adjusted R-Square to judge "goodness of fit" for your calibration model. There are no rules about what adjusted R-Square value is acceptable, but in general, we expect to achieve values of 0.85 or better for most parameters.

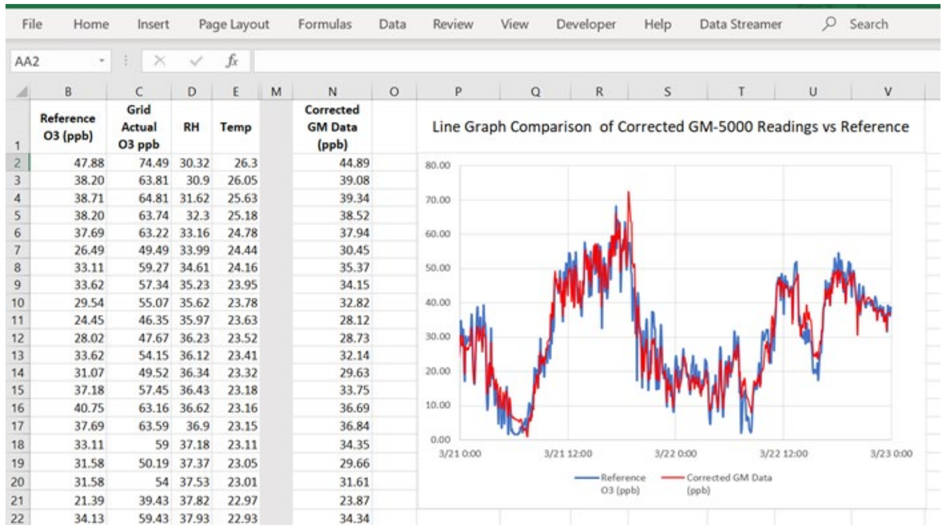
Values below 0.85 often occur if the sensor is being influenced by pollutants other than the target, or if the concentration of the target pollutant was too low to be reliably measured with the GM-5000 sensors. For example, typical SO_2 concentrations in most ambient environments are below the SO_2 sensor's detection limit, so attempts to calibrate by colocation will generate poorly fit models and adjusted R-Square values well below 0.5.

While the adjusted-R value is a good statistical indicator of fit, generating and plotting a "corrected" data set can sometimes provide a more intuitive understanding of the calibration. To generate a corrected data set, we simply use the original GM-5000 data plus the intercept, Var_1, Var_2 and Var_3 coefficients in the equation shown below to generate a new column of data that should closely match the original reference data.

Corrected = Intercept + (Var_1 X Actuals) + (Var_2 X Temperature) + (Var_3 X RH)

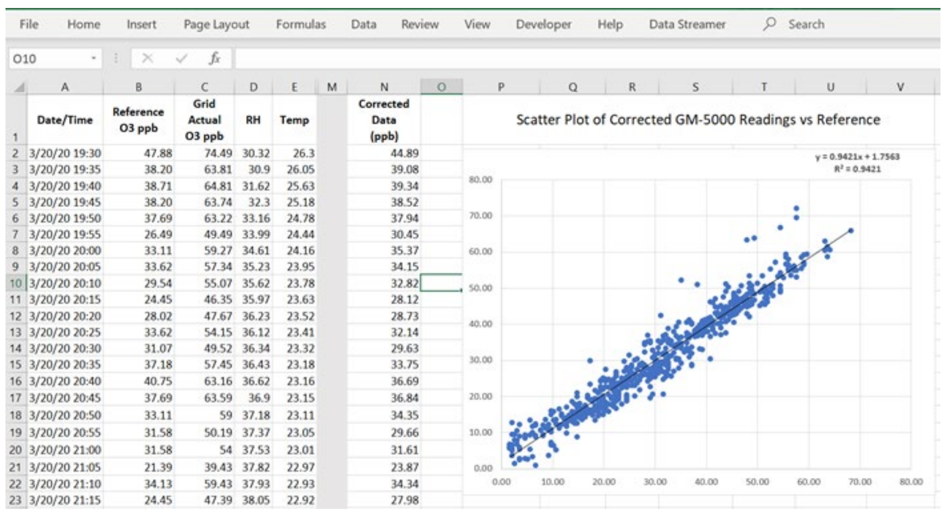
Once the "corrected" data set is created, it is then useful to go back and plot new line charts and/or scatter charts like those that were used in the original data validation. Since we are testing the model with the same data that we used to generate the model, the line chart should show the reference and corrected data more or less superimposed and the scatter chart should generate a line with a slope close to 1.0 and an intercept close to zero.

Sample worksheets showing how a sample set of "corrected data" compares to the reference readings can be found in Figure 4–13 and Figure 4–14.



	Reference O3 (ppb)	Grid Actual O3 ppb	RH	Temp	Corrected GM Data (ppb)
2	47.88	74.49	30.32	26.3	44.89
3	38.20	63.81	30.9	26.05	39.08
4	38.71	64.81	31.62	25.63	39.34
5	38.20	63.74	32.3	25.18	38.52
6	37.69	63.22	33.16	24.78	37.94
7	26.49	49.49	33.99	24.44	30.45
8	33.11	59.27	34.61	24.16	35.37
9	33.62	57.34	35.23	23.95	34.15
10	29.54	55.07	35.62	23.78	32.82
11	24.45	46.35	35.97	23.63	28.12
12	28.02	47.67	36.23	23.52	28.73
13	33.62	54.15	36.12	23.41	32.14
14	31.07	49.52	36.34	23.32	29.63
15	37.18	57.45	36.43	23.18	33.75
16	40.75	63.16	36.62	23.16	36.69
17	37.69	63.59	36.9	23.15	36.84
18	33.11	59	37.18	23.11	34.35
19	31.58	50.19	37.37	23.05	29.66
20	31.58	54	37.53	23.01	31.61
21	21.39	39.43	37.82	22.97	23.87
22	34.13	59.43	37.93	22.93	34.34

Figure 4–13. Excel line chart showing "corrected" GM-5000 readings overlaid with reference measurements



	Date/Time	Reference O3 ppb	Grid Actual O3 ppb	RH	Temp	Corrected Data (ppb)
2	3/20/20 19:30	47.88	74.49	30.32	26.3	44.89
3	3/20/20 19:35	38.20	63.81	30.9	26.05	39.08
4	3/20/20 19:40	38.71	64.81	31.62	25.63	39.34
5	3/20/20 19:45	38.20	63.74	32.3	25.18	38.52
6	3/20/20 19:50	37.69	63.22	33.16	24.78	37.94
7	3/20/20 19:55	26.49	49.49	33.99	24.44	30.45
8	3/20/20 20:00	33.11	59.27	34.61	24.16	35.37
9	3/20/20 20:05	33.62	57.34	35.23	23.95	34.15
10	3/20/20 20:10	29.54	55.07	35.62	23.78	32.82
11	3/20/20 20:15	24.45	46.35	35.97	23.63	28.12
12	3/20/20 20:20	28.02	47.67	36.23	23.52	28.73
13	3/20/20 20:25	33.62	54.15	36.12	23.41	32.14
14	3/20/20 20:30	31.07	49.52	36.34	23.32	29.63
15	3/20/20 20:35	37.18	57.45	36.43	23.18	33.75
16	3/20/20 20:40	40.75	63.16	36.62	23.16	36.69
17	3/20/20 20:45	37.69	63.59	36.9	23.15	36.84
18	3/20/20 20:50	33.11	59	37.18	23.11	34.35
19	3/20/20 20:55	31.58	50.19	37.37	23.05	29.66
20	3/20/20 21:00	31.58	54	37.53	23.01	31.61
21	3/20/20 21:05	21.39	39.43	37.82	22.97	23.87
22	3/20/20 21:10	34.13	59.43	37.93	22.93	34.34
23	3/20/20 21:15	24.45	47.39	38.05	22.92	27.98

Figure 4–14. Excel scatter chart showing correlation between "corrected" GM-5000 readings and reference measurements

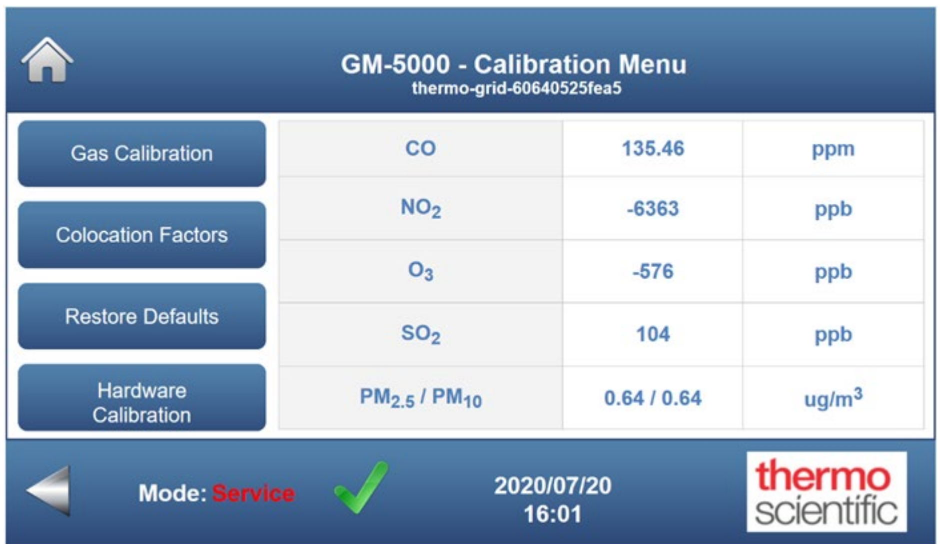
If a sub-set of the original data was set aside to use as a "test set", then the same procedure that is described above for generating "corrected data" can be used to simulate an actual calibration. If the equation shown generates a good match to the reference data when applied to the test set, then you should have confidence that the colocation calibration procedure was successful.

Restore Defaults

If, for some reason, it should become necessary to reset all gas calibration coefficients and colocation factors back to the original factory default values, the following procedure can be used. Any current user calibration settings will be erased and cannot be recovered.

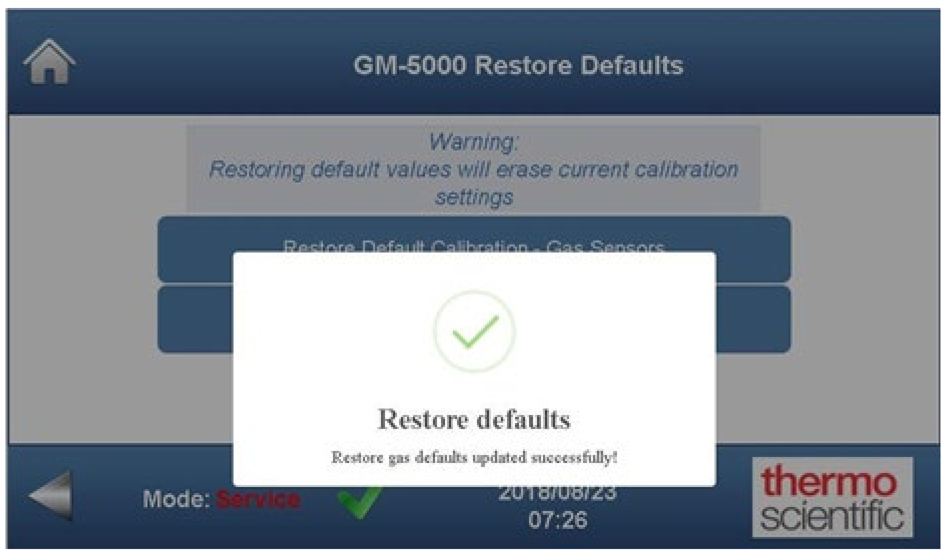
Note Restoring the default calibration values for the gas sensors is done independently from the PM (particulate matter) sensors. That is, the user can restore defaults on one type of sensor without having to restore defaults on the other type of sensor. ▲

1. From the Home Screen, choose **Calibration>Restore Defaults**.

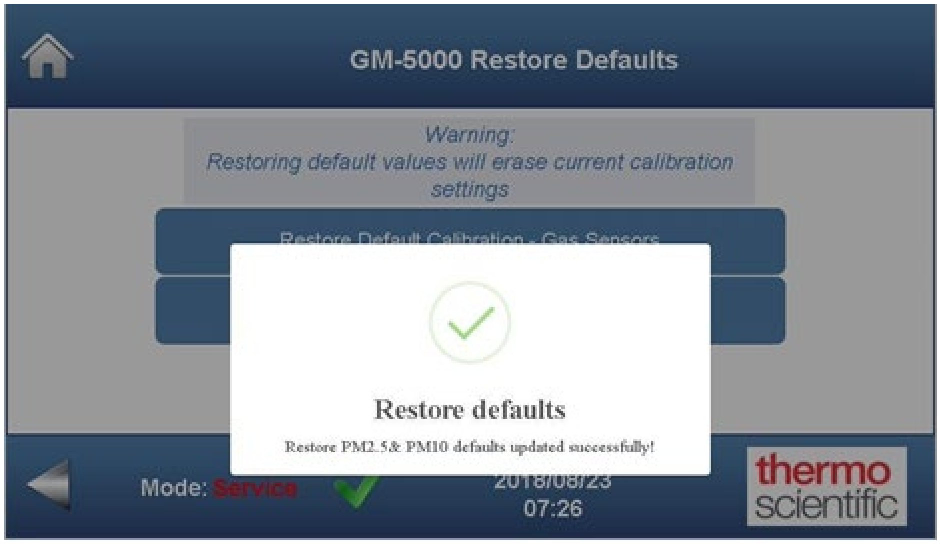


2. Next, choose to restore the default calibration for either the gas sensors or the PM sensors.

3. The user is then notified that the default values have successfully been restored for the group of sensors that were selected.



4. The Restore Defaults screen will appear again, and the user can either choose to restore the default calibration values on the other group of sensors or choose the Home button to return to the Home Screen.


