CALIFORNIA AIR RESOURCES BOARD

STANDARD OPERATING PROCEDURES FOR SABIO INSTRUMENTS MODEL 4010 GAS DILUTION CALLIBRATOR

AQSB SOP 701

First Edition

MONITORING AND LABORATORY DIVISION

August 2020

CALIFORNIA AIR RESOURCES BOARD

Approval of Standard Operating Procedures

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Division:	Monitoring and Laboratory Division (MLD)
Prepared by:	Reginald R. Guanlao

Reviewed by:

Manisha Singh, Ph.D., Chief
Quality Management Branch

Date: 9/21/2020

Approved by:

Reggie Smith, Manager
Operations and Data Support

Date: 14 Sep 2020

Kathleen Gill, Chief
Air Quality Surveillance Branch

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REVISION HISTORY

Edition	Release Data	Changes
First	August 2020	New Document

LIST OF ACRONYMS

AMNS - Air Monitoring North Section
AMSS - Air Monitoring North Section
AQS - Air Quality System
AQSB - Air Quality Surveillance Branch
CARB - California Air Resources Board
CFR - Code of Federal Regulations
CL - CARBLogger
CO – Carbon Dioxide
DAS - Data Acquisition System
DMS - Data Management System
ESC – Escape Key
FEP – Fluorinated Ethylene Propylene
FRM - Federal Reference Method
GPT - Gas Phase Titration
ID – Inside Diameter
LPM - Liters per Minute
MFC - Mass Flow Controller
MFM - Mass Flow Meter
MLD - Monitoring and Laboratory Division
NLB - Northern Laboratory Branch
ODSS - Operations and Data Support Section
NIST - National Institute of Standards and Technology
NO - Nitric oxide
NO_X - Nitrogen oxides, used here as the sum of NO and NO_2
NO_2 - Nitrogen dioxide
O3 – Ozone
OD – Outside Diameter
PC – Personal Computer
ppb - parts per billion
ppm – parts per million
PS2 – IBM Personal System 2
PST – Pacific Standard Time
RS – Recommended Standard
sccm –Standard Cubic Centimeters per Minute
SLPM - Standard Liters per Minute, gas flow at standard temperature and pressure
SO2 – Sulfur Dioxide
SOP - Standard Operating Procedure
TAPI - Teledyne Advanced Pollution Instrumentation
U.S.EPA – United States Environmental Protection Agency
UV – Ultraviolet
VAC – Volts Alternating Current

1.0 GENERAL INFORMATION

1.1 Introduction:

This standard operating procedure (SOP) describes the California Air Resources Board's (CARB) procedures used to operate and maintain the Sabio Model 4010 Gas Calibration System (4010). The 4010 performs automated calibrations on gas analyzers used throughout CARB's ambient air monitoring network. CARB has implemented this SOP to supplement the 4010 operations manual. It describes modifications in hardware and operating procedures used in the field and will refer to the 4010 operations manual where applicable.

Prior to operating or working with the 4010 units, field staff should read and understand the operations manual.

1.2 Description of Operation:

The Sabio 4010 is a single unit module. It uses an embedded microprocessor technology that enhances the accuracy and control features of the calibration system. The 4010 can be used manually, automatically, semi-automatically, or remotely to control and conduct calibrations. The 4010 calibrator features mass flow controllers (MFCs), an internal ozone generator, and UV absorption photometer. Figure 01 shows a schematic of the 4010 components.

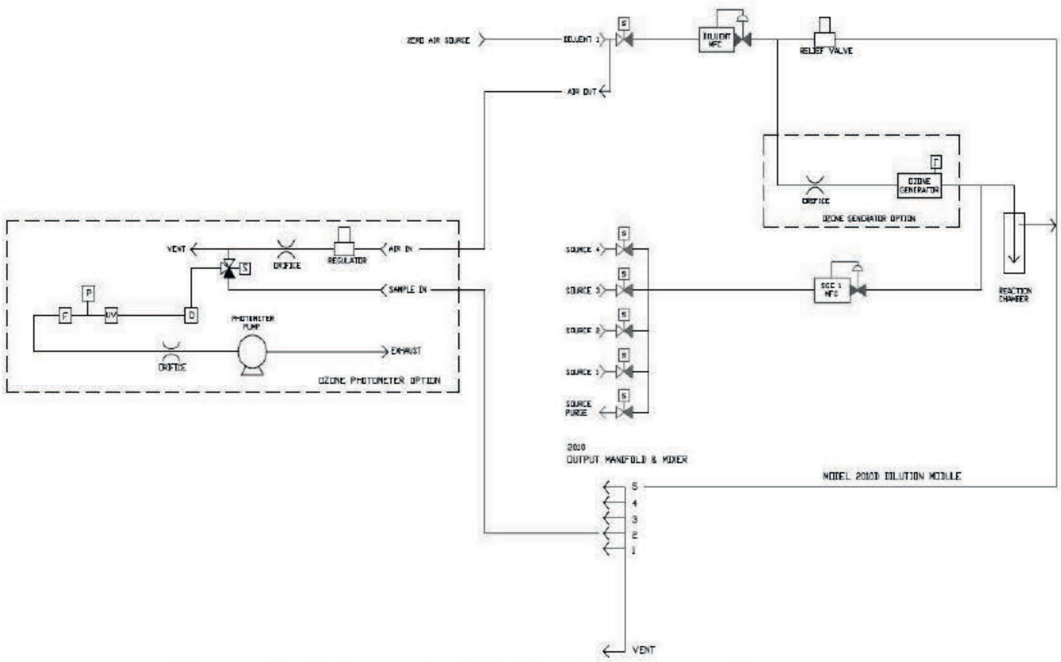


Figure 01: Schematic of Sabio 4010 System Components

MFC

CARB's Air Quality Surveillance Branch (AQSB) configures the 4010 with one air dilution mass flow controller (DILUENT) and one gas dilution mass flow controller (SOURCE). The diluent MFC has a range of 0 to 20 standard liters per minute (SLPM). The source MFC has a range of 0 to 100 standard cubic centimeters per minute (sccm). When combined with a zero air source and a certified gas cylinder, the 4010 can provide various gas concentrations. The MFCs reference standard conditions: 760 mm Hg (millimeters of mercury) and 25°C. The 4010 is a calibrator, which automatically performs standard temperature and pressure corrections to maintain accurate flows in any operating environment.

OZONE GENERATOR

The 4010 is also equipped with an ozone generator. An optical feedback system accurately controls the ultraviolet (UV) lamp system used in the ozone generator. It maintains, or ensures, constant lamp intensity in the ozone generator. In addition, a microprocessor controls and monitors pressure, temperature, and flow rate in the ozone generator, which results in stable, precise, and repeatable ozone concentrations on demand.

PHOTOMETER

The Sabio 4010 calibrators used by CARB are equipped with a photometer. The 4010 photometer is a compact, single-tube, single-detector photometric device. It measures ozone by monitoring ultraviolet light (254 nanometers) passed through a sample tube with a UV lamp at one end and a photo-detector at the other.

The wavelength of light attenuated by ozone determines the ozone concentration. A detector measures ozone free air or ambient air when passed through a sample tube.

Because the photometer is a single tube sampler, the sampling tube is alternately flooded with ozone free air and ambient air during the process. An internal pump draws sample air into the photometer, where solenoid valves direct it either through or around a catalytic ozone scrubber before entering the sample tube. The ratio of the detector output for ozone-free air to ambient air determines the ozone concentration. Figure 02 shows the typical components of a photometer.

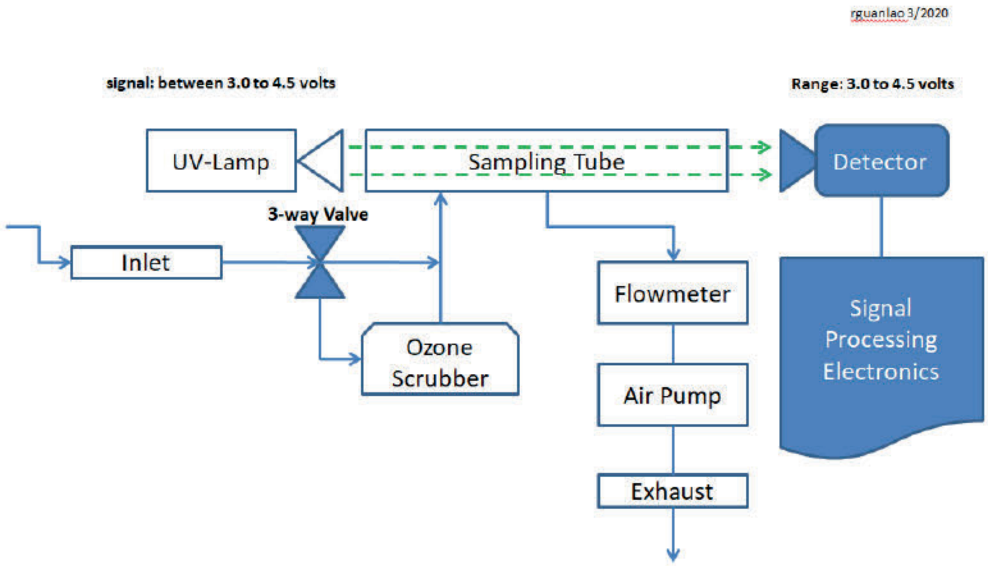


Figure 02: Photometer Components

CARB operates the 4010 with the internal photometer in "servo-on" mode. In this mode, the internal photometer controls the ozone concentration production of the ozone generator.

The Sabio 4010 has a predefined sequence called "Photo Adjust". It is a default sequence set to run automatically located in the sequence menu. The 4010 maintains the photometer's set point voltage using this sequence. Never disable this sequence because it prevents signal drift in the photo-detector.

As the photometer lamp ages, it is possible for the detector signal to drift outside of the nominal measurement window, resulting in erroneous ozone measurements. If this occurs, it might be necessary to adjust the lamp either by changing the photometer lamp set point or by using the automatic lamp adjustment procedure.

1.3 Safety Precautions:

Operating the 4010 at an incorrect line voltage will damage the instrument. Check the line voltage before plugging the instrument into any power source.

Before connecting or disconnecting any cables, wiring harnesses, or other sources of potential electrical impulse, make sure the unit is powered-off. Always use static discharge equipment when handling circuit boards.

The ultraviolet (UV) lamp utilizes high voltage. Use normal voltage precautions when working on this calibration system. **Wear UV safety glasses if working with the UV lamp**.

Calibration gas mixtures can contain high concentrations of poisonous gases and are under high pressures. Use the proper precautions when working with compressed gases.

1.4 Interferences/Limitations:

Moisture or particles from the zero air supply can potentially affect the ozone generator accuracy. To ensure accurate and repeatable ozone concentrations operators must verify the dew point for the zero air source is less than minus 16°C. Do not pressurize the diluent or source input ports more than 50 PSI.

1.5 Personnel Qualifications:

Only properly trained personnel should perform installation, operation, maintenance, repair, or calibration of the 4010 and all support equipment. Personnel should meet the training requirements and qualifications commensurate with their position or title. Qualifications for CARB field staff functions are typically, established through the successful completion of a probationary period with supervisorial oversight. Successive levels of responsibility are achieved via internal and external training classes, experience, and demonstrated display of abilities until a “journey level” is attained.

2.0 INSTALLATION PROCEDURE

2.1 General Information:

Upon receipt of a new 4010 calibrator for field use, ensure it has been acceptance tested by personnel from CARB's Operations Data and Support Section (ODSS).

To ensure sensitive components function correctly, operate the 4010 in a dust free environment when possible. It should be mounted in an instrument rack and have adequate air circulation as well. The air intake vents of the 4010 must be free-and-clear of any obstructions that can inhibit airflow. In addition, verify the 4010 exhaust fan is operating correctly and its airflow out is not obstructed.

When installing a 4010 into an instrument rack, bolt the rack firmly to the floor and properly ground the rack. The 4010 needs a properly rated power source, or supply, for normal operation. The manufacturer requires the operation voltage for the 4010 to be between 96 – 264 VAC (volts alternating current) with a frequency of 50/60 Hz (Hertz). The 4010 uses approximately 150 – 300 VA (volt-amperes).

To ensure protected and safe operations, the electrical source of the 4010 requires an earth ground. Furthermore, do not install the 4010 near any devices that produce large magnetic or electrical fields.

Before being used for station operations, the 4010 has to be given ample time to warm-up. After being powered-on, the 4010 will take approximately 30 minutes to reach normal operating temperature. Afterwards, the 4010 must operate in the station at a fixed room temperature between 20°C and 30° C and must never exceed 40°C.