GM-5000 Restore Defaults
Warning:
Restoring default values will erase current calibration settings
Restore defaults
Restore PM2.5& PM10 defaults updated successfully!
Mode: Service
07:26
thermo scientific

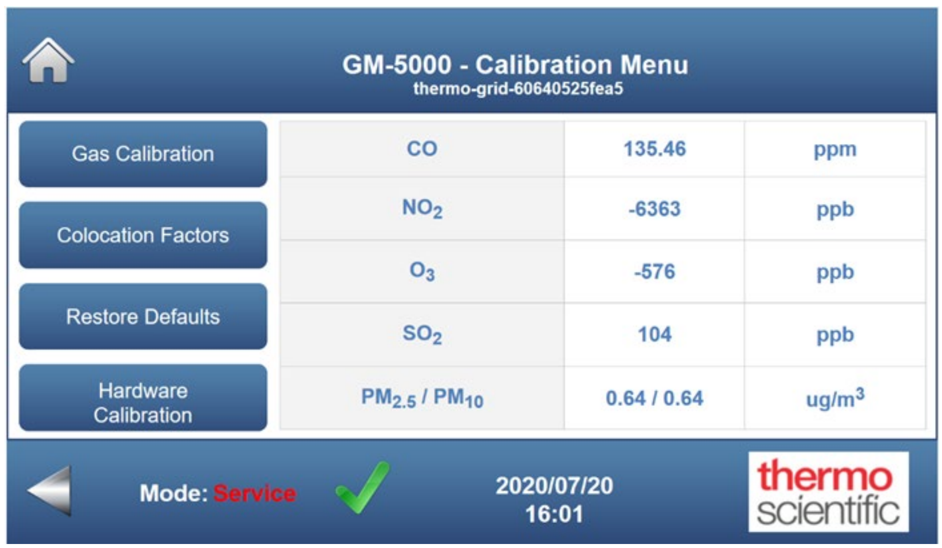
Hardware Calibration

The GM-5000 hardware sensors include the temperature, relative humidity, and pressure sensors located inside the Sensor Chamber (Sensor Enclosure), and the temperature sensors for the main GM-5000 enclosure and Sample Inlet Tube.

Periodic calibration of these sensors is not required. However, if the readings disagree with a known reference instrument, the following procedure can be used to set correction factors which will effectively calibrate the sensors to the reference instrument.

Use the following procedure to calibrate the GM-5000 hardware.

1. From the Home Screen, choose **Calibration>Hardware Calibration**.



2. The Hardware Calibration screen is displayed, which shows the current reading for each of the five sensors that can be calibrated.

3. The user can then change the displayed reading of the sensor in question to match the reading of the known reference instrument by using the up and down arrows. Choose **Calibrate** next to the appropriate sensor reading.

4. The user chooses **Continue** to return to the previous screen. Once all necessary adjustments to these sensor readings have been completed, choose **Cancel** or the "Home" button to return to the Home Screen.

Chapter 5
Maintenance

This chapter describes the periodic maintenance procedures that should be performed on the instrument to ensure proper operation. Since usage and environmental conditions vary greatly, you should inspect the components frequently until an appropriate maintenance schedule is determined.

Safety Precautions

Read the safety precautions before beginning any procedures in this chapter.

Electrical Hazard Be sure to shut AC power off at the supply and follow your organizations Lock-out Tag-out procedures to eliminate risk of shock. ▲

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly grounded antistatic wrist strap must be worn while handling any internal component. For more information about appropriate safety precautions, see Chapter 7, "Servicing". ▲

Cleaning the Air Inlet and Exhaust Screens

Use either of the following methods to clean the air inlet and exhaust fan screens.

Method 1:

Equipment required:

Brush, soft-bristled, small

Low pressure compressed air source

1. One method of cleaning the exhaust screen is to use a small soft-bristled brush from outside of the enclosure to dislodge any debris from the screen, then allowing the exhaust fan to blow the debris away. This procedure can be done without turning off the instrument power switch or disconnecting the AC power source.

2. Similarly, the small soft-bristled brush can be used to clean the cooling air inlet screen, only instead of relying on the fan to blow the debris away, low pressure compressed air can be used from the inside of the enclosure to remove the debris. Low pressure must be used so as not to dislodge the screen from its gasket. To accomplish this, the electrical protective shield needs to be removed. Remove the electrical protective shield from the enclosure per "Removing the Electrical Protective Shield" procedure (Figure 7–3) from Chapter 7, "Servicing" of this manual.

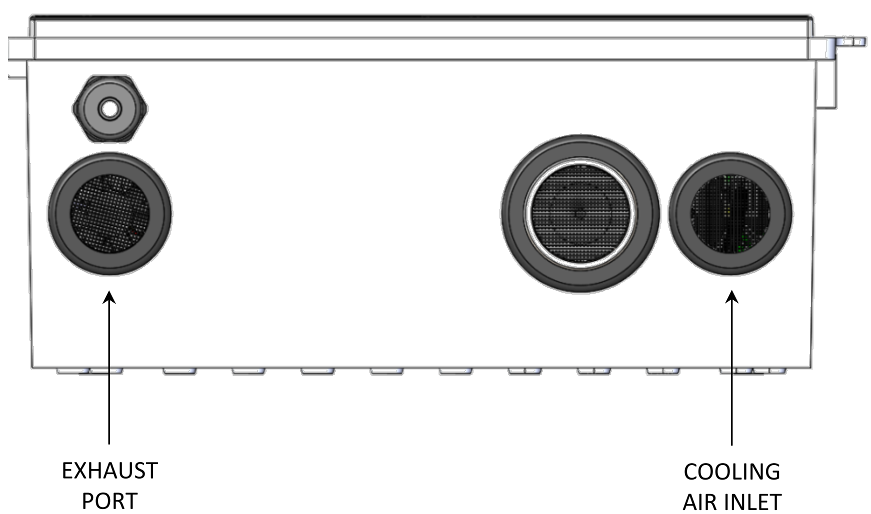


Figure 5–1. Cleaning the Air Inlet and Exhaust Screens method 1

Method 2:

Equipment required:

Nut driver, M3

Squirt bottle filled with de-ionized or distilled water

Low pressure compressed air source

1. Turn off the power switch and disconnect the AC power source.

2. Remove the electrical protective shield from the enclosure per "Removing the Electrical Protective Shield" procedure (Figure 7–3) from Chapter 7, "Servicing" of this manual.

3. Unfasten the captive thumb screw on the exhaust tube, slide it up approximately 1 inch, then pull it off the shoulder screws.

4. Gently unplug the white fan connector from the BeagleBone Cape board and slide the wires out of the bottom of the cable holder.

5. Using the M3 nut driver, loosen and remove the three M3 nuts that fasten the fan to the chassis.

6. Remove the fan from three mounting studs.

7. Using the squirt bottle, spray water down onto both the exhaust screen and the air inlet screen to dislodge any debris, being careful not to accumulate water inside the enclosure.

8. Use the low pressure compressed air to dry the screen, applying the air from inside the enclosure and blowing the water out the bottom. Low pressure must be used so as not to dislodge either screen from its gasket.

9. Re-install the fan onto the three mounting studs, making sure that the air flow arrow is pointing down (exiting the enclosure).

10. Thread the three M3 nuts back on the mounting studs until finger tight. Then using the M3 nut driver, tighten the nuts an equal number of turns until the gasket is compressed slightly. Do not over tighten.

11. Follow steps 1–3 in reverse order to complete the procedure.

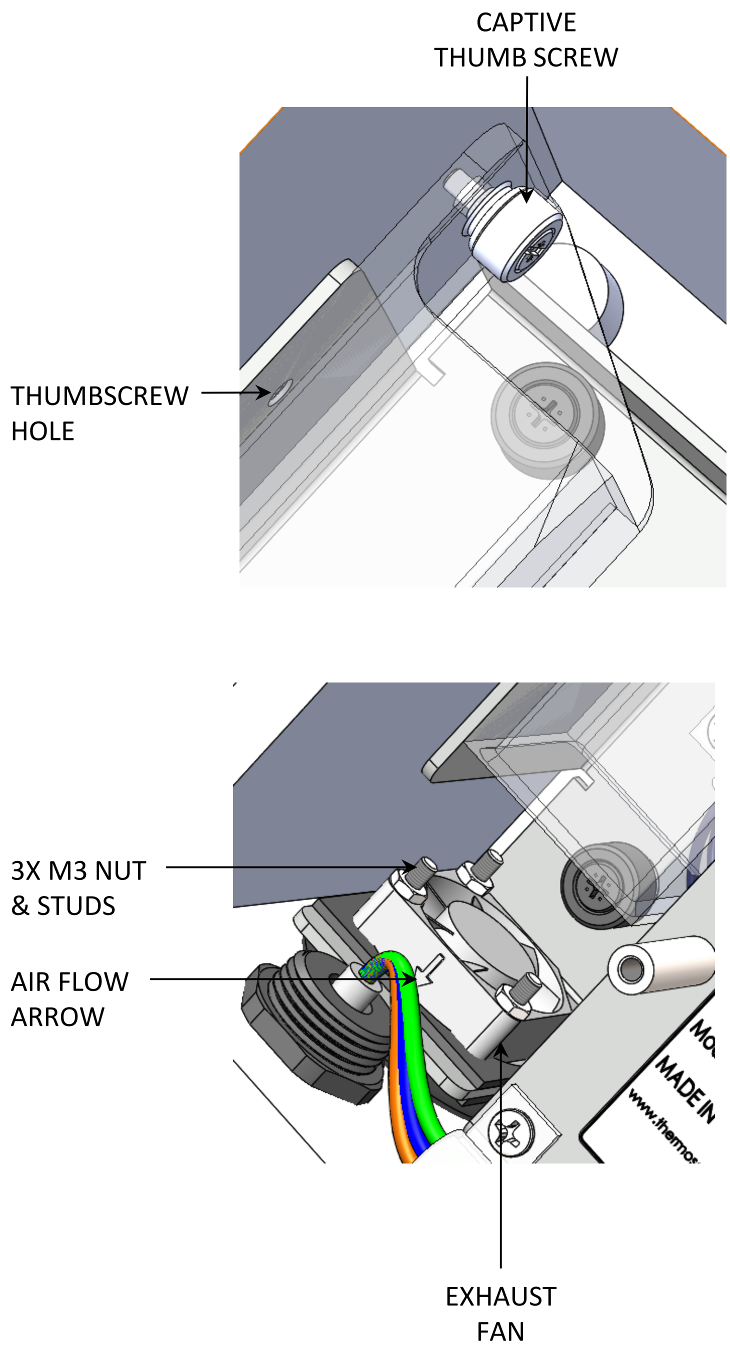


Figure 5–2. Cleaning the Air Inlet and Exhaust Screens method 2

Cleaning/Replacing the Sample Inlet Screen

Use the following procedure to clean and replace the sample inlet screen.

Equipment required:

Dental pick

Water, de-ionized or distilled

Low pressure compressed air source (optional)

1. Turn off the power switch and allow the sample inlet tube to cool.

2. Using a dental pick, carefully remove the coarse (20 mesh) wire screen from the end of the sample inlet tube. (The screen press-fits into a groove, so some force may be required.)

3. Clean the screen thoroughly with water, and then either dry it using the low pressure compressed air source or air dry. Replace the screen if necessary.

4. Re-install the cleaned or new screen by press-fitting it into its groove in the end of the sample inlet tube.

5. Turn the instrument power switch back on.

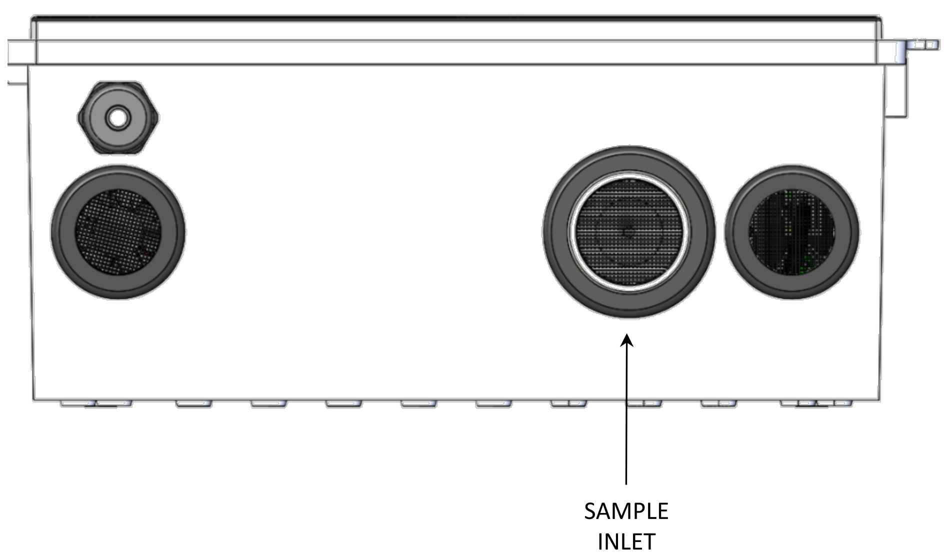


Figure 5–3. Cleaning/Replacing the Sample Inlet Screen

Cleaning/Replacing the Sensor Enclosure Screen

Use the following procedure to clean and replace the sensor enclosure screen.

Equipment required:

Screwdriver, flat blade

Phillips head screwdriver, #1

Water, de-ionized or distilled

Low pressure compressed air source (optional)

1. Turn off the power switch and disconnect the AC power source.

2. Open the cover to the sensor enclosure by sliding the latch to the left while lifting up the cover.

3. Insert the flat blade screwdriver into the slot in the filter retainer assembly and gently pry it off the mounting studs.

4. Using the Phillips screwdriver, remove the two screws and lift off the filter retainer cover. Remove the 30 mesh wire screen from the filter retainer base. Wipe the filter retainer parts clean if necessary.

5. Clean the screen thoroughly with water, then either dry it using the low pressure compressed air source or air dry. Replace the screen if necessary.

6. Re-install the cleaned or new screen into the filter retainer base, then install the cover and secure with the two Phillips head screws. Press-fit the filter retainer back onto its mounting studs until it locks into place.

7. Close the sensor enclosure cover, reconnect the AC power source and turn the instrument power switch back on.

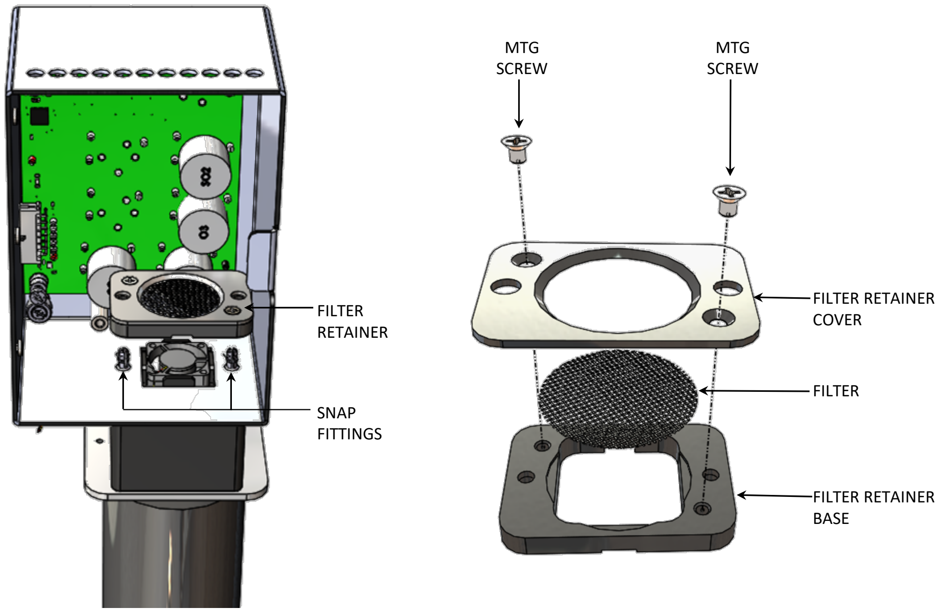


Figure 5–4. Cleaning/Replacing the Sensor Enclosure Screen

Cleaning the Main Enclosure

Use the following procedure to clean the main enclosure.

Equipment required:

Cloth, lint free

Water, de-ionized or distilled

Low pressure compressed air source (optional)

1. Turn off the power switch and disconnect the AC power source.

2. Remove the electrical protective shield from the enclosure per "Removing the Electrical Protective Shield" procedure (Figure 7–3) from Chapter 7, "Servicing" of this manual.

3. External enclosure can be wiped clean with a lint free cloth and water.

4. Using the compressed air, gently blow out any dust that has accumulated on the electronics or any other internal components. (For more information, see "Cleaning Inside the Sensor Enclosure".)

5. Clean the inside of the enclosure door and the enclosure walls (where accessible) with the lint free cloth and water. Allow to air dry. Do not wet any electronics or wiring.

6. Re-install the electrical protective shield onto the standoffs.

7. Reconnect the AC power source and turn the instrument power switch back on.

Cleaning Inside the Sensor Enclosure

Use the following procedure to clean inside the sensor enclosure, if it becomes necessary due to an excessively dusty environment.

Equipment required:

Low pressure compressed air source

Scotch tape

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly ground antistatic wrist strap must be worn while handling any internal component. ▲

1. Turn off the power switch.

2. Open the cover to the sensor enclosure by sliding the latch to the left while lifting up the cover.

3. Using the compressed air, gently blow out any dust that has accumulated on the electronics or inside the sensor enclosure.

WARNING Do not blow compressed air directly on the face of gas sensors. ▲

4. Using a piece of scotch tape, remove any accumulated dust from the top of each sensor. Gently place the tape on the top center of the sensor, but do not apply much pressure.

5. Close the sensor enclosure cover and turn the instrument power switch back on.

Cleaning the PID Lamp

The PID lamp will need to be cleaned periodically, as deposits form on the lamp window during normal operation and will decrease the sensitivity and performance of the PID. Frequency of cleaning will depend on the air quality and other environmental conditions where the PID is being used. A cleaning schedule can be developed as the user gains more experience using the PID, but an initial suggested cleaning frequency is once every 3 months. Use the following procedure to clean the PID lamp.

Equipment required:

Lamp Removal Tool

Cotton swabs or lint free nonabrasive laboratory wipes

Aluminum oxide powder

Latex gloves

Tweezers (as needed)

⚠WARNING

WARNING The lamp cleaning procedure must be performed on a clean surface using clean tools. Avoid touching the lamp's window as well as the metalized portion of the cell assembly with your bare fingers. Fingerprints left on these parts may adversely affect the sensors operation. Latex gloves are recommended. Hold the lamp by its glass body or by the edges of the window. ▲

⚠WARNING

WARNING Only use the lamp removal tool to access the PID lamp and electrode stack. Other tools such as a screwdriver may damage the PID module body and will invalidate your warranty. ▲

⚠WARNING

WARNING Lamp cleaning is done using a very fine aluminum oxide powder. Cleaning should be done in a well-ventilated area. Do not breathe in the powder and avoid contact with skin, eyes and clothing. A material safety data sheet (MSDS) is available on request from Thermo Fisher Scientific. ▲

1. Turn off the power switch.

2. Open the cover to the sensor enclosure by sliding the latch to the left while lifting up the cover.

3. Remove the PID module from location “SEN7” on the sensor board by gently and evenly pulling it away from the board.

4. Working on a clean surface, insert the tabs of the lamp removal tool in the side slots of the PID module and squeeze together until the electrode stack and lamp are released from the PID body. It is helpful to keep a finger pressed lightly on the electrode stack during this process to keep from losing it.

Figure 5–5. Lamp Removal Tool

Figure 5–6. Removing the Lamp

5. The lamp should come out with the electrode stack, but occasionally it may be lodged in the sensor body and will need to be removed carefully using the tweezers. If the small spring behind the lamp comes out when the lamp is removed, just place it back inside the sensor body.

6. At this point, inspect the underside of the electrode stack. The electrodes should appear shiny and metallic. If they are corroded, the electrode stack should be replaced.

7. To clean the lamp, open the aluminum oxide powder and deposit a small amount on either the clean cotton swab or on the laboratory wipe. Use it to polish the lamp window in a circular motion, applying only light pressure. Do not touch the lamp window with your fingers. It will usually take 15 to 30 seconds to complete, and you may hear a “squeaking” sound when the window is clean.

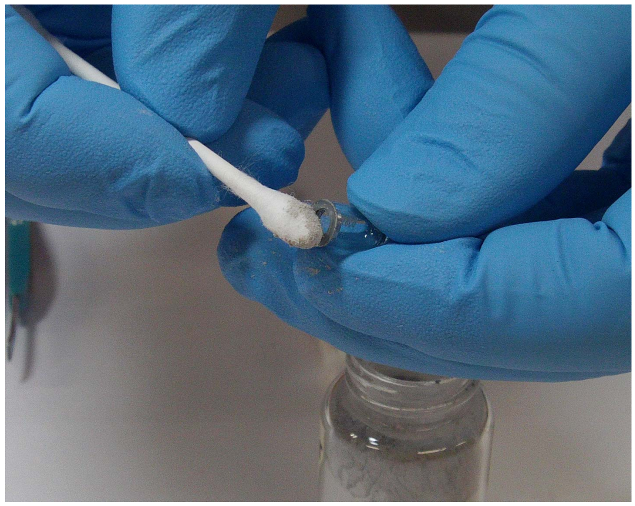


Figure 5–7. Cleaning the Lamp

8. Using another clean cotton swab or laboratory wipe, remove the residual aluminum oxide powder from the lamp window until it is clean.

9. To re-assemble the PID module, place the electrode stack face down on a flat surface and then twist and push the lamp down into the sealing area until it buts up against the front electrode face.

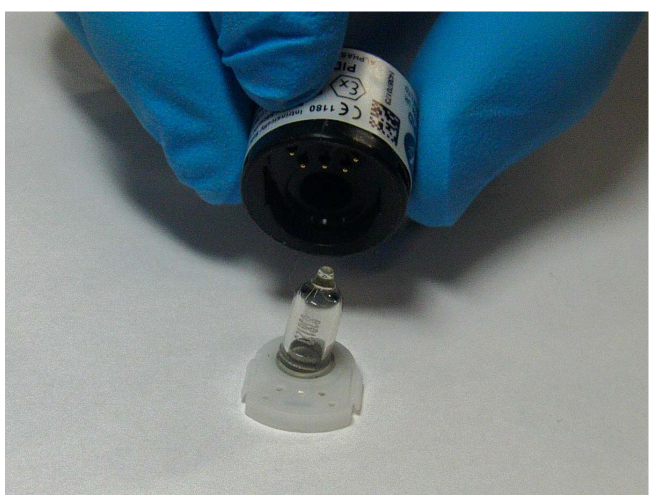


Figure 5–8. Reassembling the Lamp

10. Carefully place the PID body down over the lamp and electrode stack so as not to disturb the seated lamp, make sure the orientation is correct and then push the body firmly onto the electrode stack so that both wings engage the PID body. As this happens, you should hear two faint clicks.

11. To re-install the PID module in the sensor board, handle it by the edges, line up the 3 pins with the sockets in board position "SEN7", and press firmly until the PID module sits flat on the sensor board. Close the sensor enclosure lid.

Turn the power switch back on and let the GM-5000 warm up for 30 minutes. Calibrate the VOC channel as described in Chapter 4, "Calibration" of this manual.

Chapter 6
Troubleshooting

The troubleshooting guide presented in this chapter is designed to help isolate and identify instrument problems.

Safety Precautions

Read the safety precautions in Appendix A, "Safety, Warranty, and WEEE" before performing any actions listed in this chapter.

Troubleshooting Guide

Table 6–1 provides general troubleshooting information and indicates the checks that you should perform if you experience an instrument problem. It also lists GM-5000 specific troubleshooting information and provides recommendations about how to resolve any alarm conditions.

The user is notified of an alarm condition in several ways. If utilizing the user interface, the Diagnostics screen under the Service Menu shows parameters highlighted in red if they are in an alarm condition. In addition, the View Data screen under the Data Menu has a column called "Alarms", which for each logged data point contains hexadecimal digits that represent if the instrument is in Service Mode (will be highlighted in yellow) or if it is in an alarm condition (will be highlighted in red.) This same "Alarms" column is found in the logged data or streamed data files. Refer to Figure 6–1 at the end of this chapter on how to decode these hexadecimal digits.

Table 6–1. GM-5000 Troubleshooting Guide

Problem	Possible Cause	Action
Instrument does not start (LEDs on internal circuit boards do not come on)	No power	Verify that the power cord is wired correctly to the terminal block, is connected to the power source, and that power is available.
	Fuse is blown or missing	Disconnect power and check fuses with a volt meter.
	Bad switch or wiring connection to switch	Check all wiring connections.
No data streaming from GM-5000	No communications from wireless modem to host device	Verify unit has power.

Problem	Possible Cause	Action
		Verify that Server Name/Address and TCP Port fields are set correctly in the Comm Settings screen.
		Verify proper connection with cellular provider.
		Check cable connections at modem and circuit boards.
		Connect modem to a personal computer to see if you can establish a connection to the internet.
		Switch modem with a known good one (if available).
Unable to obtain WiFi signal	No WiFi signal from GM-5000	Verify unit has power.
		Check cable connections at WiFi dongle and circuit boards.
		Switch WiFi dongle with a known good one (if available).
	Connecting device not receiving WiFi signal	Confirm device receiving signal is WiFi enabled.
		Verify that WiFi settings are set correctly in Comm Settings screen using a wired Ethernet connection instead of the modem.
Very low or slow response	Sample gas not reaching the analyzer	Verify sample inlet and sensor enclosure screens are not blocked. Clean/replace if necessary.
		Verify that sample humidity is over 15% RH.
		Confirm sample inlet fan is operating. If damaged, replace OPC or OPC Blank (contains fan).
	Electrochemical sensors are past useful life	Replace sensor interface board.
Calibration drift	Excessive/rapid changes in relative humidity or temperature	Re-calibrate using the moisture exchanger or by colocation.
	Line voltage fluctuations	Check to see if line voltage is within specifications.
	Defective fan	Replace OPC or OPC Blank (contains sample fan) if necessary.

Problem	Possible Cause	Action
		Replace exhaust fan if necessary.
	Clogged sample inlet or sensor enclosure screens	Clean/replace screens.
Excessive noise	Defective or low sensitivity gas sensors	Replace sensor interface board.
Alarm – Internal Temperature	Exhaust fan failure	Replace exhaust fan if not operating properly.
	Clogged exhaust screen or cooling air inlet screen	Clean or replace exhaust screen or cooling air inlet screen.
	Overheating PCB	Replace Cape board if needed.
Alarm – Sensor Temperature	Sample inlet heater failed	Replace welded inlet tube assembly if necessary.
	Defective PCB	Replace sensor interface board.
Alarm – Inlet Temperature	Cable connection	Check the cable connection from the heater to the Cape board.
	Broken wire	Verify the wires are properly attached to the sample inlet heater connector.
	Defective sample inlet heater	Replace welded inlet tube assembly if necessary.
	Defective Cape board	Replace defective Cape board as needed.
Alarm – Sensor Chamber Pressure	Defective PCB	Replace sensor interface board if necessary.

Decoding Alarms

The instrument alarms are coded into 8 hexadecimal digits that represent the status of various instrument parameters. These include whether or not the instrument is in Service Mode, and if any temperatures, pressure, humidity, or critical circuit voltages are outside of their specified range. Also, included here are any failures with the Optical Particle Counter (OPC). To decode the alarms, each hexadecimal digit is converted to binary as shown in Figure 6–1. It is the binary digits that define the status of each parameter. In the following example, the instrument is reporting that it is in Service Mode, and that there is a relative humidity alarm and a sample inlet temperature alarm.

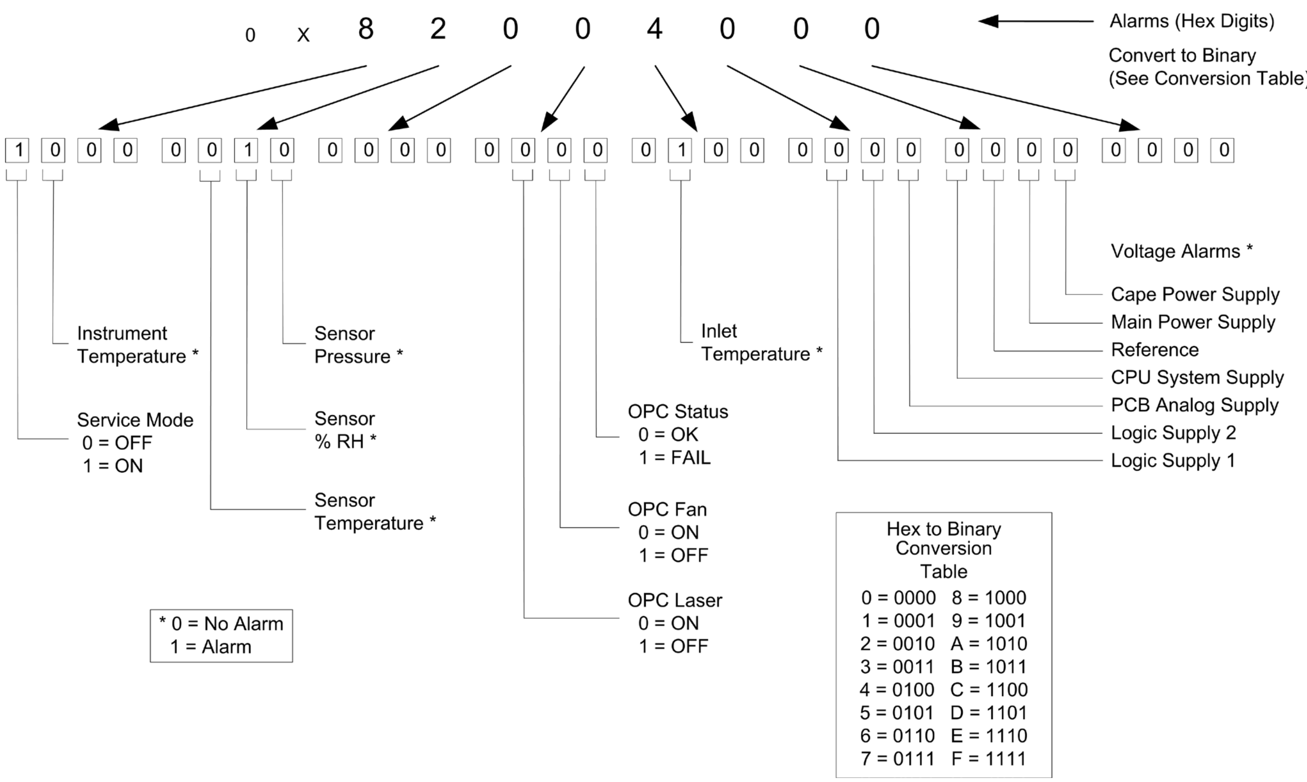


Figure 6–1. Decoding Alarms

Chapter 7
Servicing

This chapter describes the servicing procedures that should be performed on the instrument to ensure proper operation and explains how to replace the GM-5000 subassemblies.