2.2 Physical Inspection:

Upon receipt of a 4010 unit, check and make sure there are no missing parts and make sure all parts are in good condition. Next, remove the instrument cover and check inside the 4010 to see if there are any loose PC boards, tubing, filters, and/or electrical connections. If all is well, re-install the cover, connect the 4010 to an appropriate power outlet, and allow it to warm-up. Figure 03 shows the front panel of the 4010.

Figure 03: Front Panel of the Sabio 4010

2.3 Sabio 4010 Software Menu Description:

The 4010 has a touch panel interface and display that allows a user to operate the unit. The touch buttons are always active when the unit is powered-on. For convenience, a PS2 style keyboard is also available as input device in lieu of front-panel touch buttons. The keyboard connector port is located at the 4010 rear panel. Using a keyboard is the fastest and most efficient means to input commands into the 4010. For more information about menus and keyboard usage, see section 3 of the Sabio 4010 operations manual.

The menu system of the 4010 operates like most Windows applications. Figure 04 shows a screenshot of 4010 menu bar. After the 4010 finishes its boot-up, the application main menu displays in the view screen.

The main screen consists of four parts: 1) the menu bar at the top, 2) a status line near the bottom, 3) a function key line at the bottom, and a large central area for displaying windows and other screens. The menu bar at the top supports drop-down menus and sub-menus. Figure 04 shows the menu bar for the Sabio 4010 and Figure 05 shows the menu tree. When using a keyboard, menu items are selected using arrow keys and the [ENTER] key. If the 4010 front panel is used, the arrow buttons are used to navigate the menu bar and the enter button for selection. One of the most important buttons on the front panel of the 4010 is the "end-sequence" button, [END SEQ]. Use it to "exit-out" or "back-out" of a menu. For the keyboard, the end-sequence equivalent is the keyboard's escape key [ESC]. Near the bottom of the screen is the "Status Line bar". It displays information about the current state of the 4010.

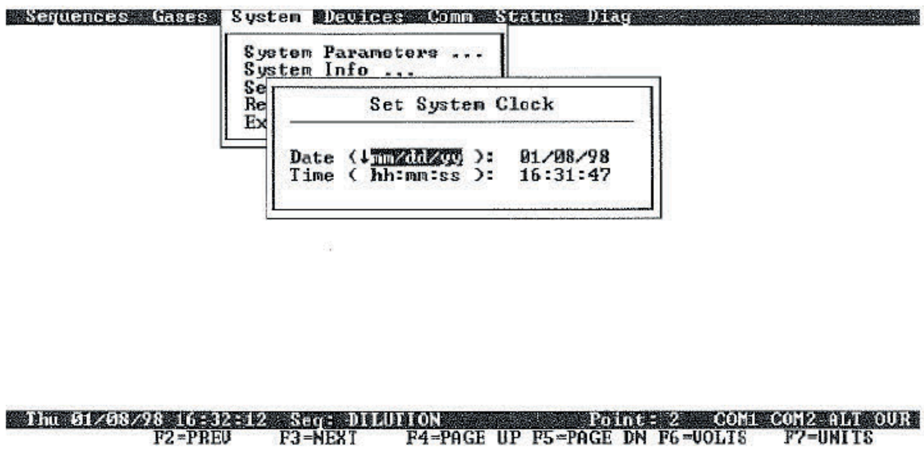


Figure 04: Menu Bar of the Sabio 4010.

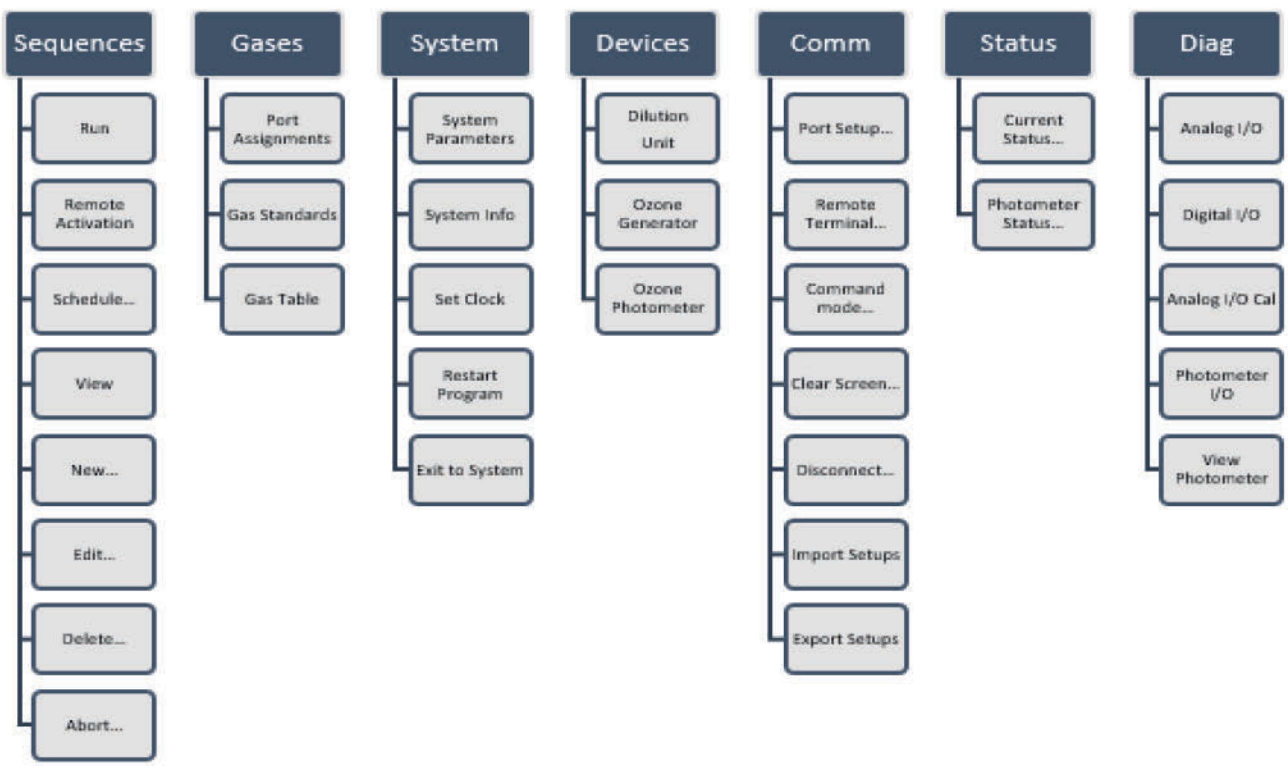


Figure 05: Menu Tree for the Sabio 4010.

The most important screens used to configure the 4010 are the "edit screens". The "edit screens" contains one or more fields for entering or changing values. Figure 06 shows an example of an edit screens used in the 4010 to configure a sequence.

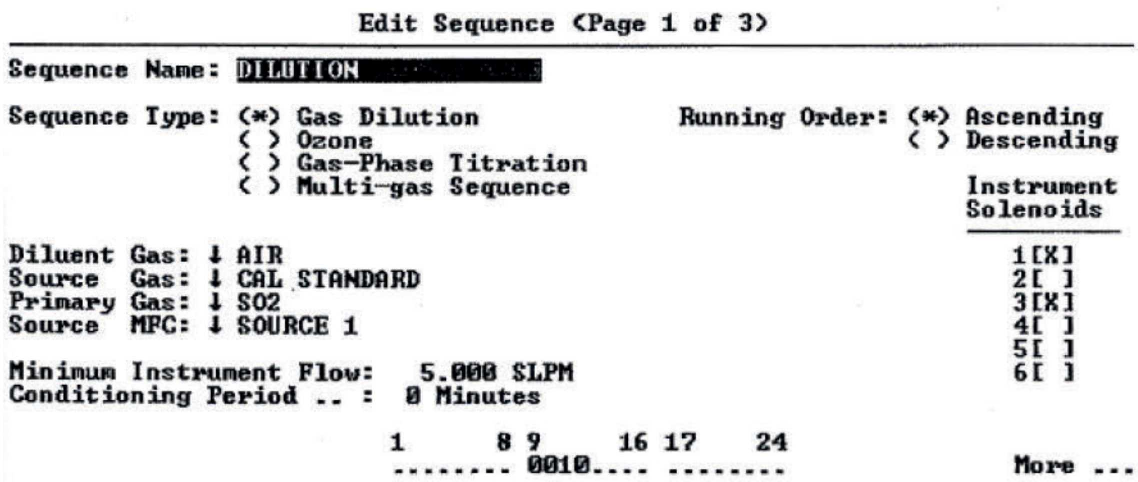


Figure 06: Sequence Edit Screen for the Sabio 4010

2.4 4010 RS-232 to Data Logger Connection:

CARB utilizes a PC-based data acquisition system (data logger) known as CARBLogger. The 4010 connects to CARBLogger via an RS-232 port and serial cable. Use the 4010 to configure and enable its RS-232 communication port. Configure the RS-232 port by using the 4010 touch panel. From the menu bar, select "Comm" then "Port Set-up Comm1". An input screen will display, use it to set the following communication parameters:

- All modes disabled except COMMAND Mode
- Baud Rate: 38400
- Parity: None
- Stop Bits: 1
- Handshaking set to: None

Once communication parameters have been set, connect an RS-232 serial cable from the 4010's COM-1 or COM-2 port to the CARBLogger's corresponding RS-232 interface. The COM interfaces are located at the back of the Sabio 4010 as shown in Figure 07.

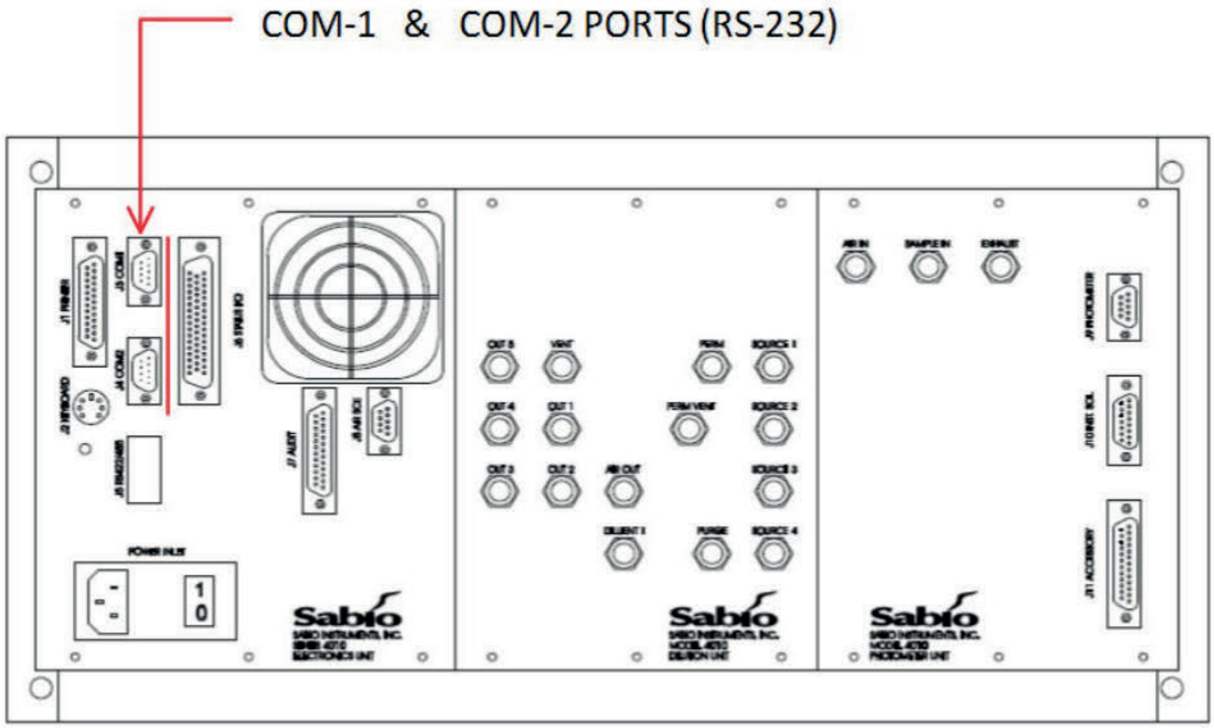


Figure 07: Back Panel of the Sabio 4010

For assistance with any specific CARBLogger configuration issues, refer to AQSB SOP 605 for CARBLogger or contact staff at CARB's ODSS.