Safety Precautions

Read the safety precautions before beginning any procedures in this chapter.

WARNING Service procedures require that the GM-5000 be disconnected from the AC power source, which should only be done by qualified personnel observing proper lock-out tag-out procedures. Disconnecting wires from the terminal block inside the GM-5000 is not an acceptable method of disconnecting the AC power source and may cause serious injury to personnel and damage to equipment. ▲

WARNING The service procedures in this manual are restricted to qualified service representatives. ▲

WARNING If the equipment is operated in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. ▲

Equipment Damage Some internal components can be damaged by small amounts of static electricity. A properly grounded antistatic wrist strap must be worn while handling any internal component. ▲

Note If an antistatic wrist strap is not available, be sure to touch the instrument chassis before touching any internal components. When the instrument is unplugged, the chassis is not at earth ground. ▲

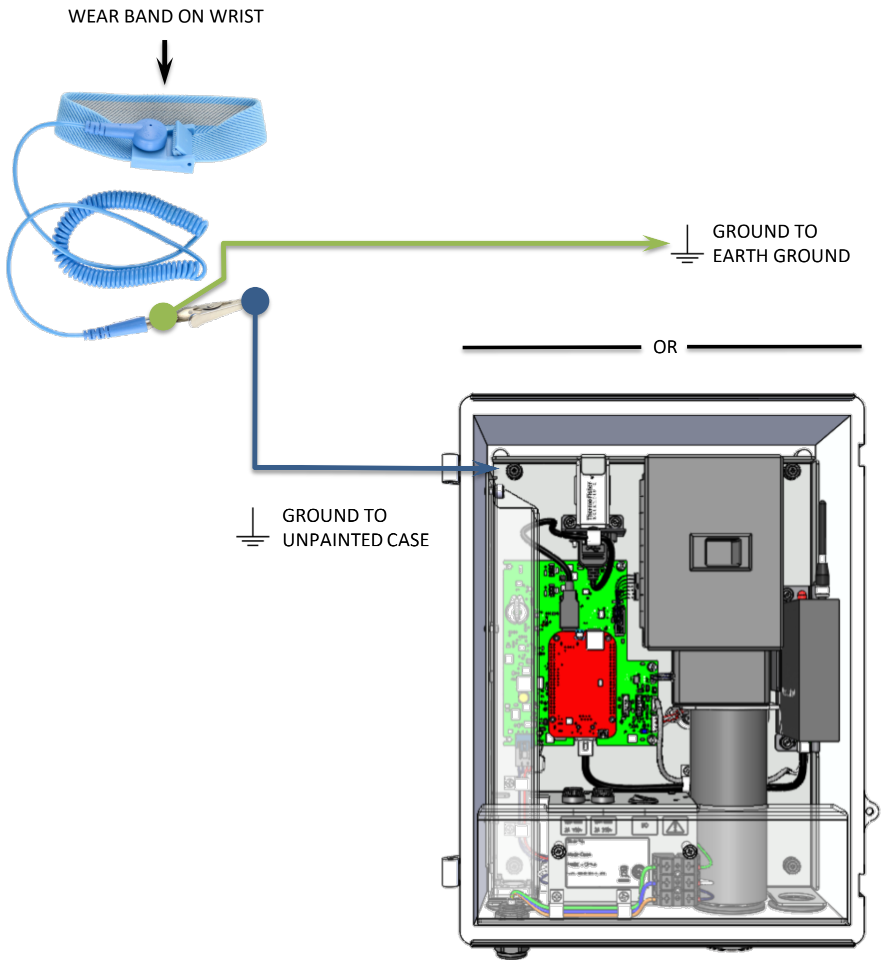


Figure 7–1. Properly Grounded Antistatic Wrist Strap

Note Ground to unpainted case or to earth ground. ▲

Firmware Updates

New versions of the instrument software are periodically made available on company website at:

www.thermofisher.com/GM5000

Replacement Parts List

For a complete list of spare parts, visit the company website at:

www.thermofisher.com/GM5000

Refer to Figure 7–2 to identify the component location.

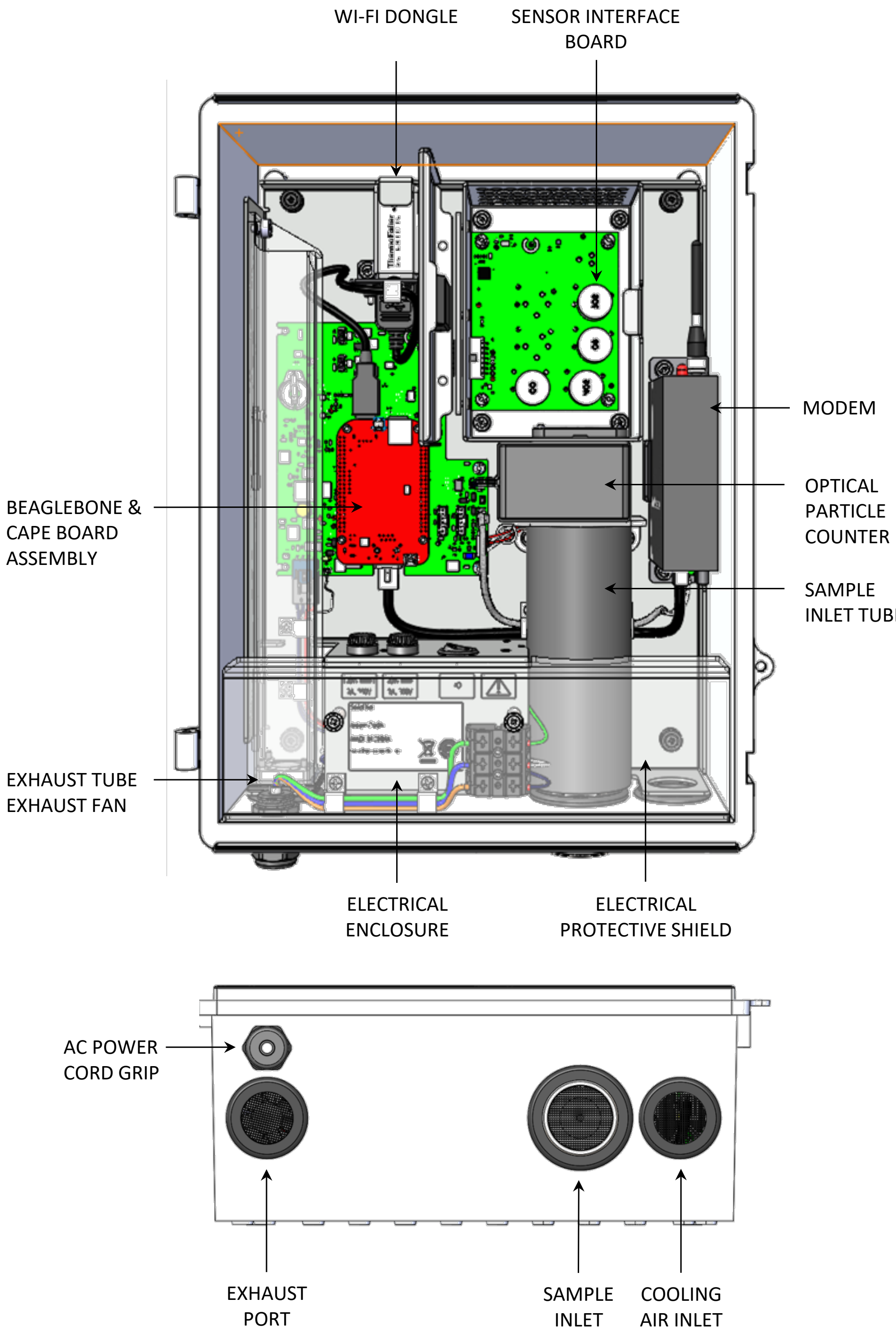


Figure 7–2. GM-5000 Component Layout Front View and Bottom View

Removing the Electrical Protective Shield

Some service procedures and connecting the AC power cord require removing the electrical protective shield to gain access to components. Use the following procedure to remove the electrical protective shield.

Equipment required:

Phillips drive, #2

1. Using the #2 Phillips screwdriver, unfasten the M4 Phillips head screws 2X and set them aside.

2. Slide the electrical protective shield out of the GM-5000 enclosure to remove.

3. To re-install the protective shield, slide it into the bottom of the GM-5000 enclosure and line up the holes with the two standoffs on the chassis.

4. Install the two M4 screws that were previously removed using the Phillips screwdriver, and tighten until snug.

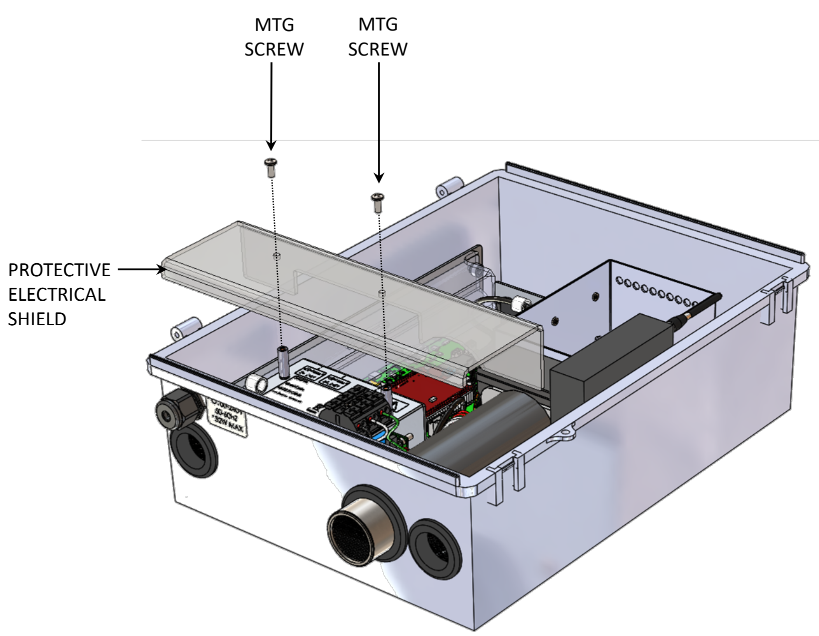


Figure 7–3. Removing the Electrical Protective Shield

Removing the Chassis

Most service procedures can be done inside the GM-5000 enclosure, but certain procedures require removing the chassis from the enclosure to gain access to components. Use the following procedure to remove the chassis.

Equipment required:

Wrench

Phillips drive, #2

1. Turn off the power switch and disconnect the AC power source.

2. Remove the electrical protective shield from the enclosure per "Removing the Electrical Protective Shield" procedure (Figure 7–3) from earlier in this chapter.

3. Depress the terminal block tabs to remove the AC power cord wires from the terminal block.

4. Slide the power cord out of the two cable holders on the bottom of the chassis. Using the adjustable wrench, loosen the nut on the wire gland to remove the AC power cord from the enclosure.

5. Unfasten the captive thumb screw on the exhaust tube, slide it up approximately 1 inch, then pull it off of the shoulder screws (see Figure 7–2).

6. Using the #2 Phillips screwdriver, unfasten the captive hardware 4X.

7. Lift the chassis towards the top of the enclosure while simultaneously pulling the top of the chassis out of the enclosure at an angle (Figure 7–4).

8. As the top of the chassis clears the enclosure, slide the sample inlet tube out of the grommet to completely remove the chassis from the enclosure.

9. Follow these steps in reverse order to install the chassis into the main enclosure. Note that some pressure may be required to push the chassis against the grommets prior to engaging the captive hardware.

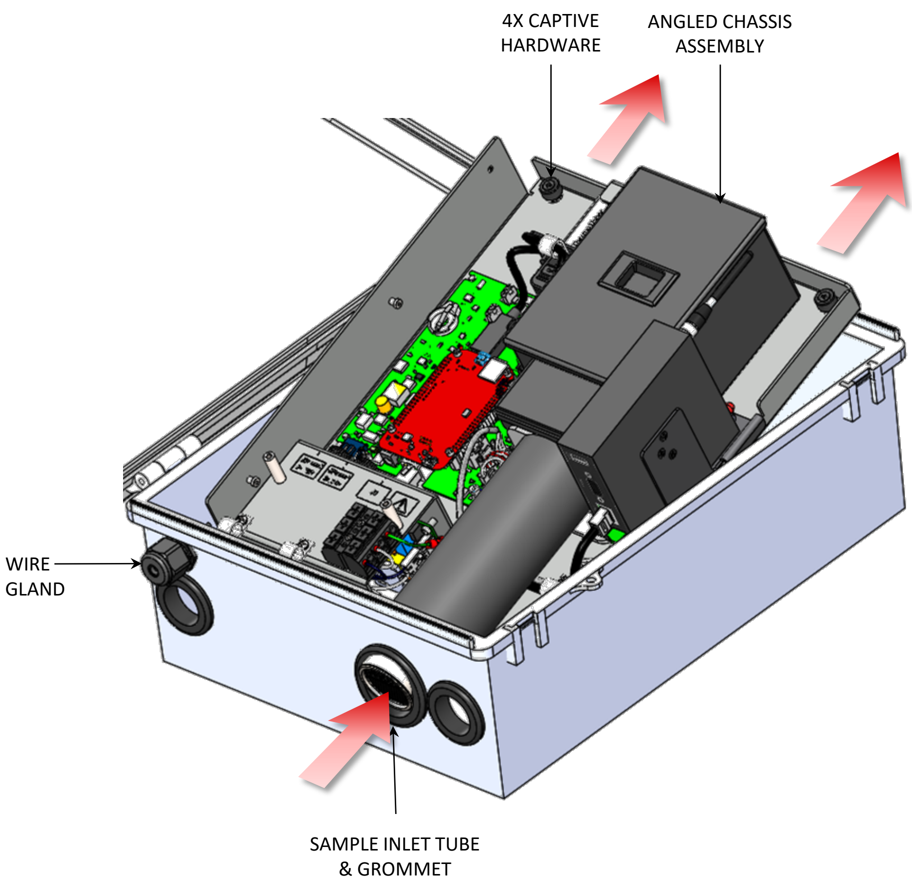


Figure 7–4. Removing the Chassis

Replacing the Cooling Air Inlet and Exhaust Screens

Use the following procedure to replace the cooling air inlet and exhaust screens.

Equipment required:

Dental pick

1. Remove the chassis from the enclosure per "Removing the Chassis" procedure (Figure 7–4) from earlier in this chapter.

2. Using the dental pick, remove the coarse (20 mesh) wire screen from the gasket below the exhaust fan and remove the fine (100 mesh) wire screen from the cooling air inlet gasket to the right of the sample tube (Figure 7–5).

3. Re-install the new screens in the appropriate positions as mentioned above, by "press-fitting" into the gaskets. Inner gasket edges can be lifted slightly if necessary to better hold the wire screens in place.

4. Re-install the chassis back into the enclosure per "Removing the Chassis" procedure (Figure 7–4) from earlier in this chapter.

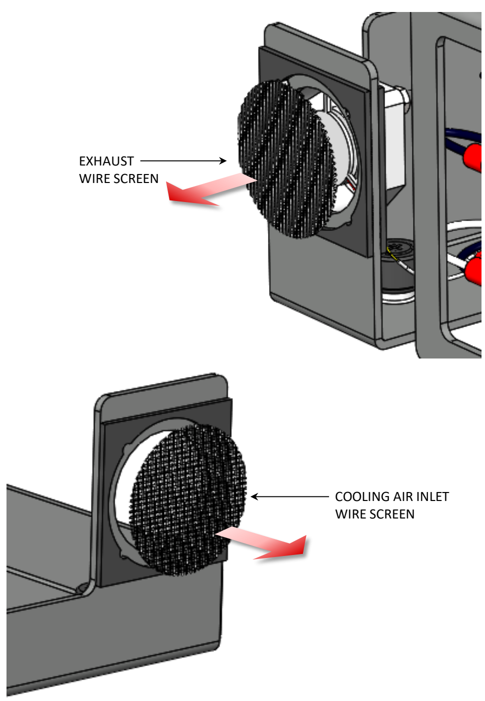


Figure 7–5. Replacing the Cooling Air Inlet and Exhaust Screens

Replacing the Fuses

Use the following procedure to replace the fuses.

Equipment required:

None

1. Turn off the power switch and disconnect the AC power source.

2. Fuse holders are located on top of the electrical enclosure. To open, depress the holder while rotating it counterclockwise (Figure 7–6).

3. Remove the blown fuse and insert the new fuse between the tabs in the holder.

4. Re-install fuse into the fuse holder body by depressing and rotating the holder clockwise until it locks into place.

Note If either fuse is blown, replace both fuses. ▲

5. Reconnect the AC power source and turn the instrument power switch back on.

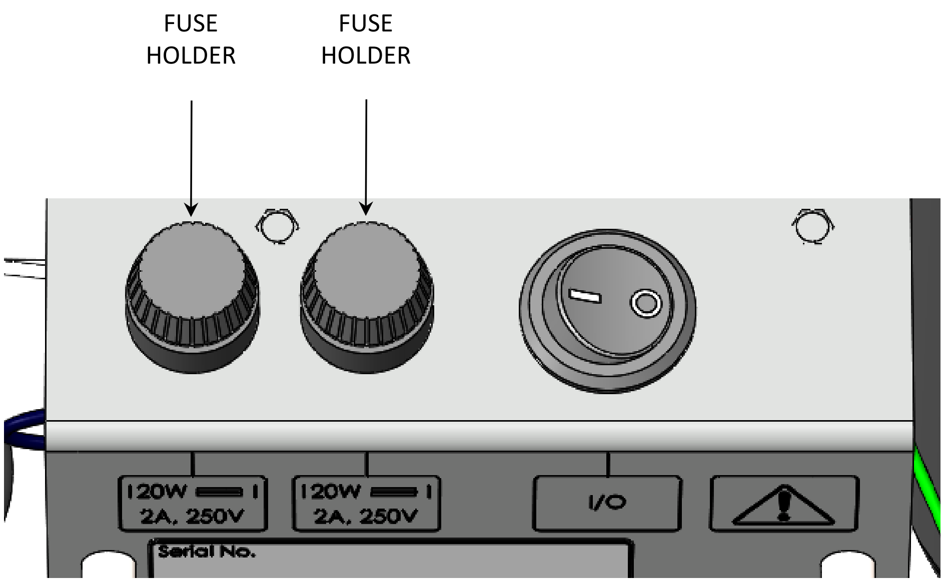


Figure 7–6. Replacing the Fuses

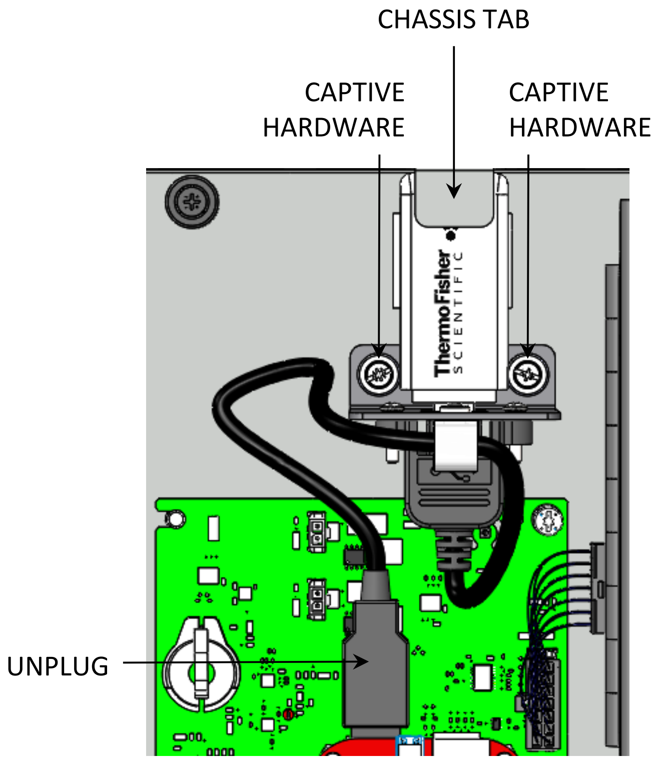
Replacing the WiFi Dongle

Use the following procedure to replace the WiFi dongle.

Equipment required:

Phillips head screwdriver, #1

1. Turn off the power switch and disconnect the AC power source.
2. Unplug the USB cable from the BeagleBone Cape Board (Figure 7–7).
3. Using the #1 Phillips head screwdriver, unfasten the captive hardware 2X that secures the WiFi bracket to the chassis.
4. Unplug the WiFi dongle from the USB socket and discard.
5. Plug the new WiFi dongle into the USB socket with the Thermo Fisher Scientific logo facing up.
6. Re-install the WiFi bracket onto the chassis using the Phillips screwdriver. Note that the end of the WiFi dongle sits under the tab on the chassis.
7. Plug the USB cable into the Beaglebone Cape Board with the WiFi symbol facing down.
8. Reconnect the AC power source and turn the instrument power switch back on.



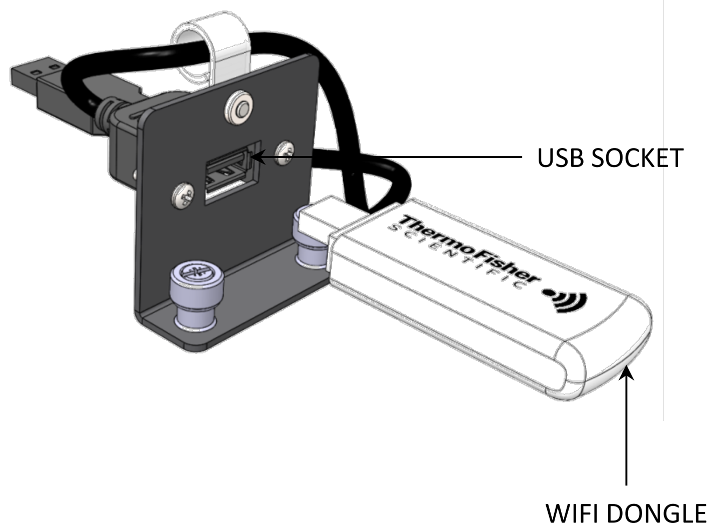


Figure 7–7. Replacing the WiFi Dongle

Replacing the Exhaust Fan

Use the following procedure to replace the exhaust fan.

Equipment required:

Nut driver, M3

1. Turn off the power switch and disconnect the AC power source.

2. Remove the electrical protective shield from the enclosure per "Removing the Electrical Protective Shield" procedure (Figure 7–3) from earlier in this chapter.

3. Unfasten the captive thumb screw on the exhaust tube, slide it up approximately 1 inch, then pull it off of the shoulder screws (Figure 7–8).

4. Gently unplug the white fan connector from the Beaglebone Cape Board and slide the wires out of the bottom of the cable holders.

5. Using the M3 nut driver, loosen and remove the three M3 nuts that fasten the fan to the chassis.

6. Remove the fan from three mounting studs.

7. Install the new fan onto the three mounting studs, making sure that the air flow arrow is pointing down (exiting the enclosure).

8. Thread the three M3 nuts back on the mounting studs until finger tight. Then using the M3 nut driver, tighten the nuts an equal number of turns until the gasket is compressed slightly. Do not over tighten.

9. Follow steps 1–3 in reverse order to complete fan replacement procedure.

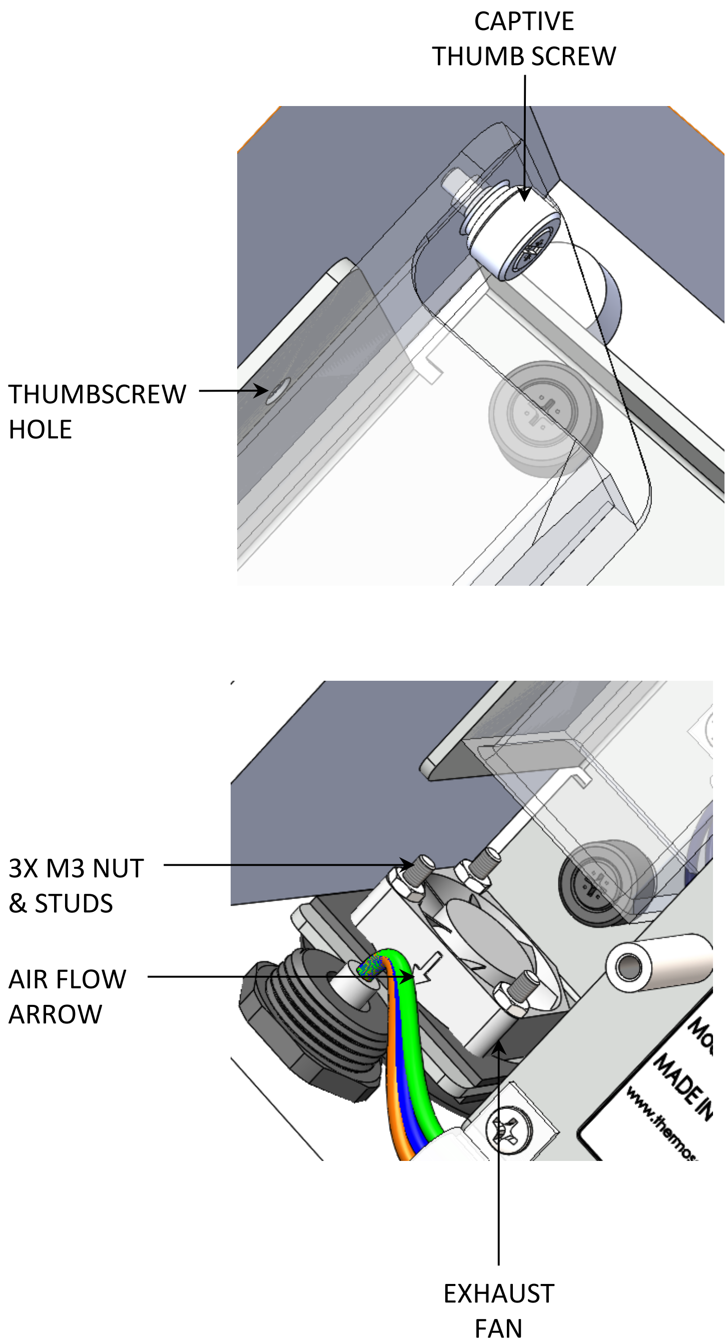


Figure 7–8. Replacing the Exhaust Fan

Replacing the Router/Modem

Use the following procedure to replace the router/modem.

Equipment required:

Phillips head screwdriver, #1

1. Turn off the power switch and disconnect the AC power source.

2. Disconnect the Ethernet cable from the modem, then remove the green connector for the power cable from the modem (Figure 7–9).

3. Using the #1 Phillips head screwdriver, unfasten the captive hardware on the modem bracket and remove it from the chassis.

4. Using the Phillips screwdriver, remove the three screws that secure the modem to the bracket.

5. Remove the unused green connector from the new modem and discard. Using the Phillips screwdriver and the screws from the previous step, mount the modem to the bracket.