3.0 SABIO 4010 CONFIGURATION

CARB uses the Sabio 4010 to conduct automated calibrations, or autocals, for ambient gas instruments operating in its air monitor network. Automated calibration routines are preprogrammed sequences. The 4010 generates a specified gas concentration by controlling its source gas and zero-air flow rates. The 4010 performs a typical autocal sequence using an airflow rate of 10.0 SLPM. Ozone automated calibrations are conducted using a set-point concentration of either 0.07 ppm (70 ppb) for precision checks and 0.320 ppm (320 ppb) for span checks. To perform automated calibrations, the 4010 uses its station manifold to deliver calibration gases to connected instruments.

3.1 Set Date and Time:

All instruments operating within the CARB air-monitoring network operate on Pacific Standard Time (PST) during the entire year. Therefore, when setting the time and date on the 4010 the system clock must be set to PST. Reference section 3-9 of 4010 operations manual for the procedure on setting the time and date.

3.2 Determining and Selecting Diluent and Source Gases:

In order for the 4010 to calculate gas concentrations, you must first program all calibration gases into the 4010 gas standard table. To enter a calibration gas into the gas standard table, follow the steps listed below:

1. Go to the main menu bar of the 4010.
2. Select "Gases" and then select [ENTER].
3. A menu box will appear. Next, select "Gas Standard" and an entry table will display as shown in Figure 08.
4. Fill-out the gas entry table, and make sure to add the gas concentration as well as the serial number.
5. Section 6-2 of the 4010 operations manual provides more information on how to fill out this screen.
6. To save the new entry and return to the main menu, use the escape key [ESC] on the keyboard or use the [END SEQ] button on the 4010 touch panel.

The 4010 uses a zero-air standard to produce its diluent gas (zero air). CARB uses a zero air generator as its zero air standard to produce the diluent gas. By default, the 4010 gas standard table should already have an entry for the diluent gas. If not, add the diluent gas directly to the 4010 gas standard table. Adding a diluent gas follows the same steps as mentioned above for the source gas.

When using gas blends for the automatic calibration of a multiple gas analyzer, the 4010 will calculate gas concentrations for each gas in the blend. For example, you can calibrate three instruments simultaneously using a gas blend containing SO2, NO, and CO. One of these gases must be assigned as the "primary gas" when the sequence is set up; the other two will be considered secondary gases. The 4010 will automatically calculate the concentrations of all gases in a multi-blend gas standard and present them in a status screen. The concentrations assigned to the primary gas for each sequence point will determine the concentrations of the secondary gases. The 4010 calculates gas concentrations using the dilution ratio to produce the primary gas and the relative concentrations of the secondary gases listed in the 4010's gas standard table.

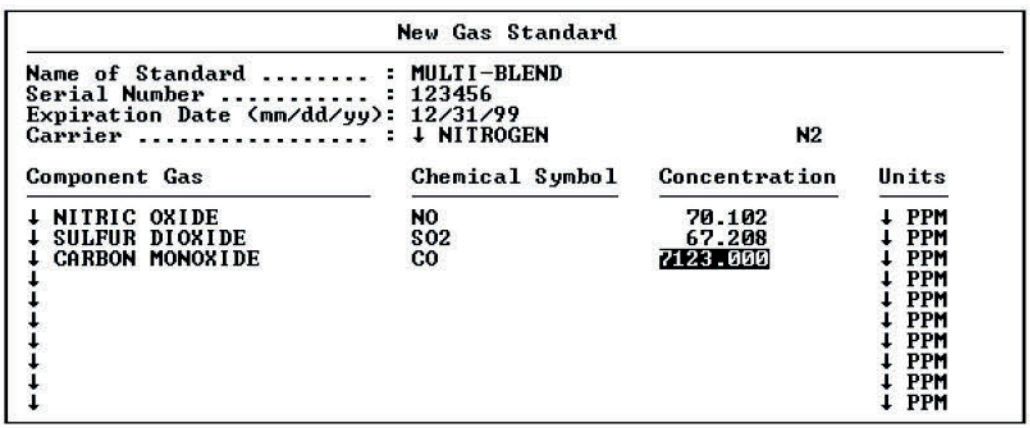


Figure 08: New Gas Standard Entry Table.

3.3 Calibration Setup:

Before the 4010 can perform automated gas dilutions or calibrations, you need to program the sequence routines into the 4010 and schedule them accordingly. The steps listed below assumes the sequences already exist and it only provides rudimentary information on what you need to do prior to running an automated dilution or calibration. For the most part, ODSS programs the sequences and CARBLogger will schedule when the sequences run. However, you can learn more about sequences, especially programming them, if you read section 6 of the 4010 operations manual.

STEPS

1. The 4010 gas standard table has entries listed for commonly used gases. Verify the 4010 gas standard table has an entry for the source (calibration gas) and the diluent (zero air) for calibration. If the calibration gas is not in the gas standard table, add it directly to the table (see 4010 operations manual section 6-2).

2. Set up a "Gas Standard" for each gas cylinder attached to the source inlet ports (see operations manual section 6-3).

3. Assign the diluent gas and the gas standards to the appropriate diluent and source inlet ports (see operations manual section 6-3).

4. Define calibration "sequences". Use the standard calibration sequences pre-programmed in the 4010 prior to its deployment in the field. Field staff should review all programmed sequences to ensure they are correct. Section 6-4 of the operations manual contains more information on defining sequences.

5. CARBLogger will run the calibration sequence routines automatically based on a schedule. Figure 09 show a screenshot of the 4010 table used to define a sequence.

   NOTE: The 4010 will use concentrations programmed in the unit as the expected output. The 4010 will automatically adjust its diluent MFC, source MFC, and ozone generator (assuming "servo-on" is engaged) to achieve the programmed gas concentration. Therefore, the sequence gas set-point value is the "true" value for determining DMS true value settings.

New Sequence (Page 2 of 5) More ...

Point	Gas Source	Gas Name	Source MFC	Concentration Primary (↓PPB)	Concentration Ozone (PPB)	Duration (Min)
1	↓ <Zero>	↓		0	0	15
2	↓ MULTI-BLEND	↓ SO2	1	450	0	15
3	↓ <Zero>	↓		0	0	15
4	↓ NO STANDARD	↓ NO	1	450	0	15
5	↓ <Zero>	↓		0	0	15
6	↓ NO STANDARD	↓ NO	1	500	0	15
7	↓ NO STANDARD	↓ NO	1	500	450	15
8	↓ <Zero>	↓		0	0	15
9	↓ <Ozone>	↓		0	450	15
10	↓ <Zero>	↓		0	0	15

More ...

Figure 09: Sabio 4010 Sequence Screen.

3.4 Operational Verification:

The operator should check the 4010 system to ensure the system is working properly. Operational verification confirms that the 4010 is ready for field use. The ozone generator can be checked by running a control point in the precision sequence for ozone and reviewing the values provided by the 4010 and determine if they are correct or not. Verify the MFCs using the same line of reasoning. Likewise, verify the CARBLogger is working properly by ensuring data displayed for the 4010 makes sense. In addition, do operational checks on the CARBLogger routines to ensure things like correct drivers for the instruments, notification e-mails, and so on are running correctly.

3.5 Data Logger Configuration:

To connect the 4010 to a CARBLogger, an RS-232 null modem cable is required. The cable connects to the 4010 serial port interface COM-1 and to the corresponding COM port interface on the CARBLogger. Prior to use, configure the COM-1 parameters as previously discussed in section 2.3.

Also, configure the CARBLogger to recognize the 4010. From the CARBLogger main menu, select "Add Instrument" then select the "Sabio 4010" driver. You will need to do the following:

- Set the CARBLogger serial port
- Set the recovery time
- Set the equilibrium time

If you do not configure the 4010 232 port, the 4010 will not be able to communicate with the CARBLogger, so verify the 232 port is configured properly. Recovery time is the amount of time CARBLogger waits after a calibration sequence ends and the start of valid data flagging. Equilibrium time is the time between calibration steps. This is when data flagging for the "ramp-up/ramp-down" time between steps commences. There are default values for setting the times discussed above, but you can override the defaults. Contact ODSS staff for any questions regarding CARBLogger configuration, or reference SOP 605 for CARBLogger.

3.6 Zero Air Connection:

The Teledyne API (TAPI) model 701H is the standard zero air generator used by CARB (see Figure 10). Using ¼-inch outside diameter (O.D.) FEP Teflon tubing, connect the output of the air generator to the port labeled, "Diluent" of the 4010. The output of the zero air source must be set to approximately 30 PSIG measured at the inlet of the 4010. The TAPI 701H is a "demand" system, so when connected to the 4010, it will deliver zero air upon actuation of diluent MFC.

For proper operation of the 4010, zero air must be extremely dry with a dew point less than minus 16°C.

Figure 10: API model 701H Zero Air Generator.

3.7 Manifold Connection:

CARB's standard station configurations use the output of the 4010 for delivering calibration gases to the instruments via an 8-port air-sampling manifold, also known as the station manifold. Connect the 4010 port labeled "Out 1" of the 4010 to the upper most port on the station manifold with ¼ O.D. FEP Teflon tubing (see Figure 11).

3.8 Vent Port Connection:

Connect the vent port to the station exhaust manifold. To prevent back flow thorough the vent port, install a three-way valve between the vent port and station exhaust manifold. Configure the 3-way valve to open the exhaust when the 4010 activates for calibration operations.

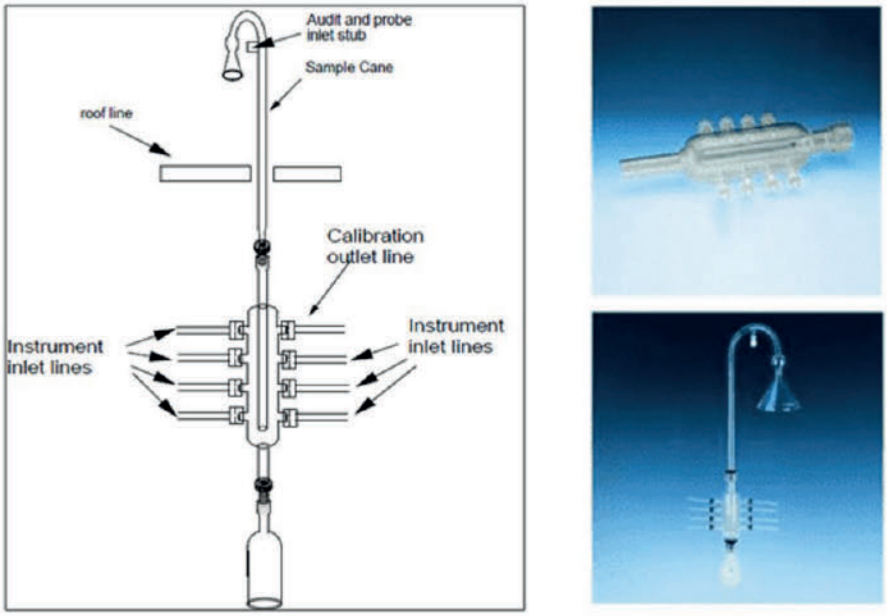
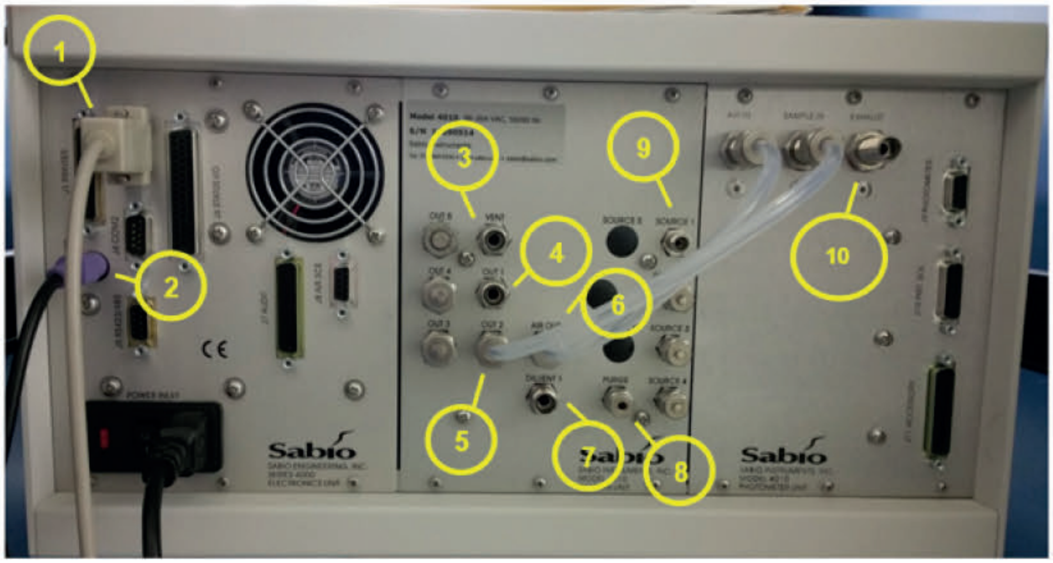


Figure 11: Standard CARB 8 Port Station Manifold.