6. If necessary, unscrew the antenna from the old modem and install it on the main jack of the new modem.

7. Follow steps 1–3 in reverse order to complete router/modem replacement procedure.

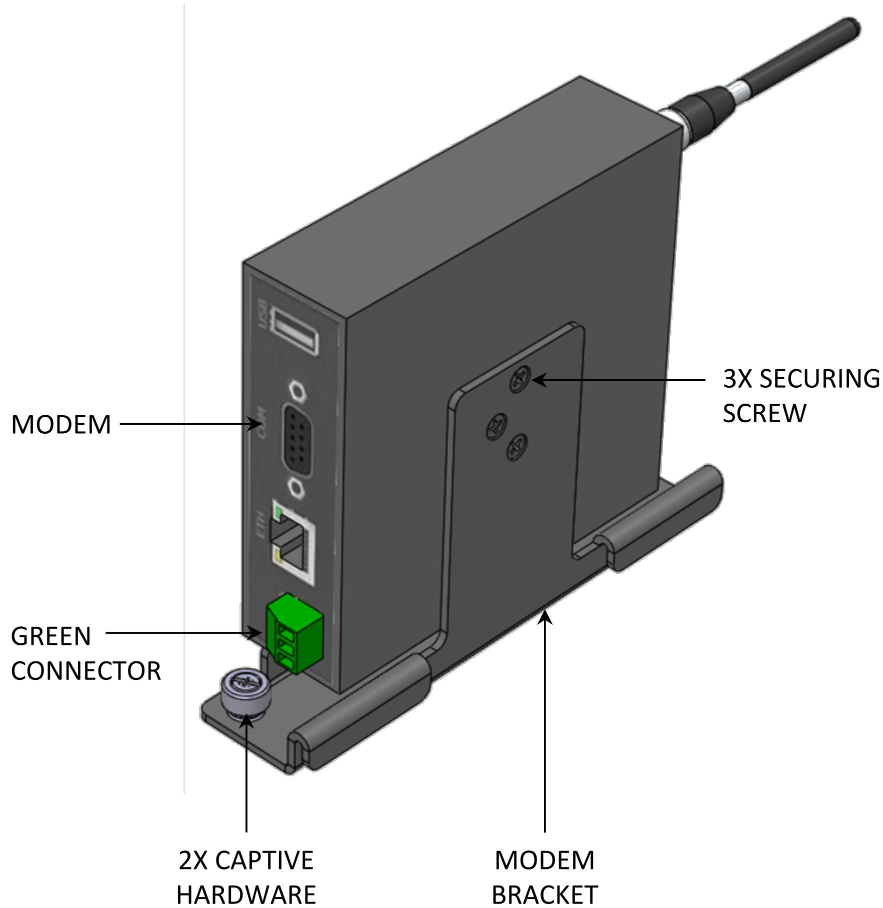


Figure 7–9. Replacing the Router/Modem

Replacing the Sensor Interface Board

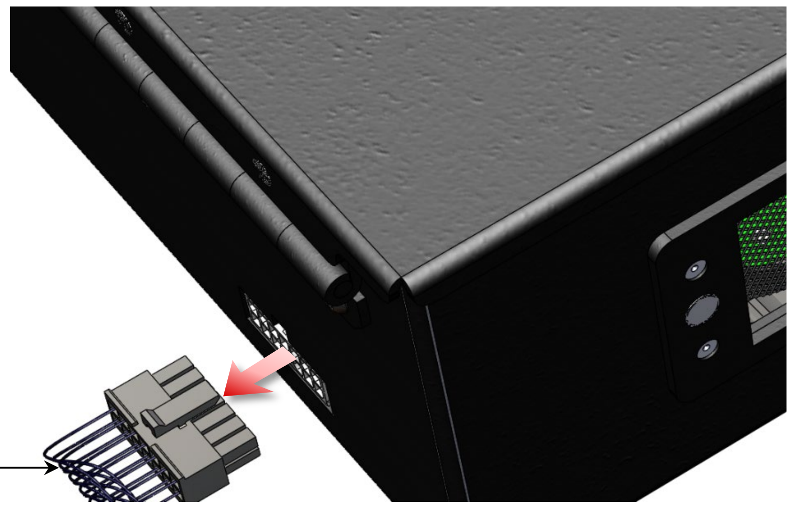
Use the following procedure to replace the Sensor Interface Board.

Equipment required:

Phillips head screwdriver, #1

1. Turn off the power switch and disconnect the AC power source.

2. Disconnect the 14-pin sensor interface cable from the connector on the side of the sensor enclosure.



14 PIN CABLE

Figure 7–10. Disconnecting the Sensor Interface Cable

3. Open the cover of the sensor enclosure by sliding the latch to the left while lifting up the cover (Figure 7–11).

4. Using the #1 Phillips head screwdriver, unfasten the hardware 4X that secures the Sensor Interface Board to the sensor enclosure and remove the board.

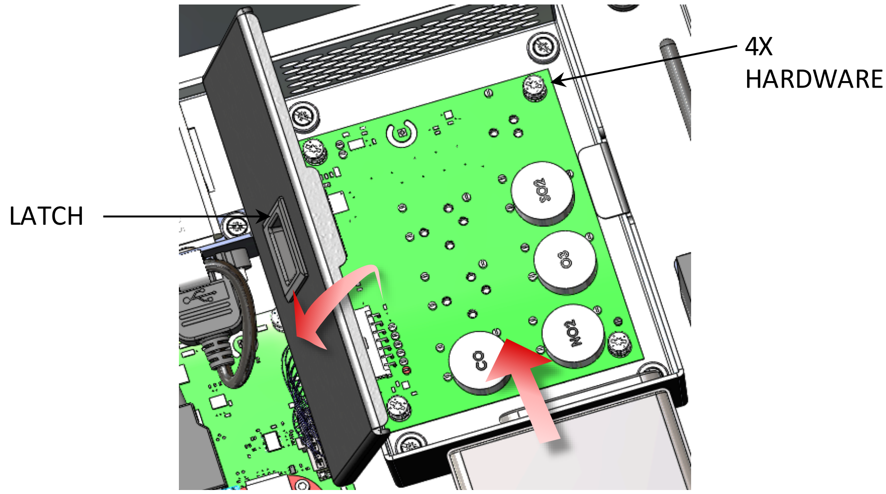


Figure 7–11. Replacing the Sensor Interface Board

5. Follow the previous steps in reverse order to install the new Sensor Interface Board. Do not overtighten the hardware.

Removing the Sample Inlet Tube Assembly

This procedure covers removing and re-installing the sample inlet tube assembly, which needs to be done to replace the welded inlet tube assembly, OPC (optical particle counter) and OPC replacement assembly.

Equipment required:

Phillips head screwdriver, #1

1. Turn off the power switch and disconnect the AC power source.

2. Remove the electrical protective shield from the enclosure per "Removing the Electrical Protective Shield" procedure (Figure 7–3) from earlier in this chapter.

3. Disconnect the 14-pin sensor interface board cable from the connector on the side of the sensor enclosure (if installed).

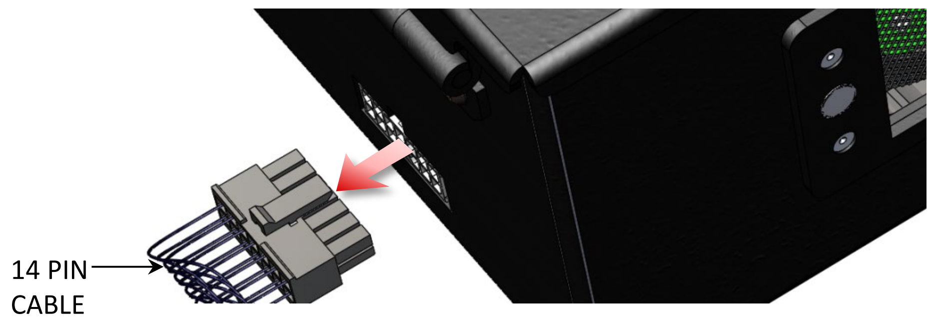


Figure 7–12. Disconnecting the Sensor Interface Cable

4. Disconnect the 4-pin heater connector from J11 on the BeagleBone Cape Board. Carefully disconnect either the OPC cable from J5 or the OPC replacement cable from J6, whichever is installed (Figure 7–13).

5. Using the #1 Phillips head screwdriver, unfasten the captive hardware 2X that secures the sample inlet tube assembly to the chassis. Some compression of the foam insulation may be required to access the captive hardware.

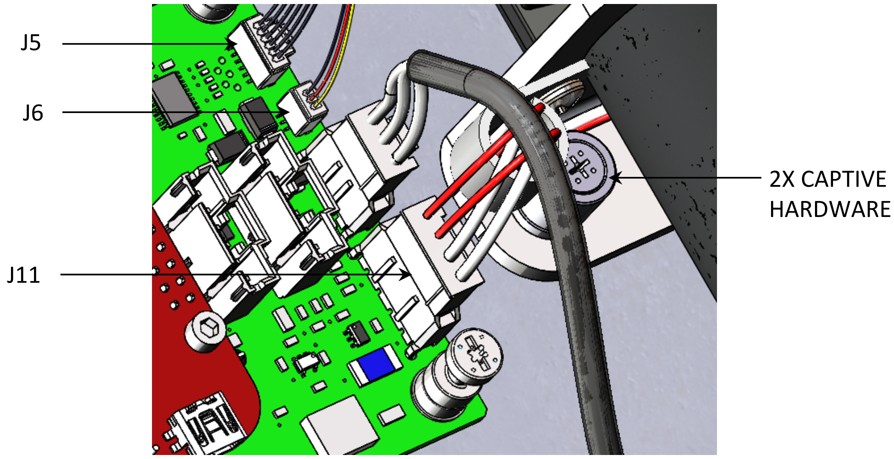


Figure 7–13. Removing Connections from BeagleBone Cape board

6. Open the cover of the sensor enclosure by sliding the latch to the left while lifting up the cover (if installed).

7. Using the Phillips head screwdriver, unfasten the captive hardware 4X that secures the sensor enclosure to the chassis and remove it, starting with the end opposite of the inlet tube (if installed).

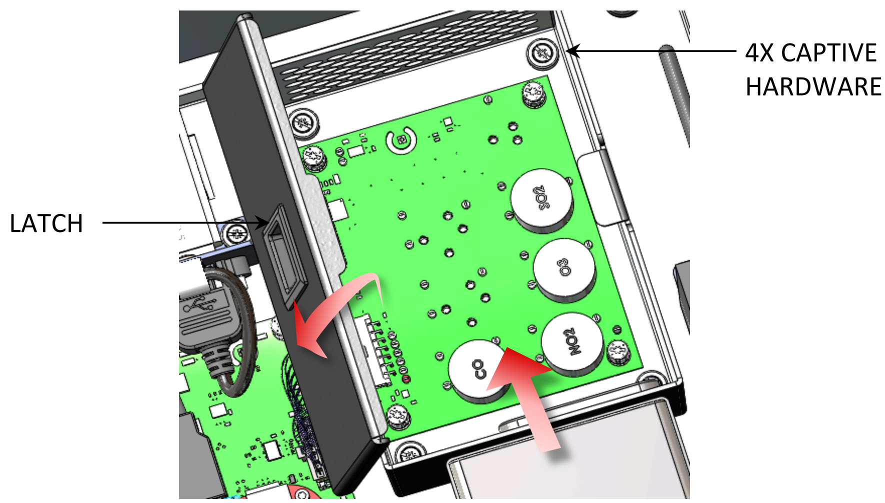


Figure 7–14. Removing the Sensor Enclosure

8. Slide the sample inlet tube assembly up out of the grommet and remove it from the chassis.

9. Slide the sample inlet tube assembly back into the enclosure grommet, and then partially tighten the captive hardware 2X. Reconnect the heater to J11. Re-connect either the OPC cable to J5 or the OPC

replacement cable to J6 on the BeagleBone Cape Board (whichever is installed).

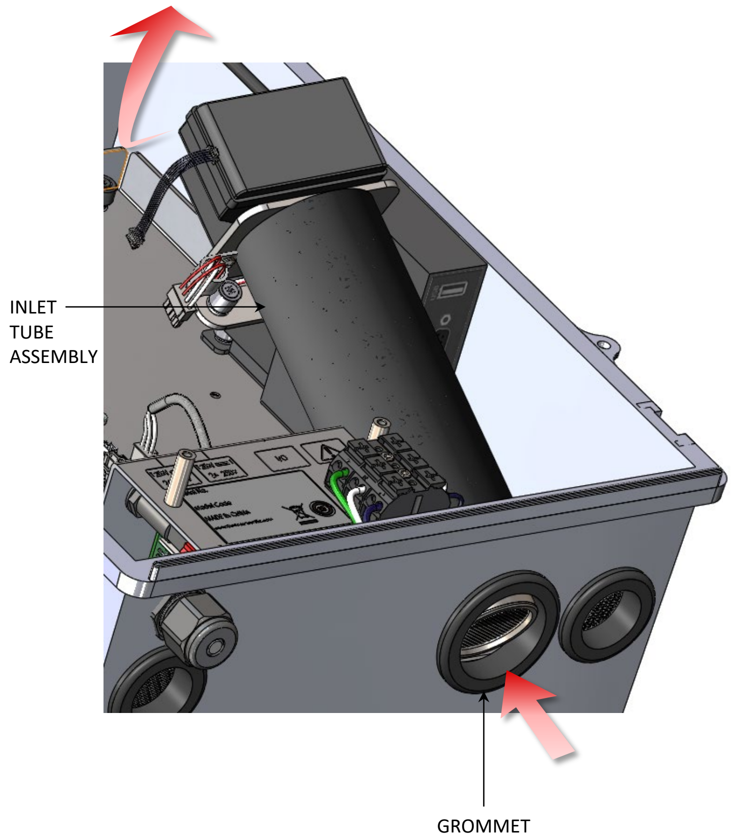


Figure 7–15. Replacing the Sample Inlet Tube Assembly

10. Re-install the sensor enclosure (if so equipped), starting with placing the side opening over the fan of the OPC or OPC replacement, and then pushing the other end until it is flush with the chassis. Tighten the captive hardware 4X to secure the enclosure in place, then close the sensor enclosure cover.

11. Finish tightening the captive hardware 2X to secure the sample inlet tube to the chassis.

12. Re-connect the 14-pin sensor interface board cable to the connector on the side of the sensor enclosure (if installed).

13. Re-connect the AC power source and turn the instrument power switch back on.

Replacing the Welded Inlet Tube Assembly

Use the following procedure to replace the welded inlet tube assembly.

Equipment required:

Phillips head screwdriver, #1

1. Remove the sample inlet tube assembly from the chassis per "Removing the Sample Inlet Tube Assembly" procedure from earlier in this chapter.

2. Carefully slide the foam insulation away from the flange and off of the inlet tube to expose the OPC or OPC replacement mounting screws, then remove these 4 screws with the Phillips head screwdriver to separate the components (Figure 7–16).

3. Attach the OPC or OPC replacement (whichever is present) to the new welded inlet tube using the 4 M3 screws and tighten until snug. Note that the OPC or OPC replacement must be oriented so that the wires exit the same side as the inlet tube heater wires.

4. Slide the foam insulation onto the inlet tube and back into place so that it is flush against the flange.

5. Slide the sample inlet tube assembly back into the enclosure grommet, and then partially tighten the captive hardware 2X. Reconnect the heater to J11 and reconnect either the OPC cable to J5 or the OPC replacement cable to J6 on the BeagleBone Cape Board.

6. Re-install the sample inlet tube assembly per "Removing the Sample Inlet Tube Assembly" procedure from earlier in this chapter.

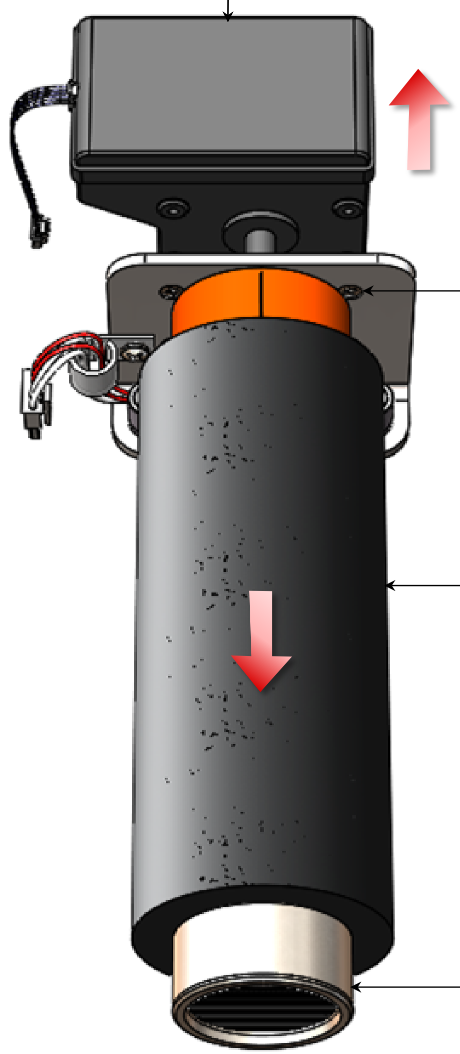


Figure 7–16. Replacing the Welded Inlet Tube Assembly or OPC

Replacing the OPC or OPC Replacement Assembly

Use the following procedure to replace the OPC or OPC replacement assembly.

Equipment required:

Phillips head screwdriver, #1

1. Remove the sample inlet tube assembly from the chassis per "Removing the Sample Inlet Tube Assembly" procedure from earlier in this chapter.

2. Carefully slide the foam insulation away from the flange on the inlet tube to expose the OPC or OPC replacement mounting screws, then remove these 4 screws with the Phillips head screwdriver to separate the components (Figure 7–16).

3. Attach the new OPC or OPC replacement (whichever component was replaced) to the welded inlet tube using the 4 M3 screws and tighten until snug. Note that the OPC or OPC replacement must be oriented so that the wires exit the same side as the inlet tube heater wires.

4. Slide the foam insulation back into place so that it is flush against the flange.

5. Slide the sample inlet tube assembly back into the enclosure grommet, and then partially tighten the captive hardware 2X. Reconnect the heater to J11 and reconnect either the OPC cable to J5 or the OPC replacement cable to J6 on the BeagleBone Cape Board.

6. Re-install the sample inlet tube assembly per "Removing the Sample Inlet Tube Assembly" procedure from earlier in this chapter.

Replacing the Power Supply Board

Use the following procedure to replace the power supply board.

Equipment required:

M3 hex wrench, long handle

1. Remove the chassis from the enclosure per "Removing the Chassis" procedure (Figure 7–4) from earlier in this chapter.

2. Stand the chassis up on its side to access the electrical enclosure.

3. Disconnect the 4 pin BeagleBone Cape power input cable and disconnect the 2 pin power supply cable from the power supply board (Figure 7–17).

4. Using the M3 hex wrench, remove the 4 M3 screws that mount the power supply board to the chassis.

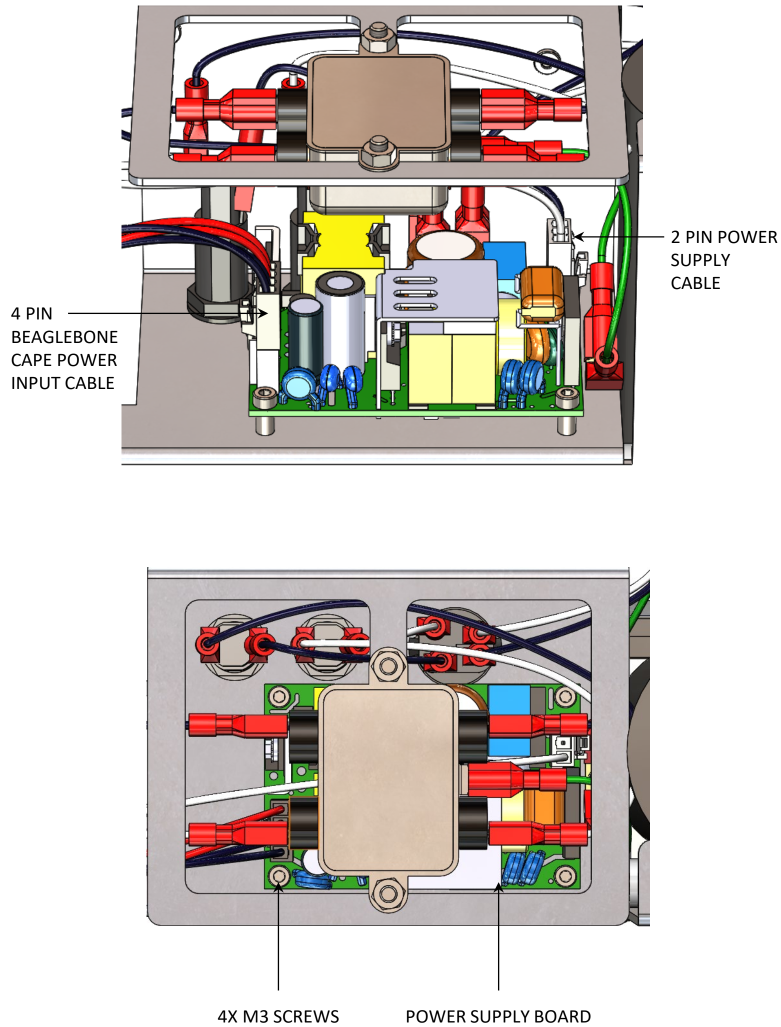


Figure 7–17. Replacing the Power Supply Board

5. Re-connect those same 2 cables in the appropriate positions on the new power supply board.

6. Install the new power supply board onto its standoffs with the 4 M3 screws using the hex wrench. Tighten until snug.

7. Re-install the chassis back into the enclosure per "Removing the Chassis" procedure (Figure 7–4) from earlier in this chapter.

Replacing the BeagleBone Cape Board

Use the following procedure to replace the BeagleBone Cape Board.

Equipment required:

Flat blade screwdriver, 1/8-inch

Note This procedure should only be performed by a qualified Thermo Fisher Scientific service technician. ▲

1. Turn off the power switch and disconnect the AC power source.

2. Unfasten the captive thumb screw on the exhaust tube, slide it up approximately 1 inch, then pull it off the shoulder screws.

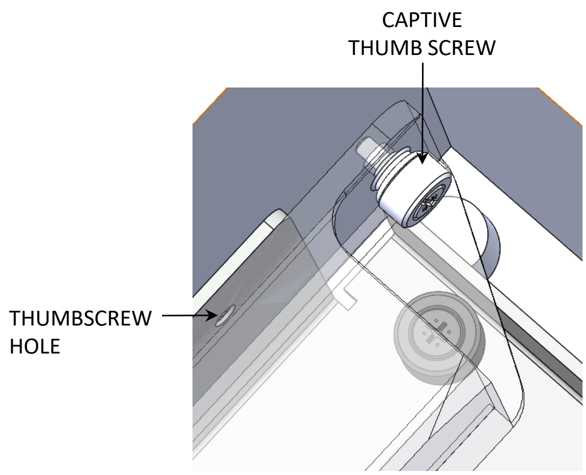


Figure 7–18. Removing the Exhaust Tube

3. Carefully disconnect all of the cable assemblies from the BeagleBone Cape Board. There will be 7 or 8 connectors in total, depending on which options are installed in the analyzer.

4. Using the flat blade screwdriver, unfasten the captive hardware 3X that secure the BeagleBone Cape Board to the chassis. Slide the board off of the 2 mounting posts and remove it.

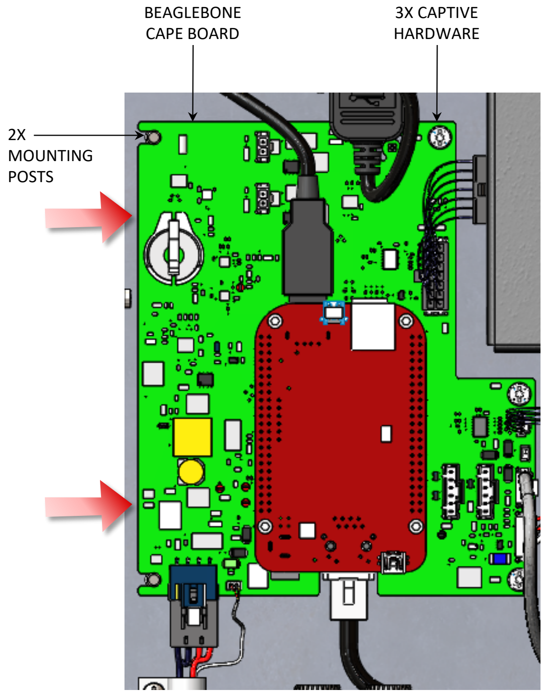


Figure 7–19. Replacing the BeagleBone Cape Board

5. Install the new BeagleBone Cape Board in the same fashion, by first guiding the 2 board slots into the mounting posts, and then re-fastening the captive hardware using the flat blade screwdriver. Do not overtighten.

6. Re-connect all the cable assemblies to their appropriate connectors on the board as follows:

   - J3 to Sensor Interface Board (if installed)
   - J5 to Optical Particle Counter (if installed)
   - J6 to OPC Replacement Assembly (if installed)
   - J9 to Router/Modem
   - J11 to Sample Inlet Tube Heater
   - J12 to Power Supply Board
   - J13 to Exhaust Fan
   - BeagleBone USB Port to WiFi Bracket Assembly
   - BeagleBone Ethernet Port to Router/Modem

7. Follow steps 1 and 2 in reverse order to complete the BeagleBone Cape Board replacement.

Replacing the PID Lamp and Electrode Stack

The PID module contains two consumable parts that will eventually need to be replaced, the electrode stack and the PID lamp. If the responsiveness or sensitivity of the sensor is greatly reduced and it does not improve noticeably after the lamp has been cleaned, then the electrode stack and/or the PID lamp may need to be replaced. Other indications may be an unusually high response to a humid sample. Use the following procedure to replace the electrode stack and the PID lamp.

Equipment required:

Lamp Removal Tool

Latex gloves

Tweezers (as needed)

WARNING PID module servicing procedures must be performed on a clean surface using clean tools. Avoid touching the lamp's window as well as the metalized portion of the cell assembly with your bare fingers. Fingerprints left on these parts may adversely affect the sensors operation. Latex gloves are recommended. Hold the lamp by its glass body or by the edges of the window. ▲

WARNING Only use the lamp removal tool to access the PID lamp and electrode stack. Other tools such as a screwdriver may damage the PID module body and will invalidate your warranty. ▲

1. Turn off the power switch.

2. Open the cover to the sensor enclosure by sliding the latch to the left while lifting up the cover.

3. Remove the PID module from location “SEN7” on the sensor board by gently and evenly pulling it away from the board.

4. Working on a clean surface, insert the tabs of the lamp removal tool in the side slots of the PID module and squeeze together until the electrode stack and lamp are released from the PID body. It is helpful to keep a finger pressed lightly on the electrode stack during this process to keep from losing it.

Figure 7–20. Lamp Removal Tool

Figure 7–21. Removing the Electrode Stack and Lamp

5. The lamp should come out with the electrode stack, but occasionally it may be lodged in the sensor body and will need to be removed carefully using the tweezers. If the small spring behind the lamp comes out when the lamp is removed, just place it back inside the sensor body.

6. To re-assemble the PID module with a new lamp and/or electrode stack, place the electrode stack face down on a flat surface and then twist and push the lamp down into the sealing area until it buts up against the front electrode face.

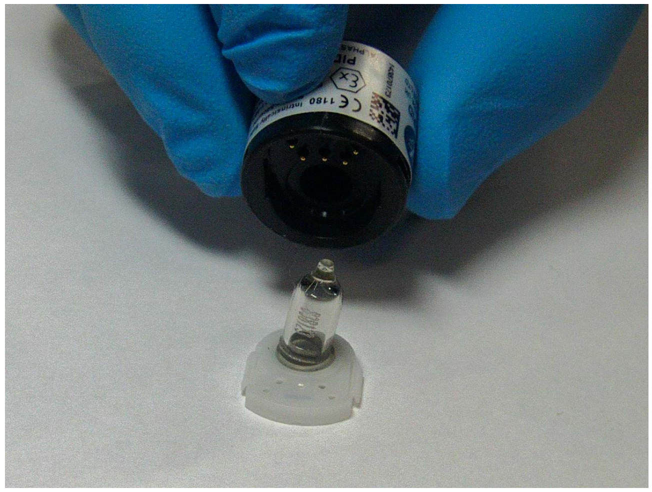


Figure 7–22. Reassembling the PID Module with a new Lamp and/or Electrode Stack

7. Carefully place the PID body down over the lamp and electrode stack so as not to disturb the seated lamp, make sure the orientation is correct and then push the body firmly onto the electrode stack so that both wings engage the PID body. As this happens, you should hear two faint clicks.

8. To re-install the PID module in the sensor board, handle it by the edges, line up the 3 pins with the sockets in board position "SEN7", and press firmly until the PID module sits flat on the sensor board. Close the sensor enclosure lid.

Turn the power switch back on and let the GM-5000 warm up for 30 minutes. Calibrate the VOC channel as described in Chapter 4, "Calibration" of this manual.

Appendix A
Safety, Warranty, and WEEE

Safety

Review the following information carefully before using the instrument. This manual provides specific information on how to operate the instrument, however if the instrument is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

Safety and Equipment Damage Alerts

This manual contains important information to alert you to potential safety hazards and risks of equipment damage. Refer to the following types of alerts you may see in this manual.

Safety and Equipment Damage Alert Descriptions

Alert	Description
DANGER	A hazard is present that will result in death or serious personal injury if the warning is ignored. ▲
WARNING	A hazard is present or an unsafe practice can result in serious personal injury if the warning is ignored. ▲
CAUTION	The hazard or unsafe practice could result in minor to moderate personal injury if the warning is ignored. ▲
Equipment Damage	The hazard or unsafe practice could result in property damage if the warning is ignored. ▲

Safety and Equipment Damage Alerts in this Manual

Alert	Description
WARNING	The GM-5000 should be operated only from the type of power sources described in this manual. ▲
	To avoid damage to the instrument, be sure the power switch is in the off position before connecting or disconnecting the AC power supply. ▲
	Personal injury could occur when mounting the instrument. Assistance may be required. ▲

Alert	Description
	• If the equipment is operated in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. ▲
	• The service procedures in this manual are restricted to qualified service personnel only. ▲
Equipment Damage	Do not attempt to lift the analyzer by the cover or other external fittings. ▲
	This adjustment should only be performed by an instrument service technician. ▲

Warranty

Seller warrants that the Products will operate or perform substantially in conformance with Seller's published specifications and be free from defects in material and workmanship, when subjected to normal, proper and intended usage by properly trained personnel, for the period of time set forth in the product documentation, published specifications or package inserts. If a period of time is not specified in Seller's product documentation, published specifications or package inserts, the warranty period shall be one (1) year from the date of shipment to Buyer for equipment and ninety (90) days for all other products (the "Warranty Period"). Seller agrees during the Warranty Period, to repair or replace, at Seller's option, defective Products so as to cause the same to operate in substantial conformance with said published specifications; provided that (a) Buyer shall promptly notify Seller in writing upon the discovery of any defect, which notice shall include the product model and serial number (if applicable) and details of the warranty claim; (b) after Seller's review, Seller will provide Buyer with service data and/or a Return Material Authorization ("RMA"), which may include biohazard decontamination procedures and other product-specific handling instructions; and (c) then, if applicable, Buyer may return the defective Products to Seller with all costs prepaid by Buyer. Replacement parts may be new or refurbished, at the election of Seller. All replaced parts shall become the property of Seller. Shipment to Buyer of repaired or replacement Products shall be made in accordance with the Delivery provisions of the Seller's Terms and Conditions of Sale. Consumables, including but not limited to lamps, fuses, batteries, bulbs and other such expendable items, are expressly excluded from the warranty under this warranty.