3.9 Calibration Gas Connection:

The 4010 can blend various types of gases from compressed gas cylinders. Connect the output of the gas cylinder to port labeled "Source 1" of the 4010 with clean, 1/8 inch OD, stainless steel tubing (see Figure 12 below, item 9). Calibration gas cylinders should use a double stage, stainless steel regulator with a CGA 560 or 690 connector. The regulator output pressure should be set to 25 PSI. All connections should be Swagelok™ or equivalent stainless steel compression fittings. Figure 12 shows the various connection interfaces of the Sabio 4010.



Picture Label	Sabio Label	Connected to
1	Serial connectivity to data logger.	CARBLogger
2	Keyboard	Keyboard
3	Vent	Station Exhaust Manifold
4	Out 1	Station Manifold
5	Out 2	Sample In
6	Air Out	Air In
7	Diluent	Zero Air Output (28-30 PSI)
8	Purge	Leave Open
9	Source 1	Calibration Gas Input
10	Exhaust	Station Exhaust

Figure 12: Port Connections for Sabio 4010.

3.10 Photometer Lamp Adjustment:

The 4010 uses a sequence to adjust and maintain the photometer lamp (photo lamp) voltage on a regular basis when necessary. This ensures precise ozone measurements for the photometer. If the photo lamp sequence is disabled, the photometer will eventually experience signal drift in the photometer detector and cause erroneous ozone concentrations. Always enable the photo lamp adjust sequence to avoid signal drift in the photometer detector. While the voltage to the photo lamp can be automatically adjusted using the lamp adjust sequence, manual adjustment is also possible.

During normal operation, the photo lamp adjust sequence is automatic. The "photo adjust" sequence is preset at the factory and can be found in the 4010 main menu under the sequence menu item. Enable this sequence to adjust the lamp automatically.

Should the "photo adjust" sequence be deleted or become corrupted, it can be re-installed. Creating the sequence can be accomplished by following the procedures titled "Introduction to Initializing Calibration Sequences" starting on page 6-7 of the 4010 operations manual or by creating an ozone sequence with the name of "Photo Adjust" and setting a zero point for a duration of 15 minutes. **Remember to add a schedule to the sequence, so it runs automatically.**

You can also adjust the photo lamp by using the lamp adjustment routine located in the 4010 menu item under ozone parameters; however, this is only a one-time adjustment. To do this, select "Devices" from the 4010 menu bar. Next, select "Ozone Photometer". Then, select the "Photo lamp Adjust" menu item. At this point, no further menu items will be displayed and oddly enough it will appear as though nothing has happened; however, the lamp adjustment has been activated (it is just not obvious).

As mentioned, manual adjustment is also possible. However, this is a trial-and-error process. The possible set point voltage for the lamp is an educated guess, in which adjustment continues, until a set point voltage causes the detector voltage to output between the listed detector maximum and minimum range. (See figure 13). More information about manual adjustment for the photo lamp is in section 9-19 of the operations manual.

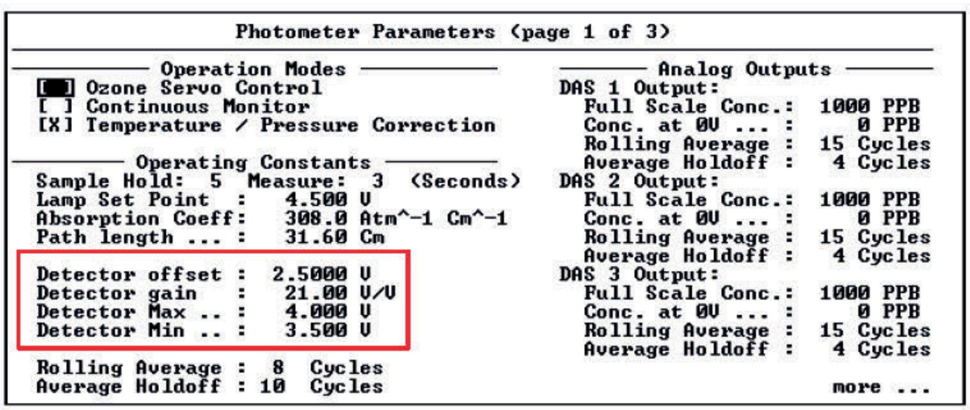


Figure 13: Photo lamp Parameters (red box).

NOTE: Before adjusting the photo lamp, make sure the 4010 is powered-on for at least one hour to ensure its lamp block is at normal operating temperature.

4.0 CALIBRATION OVERVIEW

4.1 Calibration Introduction:

A calibration is the comparison of a measurement standard, instrument, or item with a standard of higher level to detect inaccuracies and to eliminate those inaccuracies by adjustment. To ensure instrument accuracy, calibrate the Sabio 4010 in accordance with the recommendations stated in this SOP.

Calibrate the 4010 mass flow controllers (MFCs), ozone generator, and photometer upon initial field deployment, prior to relocation or shutdown, and on a semi-annual basis. In addition, calibrate these 4010 components after any major repairs and if it experiences significant instrument drift.

Using a traceable flow standard approved by the National Institute of Standards and Technology (NIST), calibrate the MFCs by flow comparison with the flow standard. Similarly, calibrate the ozone generator and photometer using a NIST traceable ozone transfer standard by comparing concentration levels. MLD's Standard Labs certifies the NIST transfer standards for the MFCs and ozone generators on yearly basis.

The 4010 may undergo three types of field calibrations: an "As-Is" verification, an interactive calibration, and a final verification or calibration.

An "As-Is" verification is performed to evaluate an instrument's accuracy when compared to a transfer standard (i.e., check for drift/bias). When performing an As-Is verification, the instrument is not adjusted, modified, or repaired in any way. The result of this verification is determined using a pass/fail only criterion.

If an instrument fails an As-Is verification, the next step to perform is an interactive calibration. When performing an interactive calibration, a field operator will adjust the instrument as necessary and compare its output to a transfer standard. The goal is to adjust the instrument component to a point where the instrument's output and linearity is at an acceptable level of accuracy.

A final calibration is a re-check of the instrument for accuracy and linearity after an interactive calibration. A final calibration re-affirms the instrument is reading at an accurate level after adjustment. Figure 14 is a flow diagram showing the calibration process used on 4010 system components.

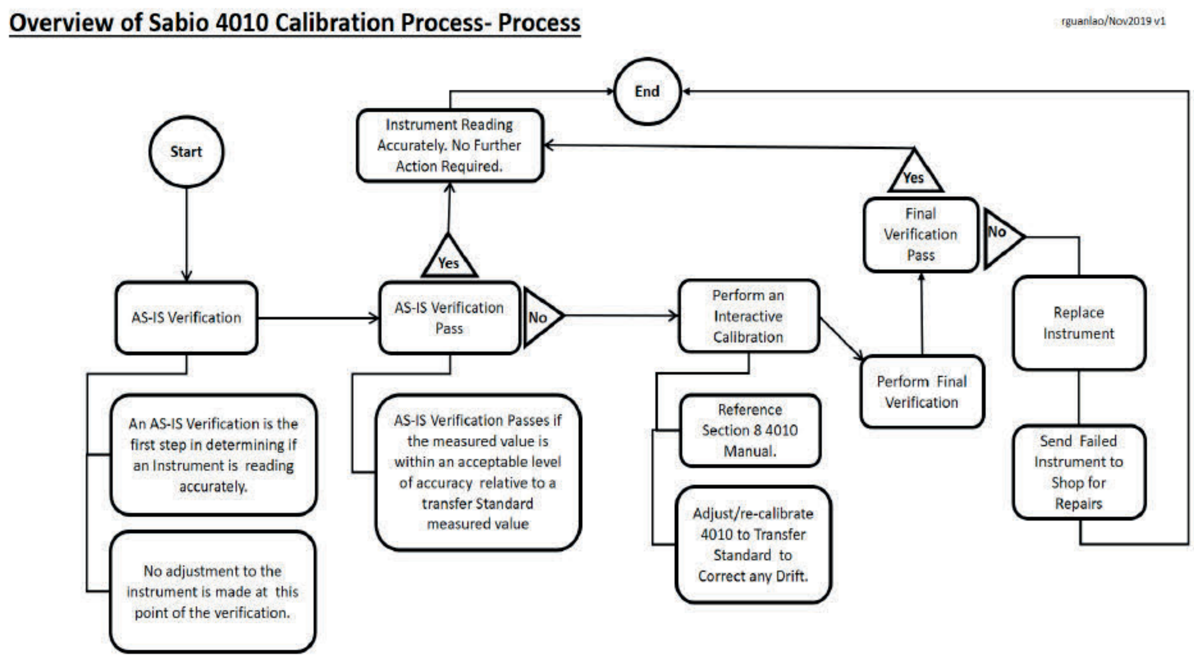


Figure 14: Overview of 4010 Calibration Process.

4.2 Calibration Overview:

The calibration of the 4010 consists of an evaluation of the three major system components:

1. mass flow controllers (MFCs),
2. ozone generator, and
3. photometer

When conducting a calibration or verification, compare the 4010 component output to a NIST traceable standard. For all the components mentioned above, the verification process and its pass-fail criteria will determine whether any of the components will require an interactive calibration. A repair on a major system component or its replacement will also require an interactive calibration on that component. Conduct a final calibration right after completing an interactive calibration. The final calibration is a re-verification of the component after doing an interactive calibration. If the component passes the final calibration, place the unit back into service otherwise, return it to the ODSS instrument shop for repairs.

Prior to starting ANY verification/calibration procedure, mark down affected data channels on CARBLogger.

There are four basic parameters (also known as calibration data) utilized in a verification, interactive, and final calibration. These parameters are the following:

1. Control value (or set point) – Selected voltage or concentration value sent to the system component under test (e.g., MFC is sent a voltage that sets mass flow).

2. Monitor value - Actual voltage or concentration output from system component under test.

3. Transfer standard reading – True flow or concentration of a system component as measured by a NIST certified transfer standard.

4. Calculated percent difference from true value – Percent difference between a system component's noted set point and its true value.

Use the calibration data to calculate a percent difference from a true value or a true concentration. The 4010 does not have any on-board programs to calculate the true value or true concentration. Instead, you will use the AQSB Calibration Form 701 (Microsoft Excel Spreadsheet) to calculate the true value. When using this form, calibration staff will need to gather specific information and enter it into the calibration form. Once entered, the form automatically calculates the calibration results.

Should a system component fail an As-Is verification, it must undergo an interactive calibration to re-establish accuracy. A linearization equation (e.g., y = mx+b), a set of control values, and a set of corresponding true values from a transfer standard are used to conduct the interactive calibration. The 4010 has these linearization equations programmed internally. The user can select which equation to use. The 4010 will automatically use calibration data and the preferred linearization equation to re-calibrate a system component. CARB uses factory default equations for all system components. Figure 15 shows the type of linearization equations that are available on the 4010, while Table 1 shows the default linearization equations used by the 4010 for each system component.

Change the linearization equation using the 4010 main menu bar, selecting the item "Devices" and then navigating various selection boxes to get to the "Linearization Method" item for a system component. See section 8-5 of the

4010 operations manual to learn more about these equations and further instruction on how to change the linearization equation for a system component.

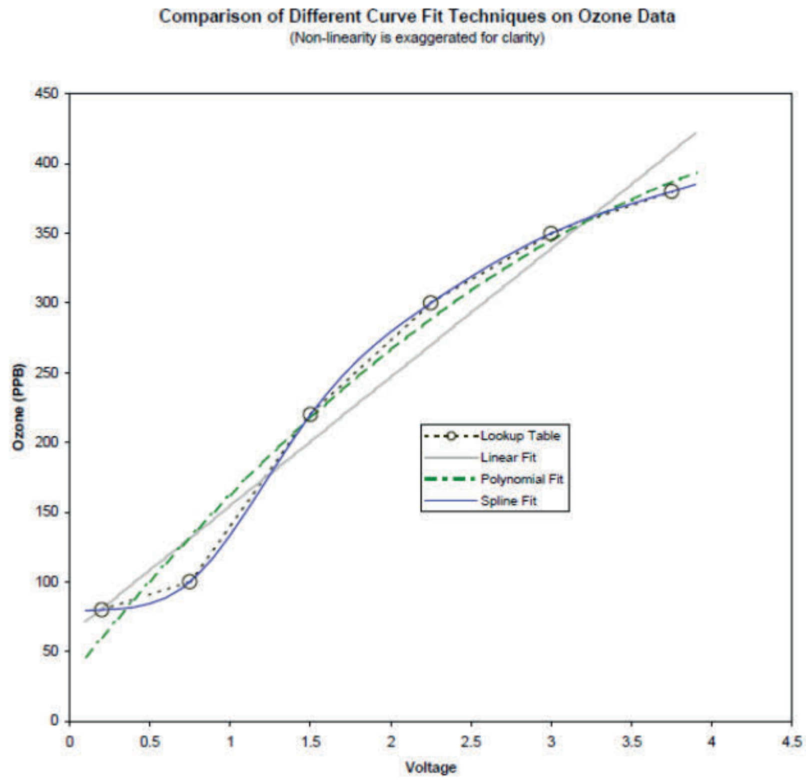


Figure 15: Linearization Equations.

4010 Component	Linearization Method (default)
DILUENT MFC	LINEAR FIT
SOURCE-1 MFC	LOOK-UP TABLE
OZONE GENERATOR	SPLINE FIT
OZONE PHOTOMETER	LOOK-UP TABLE

Table 1: Default Linearization equation used by 4010

After a system component has been re-calibrated, re-evaluate it for accuracy. Conduct a final calibration to ensure the component is measuring values within acceptable calibration criteria. If a component fails the final calibration, place the unit out-of-service and send it to the ODSS instrument shop for repairs. Figure 16 shows a detailed flow diagram for the overall calibration process.

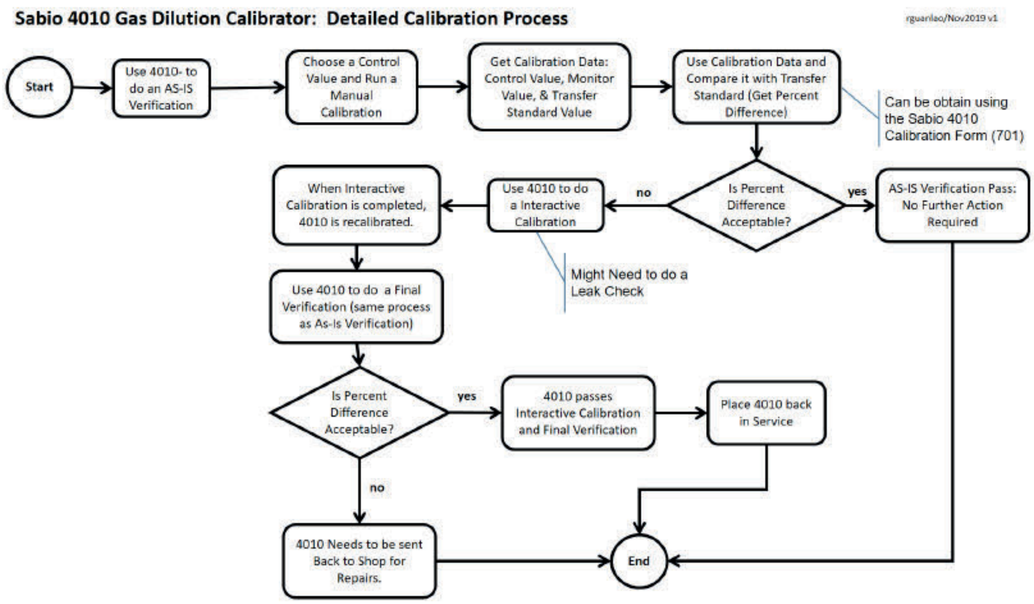


Figure 16: Detailed 4010 Calibration Process.

4.3 Calibration Apparatus for Sabio 4010:

To conduct any of the calibrations mentioned above, use the following items:

1) Certified ozone transfer standard,
2) Pure air source (zero air),
3) NIST traceable mass flow meters,
4) NIST traceable pressure and temperature standard,
5) A laptop computer and printer, and
6) Pressure gauge (0-50 PSI).

4.4 AQSB Excel Calibration Forms:

To facilitate the verification/calibration process, CARB's AQSB has developed the AQSB Calibration Form 701 for the Sabio 4010. For the interactive calibration, use the AQSB Calibration Form 701-1 to document and calculate values for the interactive calibration process.

The calibration form automates calculations and provides indicators to the user regarding the pass/fail criteria of the verification or calibration. Key features of the calibration forms are:

- Different pass/fail criteria for verification or calibration
- No zero correction to net calibration values
- Determination of pass/fail criteria based on each calibration point
- Determination of the best-fit calibration criteria

When you view a calibration form, you will notice the form entries have different colors. Some cells have entries with text color blue, red, or black. The text color in the cell is for identification of input used in that cell. The text color has the following meaning:

1) red is for calculated values,
2) blue is for entered values, and
3) black is for hard-coded values

5.0 AS-IS VERIFICATION

As previously stated, a verification is the process of evaluating an instrument's accuracy and bias when compared to a transfer standard. No adjustments, modifications or repairs are made to the instrument when conducting the "As-Is" Verification. The standard verification method is to run several control points (or values) and to record the corresponding output values. Accessing the values against a pass-fail criterion is the end-result of the verification.

Select a set of reasonable control points, enter them one-by-one into the 4010 calibration status table, and record the corresponding monitor value output.

Next, record the corresponding true value from the applicable transfer standard. Using the AQSB Calibration form 701, enter the control value, monitor value, and true value into the form. Form 701 will automatically calculate the percent difference from true. All the control points used in the verification should be within an acceptable level of accuracy. It only takes one point that is not at a level of accuracy to fail the verification. If the component passes the verification criteria, no further action is necessary. If it fails, the next step is to do an interactive calibration. Figure 17 shows a flow diagram of the verification process.

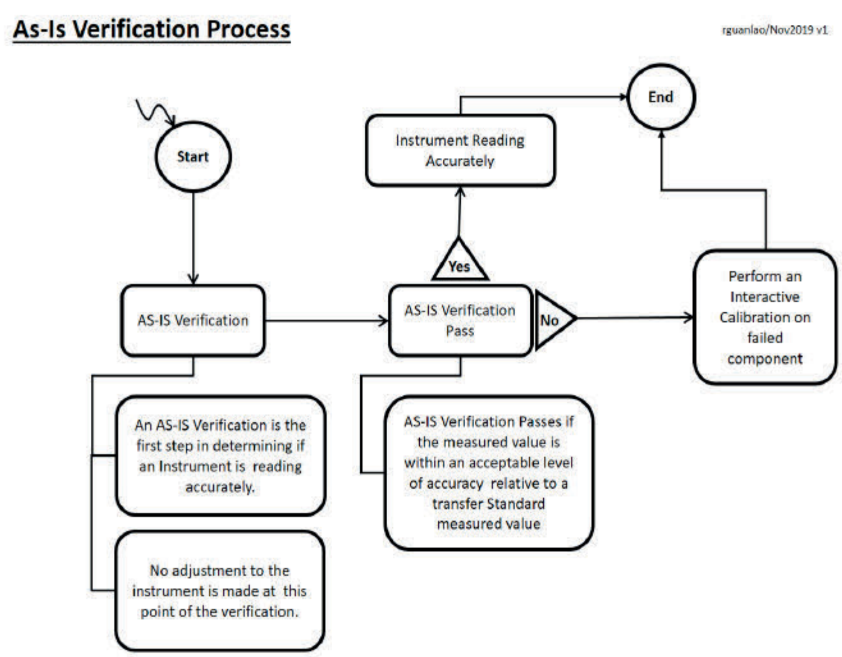


Figure 17: Flow diagram of Sabio 4010 As-Is Verification.

5.1 Manual Verification Using the 4010 Software:

The 4010 does not have a specific application to perform an As-Is verification directly; however, one can utilize the debug-mode to do the verification. Place the 4010 in debug-mode by doing the following:

1) From the main menu of the 4010 select "Status" and from the submenu item select "Current Status". This will bring up the "Idle Status Screen" (Figure 18).

2) Initially, the idle screen only allows editing of values in the unit field. The idle screen needs to be unlocked. To unlock the screen and allow editing of other fields, press the combined keys: [Alt-D] using a keyboard or use the [DIAG] button on the 4010 touch panel. In the status bar of 4010, the debug mode indicator will toggle-on. To advance to other fields in this screen, use the [TAB] key or use [F3] key. Any field that can have its value edited will have a flashing cursor and a highlighted box. Be mindful, if [ALT-D] or [DIAG] is selected again in debug mode, the "normal mode" will be active allowing only the unit field to be edited. This is an indicator the idle screen has changed modes and in now locked.

3) To exit the status screen and return to the main menu, press [ESC] twice if using a keyboard or use the [END SEQ] button on the 4010 touch panel.

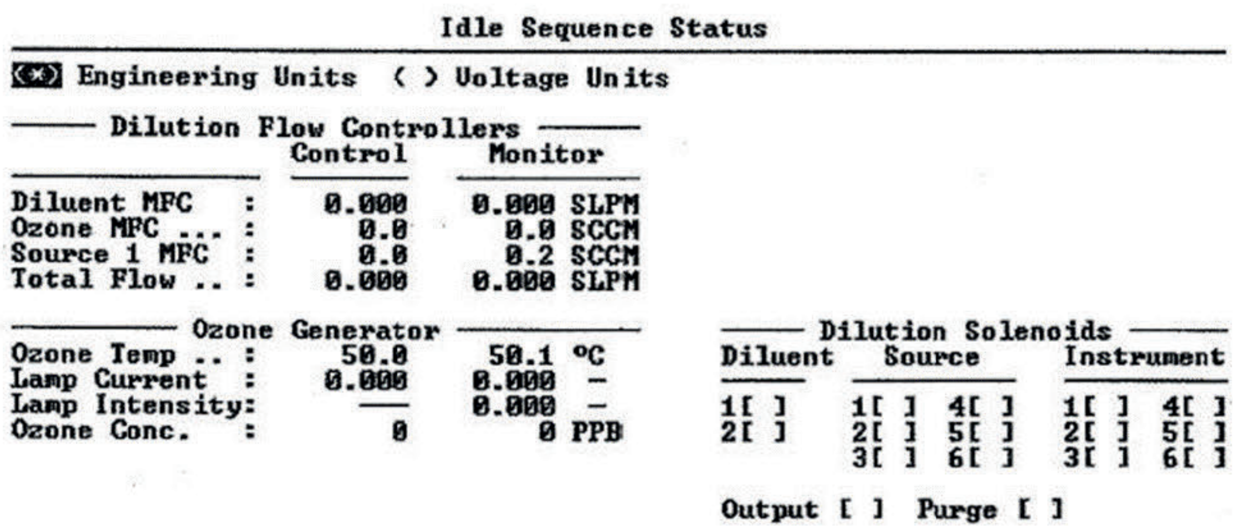


Figure 18: Idle Status Screen.

5.2 Leak Check:

Most instrument verification or calibration failures revolve around the instruments' pneumatic systems. Prior to conducting a calibration of the 4010, perform a leak check on the pneumatic system (see section 9).

5.3 Diluent (Air) MFC Verification Procedure:

To conduct an As-Is verification for the diluent MFC, the following items are required:

- Certified (0-20) LPM mass flow standard,
- A T-valve and pressure gauge (see Figure 19),
- Teflon tubing/fittings, and
- A dilution air source (zero air).

Follow the steps outlined below to perform an MFC diluent AS-IS verification. Refer to Figure 12 for additional guidance on connection setup.

1. Power-on a certified flow standard and allow it to equilibrate for 20 to 30 minutes.

2. Cap all the ports on the 4010 except the DILUENT-1 and OUT-1 ports as shown in figure 20.

3. Use ¼ Swagelok fitting and connect the OUT-1 port to the (0-20) LPM certified flow standard.

4. Connect the T-valve and pressure gauge to the zero air source as shown in Figure 19.

5. Activate the zero air source, ensure the output pressure is constant and does not exceed 25 PSI. Monitor the pressure using the gauge mentioned in step 4.