Notwithstanding the foregoing, Products supplied by Seller that are obtained by Seller from an original manufacturer or third party supplier are not warranted by Seller, but Seller agrees to assign to Buyer any warranty rights in such Product that Seller may have from the original manufacturer or third party supplier, to the extent such assignment is allowed by such original manufacturer or third party supplier.

In no event shall Seller have any obligation to make repairs, replacements or corrections required, in whole or in part, as the result of (i) normal wear and tear, (ii) accident, disaster or event of force majeure, (iii) misuse, fault or negligence of or by Buyer, (iv) use of the Products in a manner for which they were not designed, (v) causes external to the Products such as, but not limited to, power failure or electrical power surges, (vi) improper storage and handling of the Products or (vii) use of the Products in combination with equipment or software not supplied by Seller. If Seller determines that Products for which Buyer has requested warranty services are not covered by the warranty hereunder, Buyer shall pay or reimburse Seller for all costs of investigating and responding to such request at Seller's then prevailing time and materials rates. If Seller provides repair services or replacement parts that are not covered by the warranty provided in this warranty, Buyer shall pay Seller therefor at Seller's then prevailing time and materials rates. ANY INSTALLATION, MAINTENANCE, REPAIR, SERVICE, RELOCATION OR ALTERATION TO OR OF, OR OTHER TAMPERING WITH, THE PRODUCTS PERFORMED BY ANY PERSON OR ENTITY OTHER THAN SELLER WITHOUT SELLER'S PRIOR WRITTEN APPROVAL, OR ANY USE OF REPLACEMENT PARTS NOT SUPPLIED BY SELLER, SHALL IMMEDIATELY VOID AND CANCEL ALL WARRANTIES WITH RESPECT TO THE AFFECTED PRODUCTS.

THE OBLIGATIONS CREATED BY THIS WARRANTY STATEMENT TO REPAIR OR REPLACE A DEFECTIVE PRODUCT SHALL BE THE SOLE REMEDY OF BUYER IN THE EVENT OF A DEFECTIVE PRODUCT. EXCEPT AS EXPRESSLY PROVIDED IN THIS WARRANTY STATEMENT, SELLER DISCLAIMS ALL OTHER WARRANTIES, WHETHER EXPRESS OR IMPLIED, ORAL OR WRITTEN, WITH RESPECT TO THE PRODUCTS, INCLUDING WITHOUT LIMITATION ALL IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE. SELLER DOES NOT WARRANT THAT THE PRODUCTS ARE ERROR-FREE OR WILL ACCOMPLISH ANY PARTICULAR RESULT.

WEEE Compliance

This product is required to comply with the European Union's Waste Electrical & Electronic Equipment (WEEE) Directive 2002/96/EC. It is marked with the following symbol:

Thermo Fisher Scientific has contracted with one or more recycling/disposal companies in each EU Member State, and this product should be disposed of or recycled through them. Further information on Thermo Fisher Scientific's compliance with these Directives, the recyclers in your country, and information on Thermo Fisher Scientific products which may assist the detection of substances subject to the RoHS Directive are available at: www.thermoscientific.com/WEEERoHS.

WEEE Symbol

The following symbol and description identify the WEEE marking used on the instrument and in the associated documentation.

Symbol	Description
	Marking of electrical and electronic equipment which applies to electrical and electronic equipment falling under the Directive 2002/96/EC (WEEE) and the equipment that has been put on the market after 13 August 2005. ▲

Appendix B
Quick Reference

List of Figures

List of Tables

Appendix C
Connectivity

Setting Up the Router/Modem

As mentioned in Chapter 3, "Operation" of this manual, data can be exported using the streaming function in real time to a remote server at an IP address specified by the user. Data records are generally transmitted to a cloud server using a 3g/4g cellular service using a wireless router/modem.

Thermo Fisher Scientific offers an optional Robustel R3000 router/modem with the GM-5000, but other manufacturer's router/modems may be used as well. If using an alternate router, some of the instructions given here may not apply. In that case, please consult the router manufacturer if additional assistance is needed. In all cases, a cellular data account with an Internet Service Provider (ISP) and a Subscriber Identity Module (SIM) card to install in the router/modem will be required. Setting up the account and purchasing the SIM card is the distributor or user's responsibility, as each country and region has different cellular ISPs and cellular systems.

Once the SIM card is installed, power up the GM-5000. After a few minutes, the LED marked PPP on the side of the router should turn on and you should get at least one LED on the "signal strength" indicator.

If you have trouble connecting, the most common problem is the Access Point Name (APN) setting of the modem/router. Many routers have an auto-detect function, but depending on region, they may not always work and you will need to get a specific APN setting from your ISP. Using the interface for the specific modem/router being used, turn automatic APN selection off and then type in the correct APN. Refer to your modem manual for details.

If you have purchased the Robustel R3000 from Thermo Fisher Scientific, we recommend the following setup procedure. A laptop PC and ethernet cable will be required.

1. Turn off the GM-5000 and disconnect the internal ethernet cable from the modem.

2. Shut off the PC or laptop's Wifi connection and disconnect the Ethernet port from the building network. The computer should not be able to connect to the internet at this point.

3. Connect the GM-5000 modem to the computer's Ethernet port with a standard Ethernet cable.

4. Once the laptop is connected to the modem's Ethernet port, turn the GM-5000 back on to provide power to the modem.

5. Reboot the computer to make sure that it recognizes the modem.

6. Open a browser on the laptop and go to IP address 192.168.0.1 to open the modem/router interface. The user name and password are both "admin" as a default.

7. Once the interface is open, click on Interface and then Link Manager. Go down to WWAN1 and click on it, then refer to the WWAN Settings section that contains the APN settings.

8. Turn the Automatic APN Selection off, type the correct APN in the text box just below the "automatic" selection, and then click the "Submit" button.

9. Finally, at the top of the interface page, click "Save & Apply", then click "Reboot" to re-start the modem. You may need to wait for as long as 5 minutes after reboot for the router to connect to the ISP.

Please note that your ISP may give you more than one possible APN, so you might have to try them all until you find the one that connects. As stated previously, when you have a good connection, the LED marked PPP on the side of the router should turn on and you should get at least one LED on the "signal strength" indicator. If you have a good connection, you should also be able to "ping" google.com or any other internet address from the Windows "command prompt" and get a reply, or you can open a new tab on the browser and connect to a web site to verify that the router works.

If you cannot make a connection, the signal strength LEDs on the modem will blink after several minutes. That means either the APN is incorrect or the signal is too weak. If you think the APN is correct, there could be a problem with the modem antenna.

Once you know that the modem/router can connect to the ISP using the laptop, you can switch the modem's Ethernet connection back to the GM-5000 and cycle the power and everything should connect automatically. At this point you should see the modem's PPP LED turn on.

Setting Up Streaming Data

Please refer to the Stream Data section under the Data sub-menu in Chapter 3, "Operation" of this manual before proceeding.

There are two screens in the GM-5000 graphical user interface (GUI) that are used to set up the streaming data function. First, under the Service Menu, select "Settings" and then select "Comm Settings". On the right side of the screen under the "3G/4G Data Server Setting", enter the IP address and port number for the server you are sending data to. This should be a static IP address that your cloud provider gives you. You also need to set the TCP port. We use port 6666 as the default, but you can change it to something else. However, do not use anything between 0 and 1024, since those are all reserved. Your cloud server needs to be set to listen on the same port number that you enter here.

An instrument reboot will be required to implement the changes that have been made to this Comm Settings screen. To reboot the instrument, select "Firmware Update" under the Service Menu. Once on the Firmware Update screen, click on the "Reboot" button and wait for the reboot to complete.

After the reboot, go back to the Main Menu and select "Data" then "Stream Data". On the "Stream Data" screen, check the "Auto-Start on Boot-up" check box, the "Start" button and the "On" button. (Depending on the firmware version, you may not have the "On" button.) Then click the "Save" button to accept the changes.

Note that there are some situations in which the GM-5000 may have a connection to the remote server, but the operator will want the Streaming Status set to the "Off" position. This is typically done in order to allow the remote server to poll for data or to allow the server and GM-5000 to exchange data in a two-way "conversation" without the possibility of interruption from a new data record.

It takes a few minutes for streaming to start, but if everything is correct it should automatically connect to the server and start sending data. During this time, the "Connection Status" field on the "Stream Data" screen should show "Trying to Connect" and then "Connected".

If this is the first time you are using the streaming data function, we suggest you start by downloading a free program that simulates a server on your laptop. One such program that we have used successfully is called "Hercules" from HW-Group.com. To use Hercules, connect your laptop to the GM-5000 through Wifi then enter your laptop IP into the GM-5000 communications screen and start streaming as described above. The streaming data should show up in the Hercules Server window if everything is working correctly. If you do not know your computer's IP address, you can find it by opening the "Windows PowerShell" in the Windows menu and entering the "ipconfig" command. The computer's local IP address will be labeled as the "IPv4 address" and it will appear in a block labeled of text "Ethernet adapter Local Area Connection."

Communication with the Remote Server

Starting with firmware version 1.2, the GM-5000 Streaming connection is bi-directional, so you can send a small number of commands and data requests back from the server to the GM-5000. The primary purpose of this system is to allow the server to set or modify the coefficients that are used for colocation calibration. These text-based commands are grouped into three categories: set, get, and miscellaneous.

Commands starting with “set” are used to send information to the GM-5000, for example, to change calibration parameters or to set the date and time. Commands starting with “get” are used to receive information from the GM-5000, for example, to retrieve gas concentrations from the sensors or to get the firmware version installed in the instrument. Miscellaneous commands do not fall under the set or get category, such as the reboot command. The list of text-based commands along with a brief description of each are shown in the table below.

Table C–1. GM-5000 Streaming Commands

Set Commands:	**Description:**
set colo_var1 <Gas Type> <Float Val>; Example: set colo_var1 co 1.65;	Sets colocation calibration “Variable_1” for a specific gas to the value shown in <Float Val>. See Chapter 4 for a description of colocation calibration and definition of “Variable_1”.
set colo_var2 <Gas Type> <Float Val>; Example: set colo_var2 co 0.55;	Sets colocation calibration “Variable_2” for a specific gas to the value shown in <Float Val>. See Chapter 4 for a description of colocation calibration and definition of “Variable_2”.
set colo_var3 <Gas Type> <Float Val>; Example: set colo_var3 co 0.15;	Sets colocation calibration “Variable_3” for a specific gas to the value shown in <Float Val>. See Chapter 4 for a description of colocation calibration and definition of “Variable_3”.
set colo_intercept <Gas Type> <Float Val>; Example: set colo_intercept co 3.6;	Sets colocation calibration “intercept” for a specific gas to the value shown in <Float Val>. See Chapter 4 for a description of colocation calibration and definition of “intercept”.
set date yyyy/mm/dd;	Sets the system date.
set time HH:MM:SS;	Sets the system time.
set stream_status (on|off); Example: set stream_status off;	Turns data streaming on or off.
set stream_format (standard|verbose|colocation|custom); Example: set stream_format verbose;	Selects the format for data strings that will be streamed to the server. Four formats are available.

Set Commands:	Description:
`set instrument_name <name-of-instrument>;`	Sets the instrument name with a maximum of 32 characters.
Get Commands:	**Description:**
`get date;`	Returns system date as YYYY/MM/DD.
`get time;`	Returns system time as HH:MM:SS.
`get sensors;`	Returns a string with the concentration reading for each sensor, temperature, RH, pressure, time and date.
`get colo_var1 <Gas Type>;`	Returns the current value of colocation calibration "Variable_1" for a specific gas. See Chapter 4 for a description of colocation calibration and definition of "Variable_1".
`get colo_var2 <Gas Type>;`	Returns the current value of colocation calibration "Variable_2" for a specific gas. See Chapter 4 for a description of colocation calibration and definition of "Variable_2".
`get colo_var3 <Gas Type>;`	Returns the current value of colocation calibration "Variable_3" for a specific gas. See Chapter 4 for a description of colocation calibration and definition of "Variable_3".
`get colo_intercept <Gas Type>;`	Returns the current value of colocation calibration "intercept" for a specific gas. See Chapter 4 for a description of colocation calibration and definition of "intercept".
`get version;`	Returns the current firmware version number.
`get pm_readings;`	Returns the "factory" and fully calibrated concentration values for $PM_{2.5}$ and PM_{10} from the most recently saved record. Fully calibrated values include adjustments made using colocation.
`get report_interval;`	Returns the report interval period in minutes.
`get stream_status;`	Returns the current status of the data streaming function as either on or off.
`get stream_format;`	Returns the current format selection for streaming data records (standard, verbose, colocation, or custom).
`get stream_config;`	Returns the full configuration of the data streaming function including whether set to on or off, the report interval and the report format.
`get stream_data <n>;`	Returns the latest "n" data records from the instrument database. The format will be standard, verbose, colocation, or custom as specified in the streaming setup.

Set Commands:	Description:
	Example: "get stream_data 50; returns the 50 most recent records.
`get colocation_settings;`	Returns the current values of intercept, Var_1, Var_2, Var_3 for each measured pollutant. These are coefficients used in colocation calibration.
`get current_readings;`	Returns "real time" concentration readings updated every 10 seconds. Includes CO, O_3, NO_2, SO_2, NO, VOC, PM_{10} and $PM_{2.5}$.
`get instrument-name;`	Returns the instrument name.
Miscellaneous Commands:	**Description:**
`reboot;`	Issues reboot command to the system. Rebooting will cause a loss of connection.

<Gas Type> = NO|CO|O3|SO2|NO2|VOC

<Float Val> = Value in decimals

Terminating with Semicolon (;) is optional

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