6. From the main menu of the 4010, access the Idle Status Screen (see Figure 18).

7. Toggle into debug mode (press [ALT-D], keyboard or select [DIAG], 4010 touch panel.

8. At the diluent MFC control field, enter an appropriate control value, and select [ENTER].

9. When the values stabilize, enter the calibration data into the AQSB calibration form, i.e., the control flow value, the monitor flow value, and the transfer standard flow value.

10. Record the "percent from true value" calculated by the calibration form.

11. Repeat this process starting at step 8 for the remaining list of control values in the verification process. Use a minimum of three control points. The use of additional points is at the discretion of calibration staff.

12. When finished, return to the main menu by selecting the escape key [ESC] on the keyboard or use [END SEQ] on the 4010 touch panel.

13. For each level evaluated, calculate the percent difference from true. If all values are within 2% of true, then the MFC passes the As-Is verification—no adjustment is necessary. If not, an interactive calibration will be required. Refer to section 6 of this document.

Figure 19: T-valve and Pressure Gauge Connection.

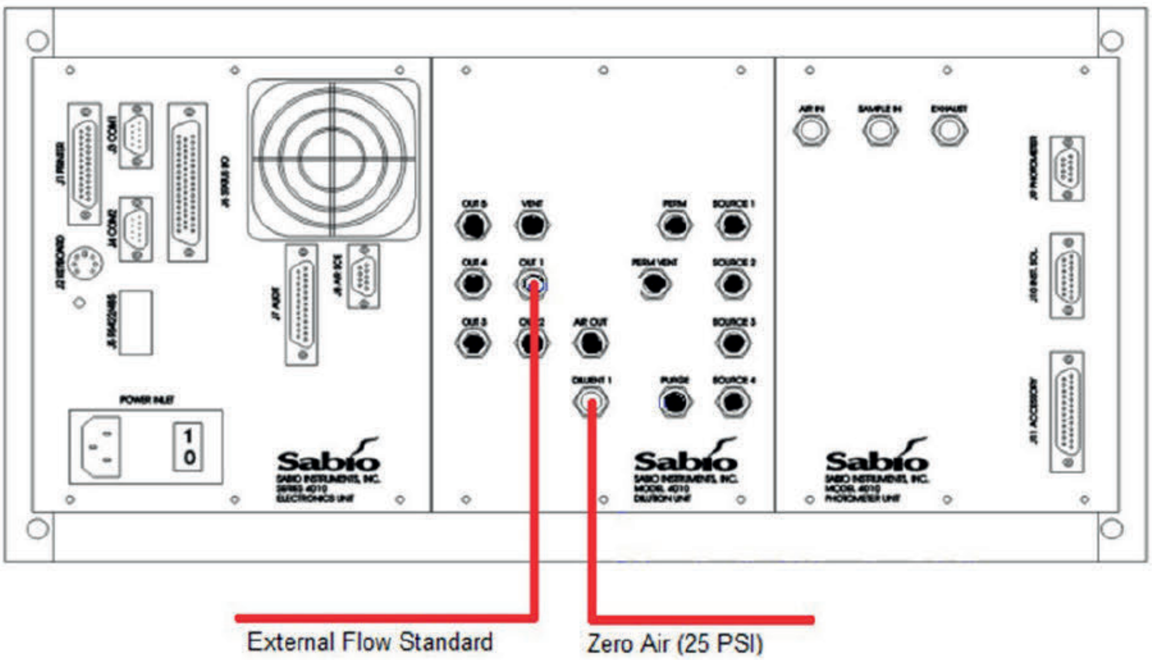


Figure 20: Back Panel Connection Setup for Diluent As-Is Calibration.

5.4 Source (Gas) MFC Verification Procedure:

The As-Is verification for the source MFC uses the same materials listed in the diluent verification. The only difference is the flow rate for the transfer standard should accommodate a flow rate between 0 to 100 sccm. Nonetheless, gather the following items:

- One certified (0-100) sccm mass flow standard,
- A T-valve and pressure gauge,
- Teflon tube/fitting, and
- A dilution air source.

The following steps are utilized in conducting an As-Is source MFC verification. This is a direct manual verification.

1. Power-on a certified flow standard and allow it to equilibrate for 20 – 30 minutes.

2. Cap all ports except the SOURCE-1" and "OUT-1" (see figure 19).

3. Connect the OUT-1 port to a (0-100) CC/MIN certified flow standard.

4. For the DILUIENT-1 port, connect a T-valve and a pressure gauge (See Figure19.)

5. Activate the zero air source and ensure the pressure is at 25 PSIG

6. Access the Idle Status Screen using the 4010 main menu of the 4010 access the Idle Status Screen, (see figure 18).

7. Toggle into "Debug Mode" by pressing [ALT-D] on the keyboard or [DIAG] on the front panel of the 4010.

8. Go to the "Dilution Solenoid" table in the status screen. Use [TAB] on the keyboard to move to the SOURCE-1 field-box or [F3] on the 4010 front panel.

9. Activate the SOURCE -1 box by pressing the [SPACE BAR] on the keyboard. The box should have an 'X' inside of it, which indicates it is now active.

10. Next, go to the SOURCE -1 MFC control field using the [TAB] key or [F3] button. In this field, enter the flow-control value for verification of the source MFC. Press [ENTER] on the keyboard or 4010 touch panel.

11. The 4010 flow value in the monitor flow field will start to change eventually converging to a flow control value previously entered. Allow time for the monitor flow value to stabilize. This may take a few minutes. Record this value as well as the control flow value. In addition, read the true flow value from the transfer standard and record this value.

12. Repeat this process starting at step 10 for the remaining list of control values used in the verification process. Use a minimum of three control points. The use of additional points is at the discretion of calibration staff.

13. After obtaining all the verification data, enter it into the corresponding cells of the AQSB calibration form (701). The calibration form will automatically calculate the percent difference from true for all control flow values (set points) used in the verification. The last step in the As-Is verification is to determine if the MFC output values are at an acceptable level of accuracy.

14. Look at the percent differences associated with all the flow control values used in the verification. If all values are within 2% of the "true flow", the

MFC passes the As-Is verification and no further action is required. This concludes the As-Is verification process.

15. If differences are not within 2 percent of the true flow, an interactive calibration is required to bring the 4010 back to an acceptable level of accuracy.

5.5 Ozone Generator and Photometer Verification Overview:

The overall procedure for conducting an As-Is verification calibration on the 4010 ozone generator or photometer is similar to the MFC verification process; however, there are a few additional items that need to be done.

First, you must configure the ozone generator and the photometer to operate in a specific mode. This will allow separate evaluations for the photometer and the ozone generator during the verification process. To allow the ozone generator to operate independently of the photometer, set the photometer to servo-mode "OFF" and also set the continuous-mode to "ON". This will "decouple" the photometer from the ozone generator allowing the ozone generator to produce a concentration without any adjustment from the photometer. In normal operational mode, the photometer only turns-on during ozone calibrations. Placing the photometer in continuous mode will allow the photometer to remain active and allow it to monitor ozone all the time. Next, you must connect the ozone output directly to the station manifold and connect the transfer standard to the manifold as well.

After doing these additional items, the verification process itself follows the same steps as the MFC verification. Use the 4010 to enter in a set of control points. Next, record the output values and record the transfer standard values. Afterwards, enter these recorded values into the AQSB calibration form 701. The calibration form will automatically calculate the true values and percent difference of the corresponding output for each set-point value. Review the set of percent difference from true against the pass/fail criterion. The results of the review will determine the outcome of the verification.

Finally, when conducting a verification, the ozone generator and photometer verification values will be located on two different status screens. Ozone generator values will be retrievable from the "Idle Status Screen" while the photometer values will be retrievable from the "Ozone Calibration Status Screen" (see Figure 21). There will be some "back-and-forth" action moving between these two screens when recording verification data. Figure 22 shows a set up diagram for the 4010 when conducting an ozone verification.

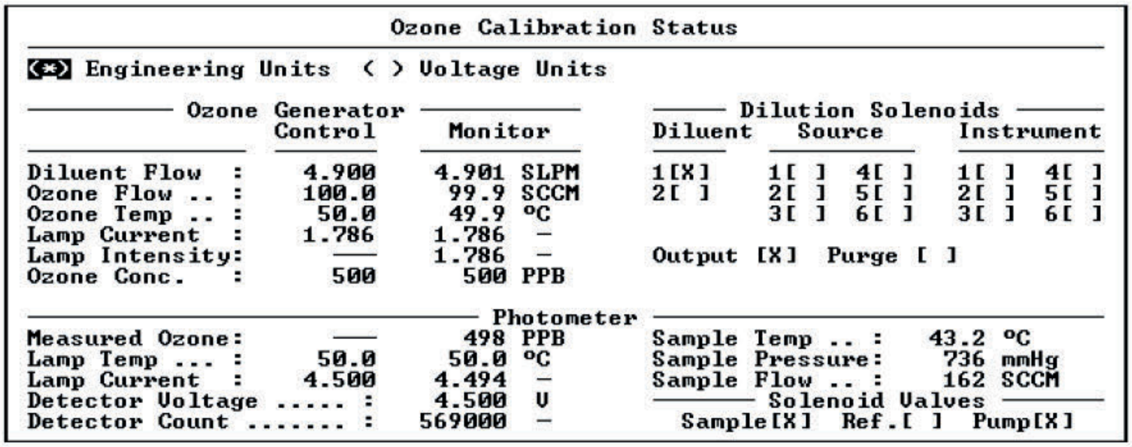


Figure 21: Photometer Status Screen bottom portion of the ozone status screen.

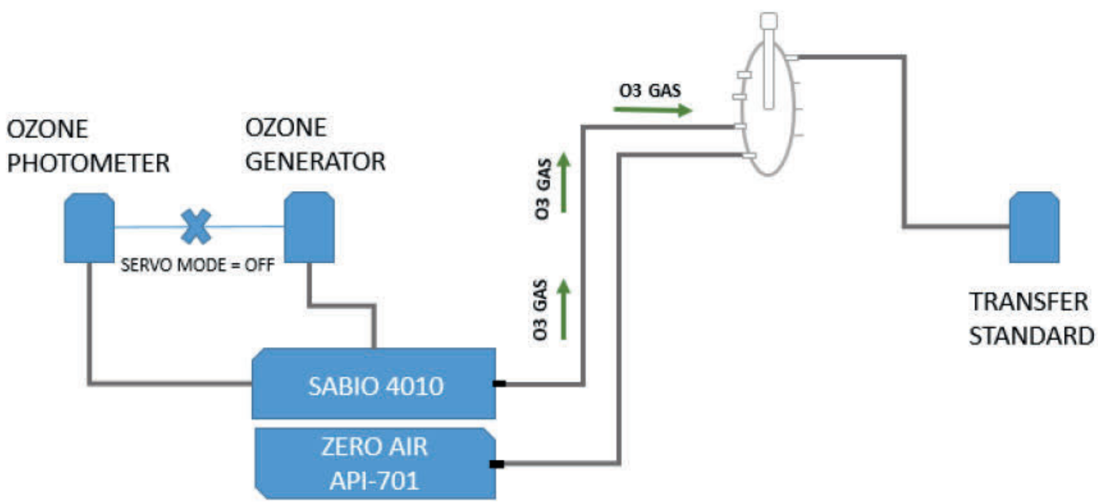


Figure 22: Setup for the Sabio 4010 ozone and photometer during verification.

5.6 Ozone Generator and Photometer Verification Process:

The verification process for the ozone generator and the photometer follow the same basic steps; however, where you read the ozone concentration value is different. After all, you are evaluating two different system components. As you read further, verification step number 12 discusses where to read the ozone concentrations values for the ozone generator and the photometer. Nonetheless, the verification process described here applies to both the photometer and the ozone generator.

Conduct the ozone generator verification or the photometer verification using the same setup mentioned in the previous section. Again, the photometer is set to servo mode "OFF" and continuous mode is set to "ON". These settings allow the photometer and ozone generator to operate independently.

In the verification process, the data you will record are the following:

- The control value concentration (ppb),
- The ozone lamp current (V),
- The ozone concentration reading (ppb), and
- The true ozone concentration (ppb) from a transfer standard.

When you enter the verification data into the AQSB Calibration Form 701, the calibration form calculates the percent difference from true concentration for each control point value used.

Next, you will review the percent difference from true against a pass/fail criterion for each set point used in the verification to determine if the ozone generator or photometer is within an acceptable level of accuracy. If the level of accuracy is within specifications, the system component has passed the verification and no further action is required.

Below are the steps you will perform to the do the As-Is verification for the ozone generator or the photometer.

<u>As-Is verification steps for the ozone generator and photometer</u>:

1. Connect the "Out-1" port on the Sabio 4010 to the station manifold and connect the "Diluent-1" port line to the station zero air source.

2. Configure the ozone transfer standard by making connections to the station manifold, calibration zero air source, ozone feedback-loop, and exhaust.

3. From the 4010 main menu, select "Status" and then "Current Status". The Idle Status Screen will appear (see Figure 18).

4. Next, enter Debug Mode by pressing the key combination [ALT–D] on the keyboard or the [DIAG] button on 4010 touch panel. To unlock the screen, press [TAB] on the keyboard or [F3] on touch panel.
5. Go to the "Diluent MFC-1" field and type "10" (LPM) and press the [ENTER] key. The 4010 will begin to deliver zero air.

6. Go to the "Ozone Concentration" field and enter a control value (ppb) to verify.

7. When the ozone value stabilizes, record the control value, lamp current value, and the transfer standard value.

8. Access the "Photometer Status" Screen by pressing [ESC] on the keyboard or [END SEQ] on 4010 touch panel. The main menu of the 4010 will be accessible.

9. Select "Status" from the main menu.

10. In the submenu, select "Photometer Status".

11. The 4010 displays the "Ozone Calibration Status Screen" (see Figure 21).

12. From this screen, record the "Ozone Concentration" value. If you are verifying the ozone generator, read the concentration from the "ozone generator section" of the screen. If you are verifying the photometer, read the concentration from the "photometer section" of the screen.

13. Exit the Ozone Calibration Status screen by pressing [ESC] on the keyboard or [END SEQ] on the 4010 touch panel. Repeat Steps 3 through 13 for all remaining control values to be tested. Note: omit step 4 when repeating this process because the 4010 is already in debug mode.

14. Enter all the verification data into the AQSB Calibration Form 701 for ozone. The calibration form will calculate the percent difference from true for the control value and for the true ozone concentration.

15. Review the percent difference from true for all the control values or true ozone concentrations to ensure they are within the acceptable level of accuracy.

16. Ozone generator - If each control value is within 4 percent difference or within 4 ppb difference from true (which ever if greater), the ozone generator has passed the As-Is verification and no further action is required. If not, perform an interactive calibration.

17. Photometer - If each control value is within 3 percent difference or within 1.5 ppb difference from true (which ever if greater), the photometer has

passed the As-Is verification and no further action is required. If not, perform an interactive calibration.

One scenario that can happen is the ozone generator passes its verification and the photometer fails or vice versa. Should this occur, you must perform an interactive calibration accordingly because of the dependencies that exist between the ozone generator and the photometer when using the 4010. Table 2 summarizes the calibration acceptance criteria used for a particular system component of the 4010.

Table 2: Sabio 4010 Calibration Acceptance Criteria

Component	Frequency	Acceptance Criteria	Target Calibration Points
Photometer	Upon receipt/adjustment/ repair/installation/moving; then every six months (typically Spring and Fall)	Zero and 5 upscale points; Accuracy: Each upscale point ± 3.1 % from true or 1.5 ppb from true (whichever is greater). Zero less than 1.5 ppb.	400, 320, 160, 70, 30 ppb
Ozone Generator	Upon receipt/adjustment/ repair/installation; then every six months (typically Spring and Fall)	Zero and 5 upscale points; Accuracy: Each upscale point ± 4.1 % from true or 4 ppb from true (whichever is greater) Zero less than 3 ppb.	400, 320, 160, 70, 30 ppb
Air MFC	Upon receipt/adjustment/ repair/installation/moving; then every six months (typically Spring and Fall)	5 evenly spaced points covering (90% to 10% MFC range); Accuracy: Each point ± 2.0 % from true.	18, 15, 10, 5, 2 LPM
Source MFC	Upon receipt/adjustment/ repair/installation/moving; then every six months (typically Spring and Fall)	5 evenly spaced points covering (90% to 10% MFC range); Accuracy: Each point ± 2.0 % from true.	92, 82, 50, 22, 12 sccm

6.0 INTERACTIVE CALIBRATION AND FINAL CALIBRATION

6.1 Interactive Calibration Overview:

An interactive calibration is done when a system component of a 4010 fails an As-Is verification. When conducting an interactive calibration on a system component, the 4010 uses its on-board software to recalibrate the system component based on the calibration data you collect. An interactive calibration of any component should consist of a set of reasonable control set points (voltage or concentration). These values should represent control points the 4010 uses during normal operations. The interactive calibration of the ozone generator requires the photometer to be set to servo-mode "OFF" and continuous mode "ON". This prevents the photometer from controlling the ozone concentration produced by the ozone generator and keeps the photometer actively powered-on to monitor ozone.

6.2 General Information:

When selecting interactive calibration set points, the 4010 instrument manual recommends choosing points that cover a broad range of operational values. A few points near the system component's upper limit, a few points in the mid-range, and a few points below the lower limit. The manufacturer recommends selecting up to 12 points when conducting an interactive calibration. **This SOP requires a minimum of three interactive calibration points within the normal range of values typically used by the system component on a daily basis.**

When you have gathered all the calibration data, you enter it into a blank interactive calibration table. The calibration table is located in a specific status screen that is part of the 4010's system software. After you enter the calibration data into the table, the 4010 will recalibrate the system component using a predefined calibration algorithm. Upon completing the interactive calibration process, the last step in this process is to perform a final verification on the newly calibrated system component. The final verification will ensure the system component is measuring at an acceptable level of accuracy.

6.3 Interactive Calibration Procedures:

6.3.1 Diluent MFC Interactive Calibration:

1. From the 4010 main menu, select "Device", "Dilution Unit". Another submenu appears; select "Diluent MFC", "Calibration". In the calibration submenu, select "Interactive Calibration".

2. A blank "Dilution MFC" interactive calibration table will display (see Figure 23). Enter a control flow voltage. The range of control voltages should represent the full-scale of the MFC. The 4010 will automatically populate the corresponding monitor voltage value reading for control voltage in the table. Next, read the true flow value from an external transfer standard device and enter the true flow value in the true flow field, "Flow" column of the table.

3. Repeat step (2) for all remaining flow control voltages of the interactive calibration. When all control voltages have been entered, press [ESC] on the keyboard or [END SEQ] on 4010 touch panel. The 4010 will return a dialogue box asking to calculate the correlation coefficients; answer, YES.

NOTE: The correlation value should be greater than 0.999.

4. Conduct a final MFC calibration to ensure the MFC is within specifications. If the final calibration fails, the MFC may need repairs.

6.3.2 MFC Gas Interactive Calibration:

1. From the 4010 main menu, select "Device", "Source 1 MFC Calibration" and "Interactive".

2. The 4010 will generate a blank calibration table to fill-out, like the edit screen shown in Figure 23. For the first entry, enter a control voltage in the first row. Next, the 4010 will generate the corresponding monitor voltage of the MFC and display the value in the monitor column. Using an external transfer device, record the true flow value and enter true flow into the table column "Flow".

3. Repeat step (2) for all flow remaining control voltages that you use for the interactive calibration. When all control voltages have been entered, press [ESC] on the keyboard or [END SEQ] on the touch panel. The 4010 will return a dialogue box asking to calculate the correlation coefficients; answer, YES.

NOTE: The correlation value should be greater than 0.999.

4. Conduct a final calibration to ensure the source MFC is within specifications. If the source MFC fails, the MFC may need repairs.

Diluent MFC, New Calibration Table

Point	Control (V)	Monitor (V)	Flow (SLPM)	Point	Control (V)	Monitor (V)	Flow (SLPM)
1	0.500	0.501	1.1131	11			
2	1.000	1.001	2.2105	12			
3	1.250	1.251	2.7382	13			
4	2.500	2.502	5.4655	14			
5	3.750	3.752	8.1900	15			
6	5.000	5.003	10.9200	16			
7				17			
8				18			
9				19			
10				20			

Control Equation	A:	30	Monitor Equation	A:	28
x: Control V	B:	2170	x: Monitor V	B:	2169
y: Flow (SCCM)	C:	1.6	y: Flow (SCCM)	C:	1.5
Correlation coeff:		0.999999	Correlation coeff:		0.999999

Figure 23: Blank Calibration Input Screen.

6.3.3 Ozone Interactive Calibration:

1. Connect the "Out 2" port of the 4010 to the station manifold. Connect the "Diluent 1" port to the zero air source. Ensure the 4010 internal photometer is set to "Servo-Off" mode. To do this, go to the 4010 main menu, select "Device", "Photometer Parameters". In the operations mode window, set the servo control to "NO".

2. Configure the ozone transfer standard by making connections to the station manifold, calibration zero air source, ozone feedback loop, and exhaust.

3. From the 4010 main menu, select" Devices", "Ozone-Generator" menu. Next, select "Ozone Generator Calibration" then "Interactive calibration". A blank Ozone Generator Interactive table displays. See Figure 24.

4. Confirm that the "total (Air+O3) flow" field is set to a desired airflow rate. For standard CARB calibration operations, this value is defaulted to 10 LPM.

5. Enter desired control ozone generator voltages in the first column under control. The next column will automatically display monitor O3 voltages corresponding to set point voltages. Read the true ozone concentration from the ozone transfer standard and enter it into the ozone column of the table. The first row is now completed.

6. Continue to populate the table for the remaining ozone generator

control voltages used in the interactive calibration for the ozone generator.

7. Once complete, press the [ESC] key on the keyboard or [END SEQ] on the 4010 touch panel, a dialogue box will appear asking if coefficients should be calculated--answer "yes". The 4010 will place coefficients values in the control correlation fields. These values should be greater than 0.999. Save these values by pressing the [ESC] and selecting "YES" to save.

8. Conduct a final calibration to ensure the ozone generator is measuring accurately.

Ozone Generator, Interactive Calibration

Point	Control (V)	Monitor (V)	Ozone (PPB)	Point	Control (V)	Monitor (V)	Ozone (PPB)
1	0.800	0.759	49.0	11			
2	1.000	0.963	138.0	12			
3	1.250	1.214	263.0	13			
4	1.750	1.719		14			
5				15			
6				16			
7				17			
8				18			
9				19			
10				20			

Total Flow Rate (Diluent + Ozone Flow) : 5.000 SLPM

Control Correlation: Monitor Correlation:

Figure 24: Ozone Calibration Table.

6.3.4 Photometer Interactive Calibration:

The photometer is a measurement only device, thus it only has a monitor correction equation. The monitor value and external transfer standard are in ppb units.

NOTE: The procedure below assumes the 4010 uses its ozone generator as the source of ozone for its photometer.

STEPS:

1. From the 4010 main menu, choose "Devices", "Ozone Photometer". Next, select "Photometer Calibration" then "Interactive". A blank Status Screen displays (see Figure 25).

2. Go to the "Diluent" field and enter the desired calibration total airflow rate. Default value is 10 LPM.

3. Verify that "ozone servo control" is set to OFF.

4. Enter a control voltage for the ozone generator.

5. Record the 4010 photometer value.

6. Record the true ozone value from an external ozone standard.

7. Repeat starting at step 4 for the remainder control values used in the interactive calibration.

8. When done, press the [ESC] key on the keyboard or [ESC SEQ] on the 4010 touch panel. A dialogue box will ask to calculate the coefficients, answer "YES". The 4010 will populate the control correlation fields with coefficients. These values should be greater than 0.999. Press the [ESC] key again to save the values.

9. Conduct a final calibration to ensure the photometer is reading accurately.

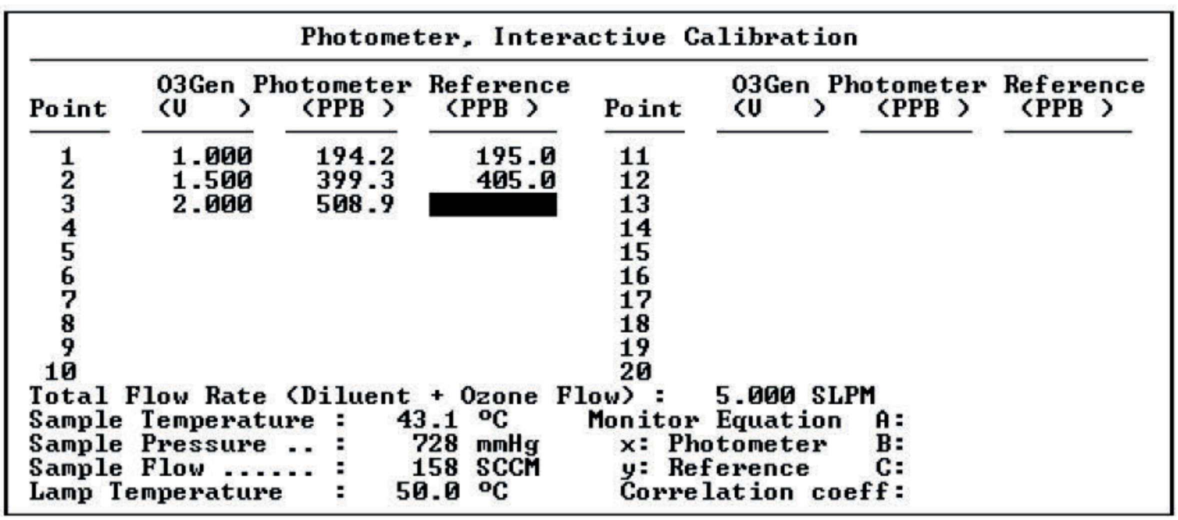


Figure 25: Photometer Interactive Calibration Screen.

7.0 OPERATIONAL AND ROUTINE SERVICE CHECKS

7.1 General Information:

Perform routine checks at the suggested intervals listed in Table 3. However, you may perform routine checks more frequently depending on your situation. Complete AQSB QC Form 700 (Appendix A) weekly and include it along with the monthly data submittal documents and other maintenance records.

7.2 Daily Checks:

1. Verify 4010 power is on.
2. Check instrument display.
3. Ensure that the 4010 displays the correct time and the correct date.
4. Review the DMS system information for your site.
5. Read the daily CARBLogger e-mail notifications for your site.
6. Review the control charts for auto QC checks and ensure that all instrument responses fall within appropriate control limits.

7.3 Weekly Checks:

Observe and validate zero, precision, and span values for all the appropriate pollutants.

7.4 Monthly Checks:

1. Check and record calibrator/gas cylinder parameters:
   a. output pressure value set to 25 PSI,
   b. cylinder pressure 300 PSI,
   c. certification expiration dates, and
   d. verify cylinder identification number.

2. Check and record 4010 calibration date.
3. Verify that the cooling fan is operating.
4. Inspect tubing and power cord for loose connections, kinks, cracks, or other defects. Repair and/or replace as necessary.
5. Order replacement gas cylinder when tank pressure drops below 300 PSI.

7.5 Semiannual Checks:

Perform field verification/calibration of the Sabio 4010 components.

Setting or Parameter	Value	*Daily	Weekly	Monthly	Semi-Annual
Power On	On	X			
Time/Date	PST	X			
Observe Zero & Prec./Span	Record		X		
Gas Standard Output Pres.	25 PSI			X	
Gas Standard Tank Pres.	> 300 PSI			X	
Gas Cylinder Expiration date				X	
Verify Gas Cylinder ID Number				X	
Check Cylinder Capacity and Order replacement when pressure drops below 300 PSI				X	
Observe Fan Operating	Clean			X	
Check tubing and fittings	Clean			X	
Perform Field Calibration	6 Months				X

***Daily or each site visit**

Table 3: Sabio 4010 Routine Service Checks

8.0 MAINTENANCE PROCEDURES

8.1 General Information:

The Sabio 4010 Gas Calibration System requires little if any maintenance. In general, operators should use standard operating procedures when operating the unit. Refer to Sabio operating manual "Warranty" section located at the very end of the 4010 operations manual for more detailed service policy issues.

If maintenance issues arise, contact appropriate calibration personnel or the ODSS Instrument Repair Laboratory to initiate a repair.

9.0 TROUBLESHOOTING

The 4010, with few moving parts and durable electronics package, should provide a high level of reliability. In the event there is an instrument failure, contact the appropriate air monitoring calibration personnel or the ODSS Instrument Repair Laboratory.

Leaks can develop due to the deformation of seals or by loose connections due to vibration. A leak within the photometer assembly or in the pneumatic path before the photometer can result in erratic or low span readings. A leak between the photometer and pump can result in low flow or erroneous pressure indications.

The 4010's pneumatic system must be free of leaks before performing flow calibrations, particularly when calibrating the source flow controllers. If there is any doubt that the 4010 is leak-tight, perform a leak check.

9.1 MFC Leak Check:

Performing a leak check on the dilution MFC involves pressurizing the MFC to a specified pressure and allowing the MFC to hold the pressure for a specific period (typically 5 minutes). If the pressure in the MFC drops significantly, there is a leak in the 4010. Use the following items to do a leak check:

1. One T-valve and pressure gauge to confirm the pressure of the zero air source.
2. Pressure gauge (0-40) PSIG.
3. Six 9/16 inch Swagelok plugs with 7/16 inch I.D. (inside diameter).
4. Vacuum source with gauge and shut-off capabilities.

Follow the steps outlined below to perform a leak check on the dilution MFC.

1. Connect a zero air source to the Diluent-1 port and set the pressure to 30 PSI.
2. Connect a pressure gauge (minimum 0 – 40 PSIG) to the vent port.
3. Plug all other output ports (1-5) and the air out port with Swagelok plugs. Make certain the plugs are leak tight.

4. From the front panel of the 4010, choose Status and press [ALT-D] to enter debug mode.

5. Advance the cursor to the diluent field, assign a flow rate of (6) SLPM and press [ENTER]. This causes the diluent solenoid valve to open. Wait for the pressure to equalize with the zero air generators, i.e., 30 PSI.

6. Once the pressure reaches 30 PSI, de-energize the diluent solenoid valve by navigating to diluent field marked with "[X]". Use the TAB or ENTER button on the 4010 touch panel or use [SPACE BAR] on keyboard, to remove the "X". The diluent solenoid will change from [X] to [ ] which indicates that dilution solenoid valve is inactive. Deactivating the solenoid valve will isolate the pneumatic system from the output of the dilution solenoid valve to the pressure gauge connected to the vent port.

7. Use the current pressure displayed on the gauge in step (2) of this section to confirm the starting pressure reading. Allow the unit to sit idle for five minutes before checking the pressure reading again.

8. If the unit drops more than one PSI in five minutes, there is a leak in the air-out system.

9. Next, check the purge port system for leaks. Allow the dilution MFC flow setting to remain at (6) SLPM and activate the solenoid valve by placing an "X" in both the dilution and solenoid valves. Cap source ports 1-4 and the purge port. Enter 50 into the source-1 MFC control field.

10. Activate source-1 through source-4 and purge solenoids valves.

11. After the pressure gauge reaches 30 PSI, deactivate the diluent solenoid and note the pressure. Allow the unit to sit idle for 5 minutes before checking the pressure gauge again. If the pressure drops more than 2 PSI in five minutes, there is a leak in the air-out system.

12. The 4010 operations manual states that there should not be any leaks in its system when performing verification or a final calibration. If a leak cannot be resolved, send the unit back to the shop for repairs.

13. Remove the caps from the source ports and purge port. Press [ESC] on the keyboard or [ESC-SEQ] on the touch panel to end the leak test

and return to the main menu.

9.2 Photometer Leak Check:

1. Disconnect the power from the Sabio 4010 and remove the cover by removing the screws from either side of the cover using a screwdriver. Locate the output connection on the photometer.

2. Remove the tube connected to the output using a ½-inch wrench and a 9/16 inch wrench to loosen the nut.

3. Connect a vacuum source to the output using a ½-inch wrench and a 9/16 inch wrench to tighten the connecting nut.

4. Plug the "Sample-In" port located on the photometer rear panel (see Figure 26 below) using a 9/16 inch wrench to tighten the plug.

5. Turn-on the 4010 and navigate to "Status" screen on the menu bar using the arrow keys on the keyboard or keypad. At the status screen, enter "photometer status" to display the associated entry screen. Activate the sample valve.

6. Turn on the vacuum source and allow the pressure gauge to reach approximately 15-25 TORR. If the pressure changes by more than (1) TORR in five minutes, there is a leak. Fix the leak before doing any calibration on the 4010.

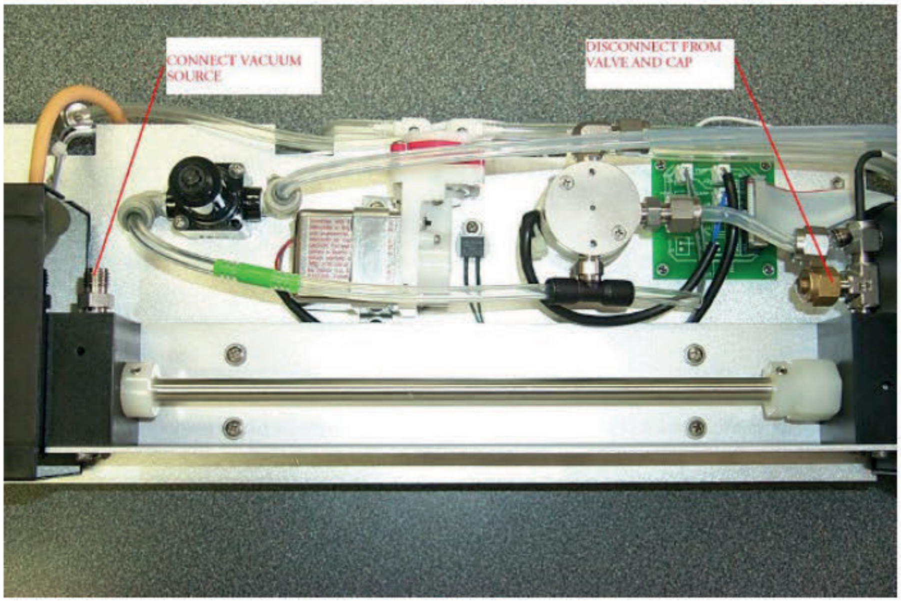


Figure 26: Photometer and Leak Check Setup.

9.3 Photo Lamp Adjustment Failure:

If you are unable to adjust the photo lamp, then it may be faulty and needs replacing. To keep the 4010 in operation, deactivate the photometer by turning it OFF (see section 9-10 of 4010 operations manual). In this mode, the ozone generator will produce ozone based on its ozone calibration table. Remember to send the instrument back to the shop to have the faulty lamp serviced as soon as possible.

NOTE: Power-on the 4010 for about 1 hour to ensure the lamp block reaches normal operating temperature.

10.0 QUALITY CONTROL AND ASSURANCE

10.1 General Information:

Under normal conditions, the 4010 conducts automated 1-point Quality Control (QC) checks. The 4010 auto calibration serves as a drift check for gaseous analyzers. Most importantly, you should not consider these automatic calibrations as an instrument calibration. These checks are for the following purposes:

1. Provide daily zero, precision and span checks.
2. Generate instrument control charts.
3. Represent 1-point QC checks per CFR (US EPA Code of Federal Regulation).

Do not adjust station analyzers based on the results of the automated quality control checks!

10.2 Normal Nightly Operation:

During normal operation, the 4010 operates under the control of the station's CARBLogger data acquisition system, seven days a week.

An automated calibration consists of four 18-minute steps beginning at 0350 hours. During the first step, all instruments receive zero air. During the next step, port-2 opens and the 4010's programming executes the command to deliver a known gas concentration. During the third step, the ozone generator activates to perform a gas phase titration. At the fourth step, port-2 is closed and the 4010 delivers pure ozone to the manifold or station probe line.

On Fridays and Saturdays, the 4010 delivers calibration gases to check the zero and span level accuracy for each instrument.

On Sundays through Thursdays, the 4010 produces a precision level of calibration gases. The precision checks serve as the 1-point QC check required by the CFR.

If the automated zero, span and precision checks are within acceptable control limits, then all sampling instruments and the calibration system (calibrator, air supply, and gas cylinders) are operating properly.

10.3 Data Action:

CARB has established the following QC warnings, action, and upper/lower control limits based on the results of automated QC checks. CARB evaluates QC control limits for zero, precision, and span QC drift checks.

1. Warning level of ±5.1 percent for all gaseous instruments
2. Action level of ±7.1 percent for ozone, ±10.1 percent for carbon monoxide and sulfur dioxide, and ±15.1 percent for nitrogen dioxide, nitric oxide, and total oxides of nitrogen.

Quality control limits for zero checks are ±5 ppb for O3, NO, NOx, NO2, and SO2 and ±0.040 ppm for CO.

If precision and span instrument QC checks are less than ±5 percent, and zero checks are less than values stated above, assume the instruments are operating properly and no corrective action is required.

Any gaseous analyzer varying more than ±5 percent from its expected value reaches the "warning level" control limit. At this level, closely observe instrument performance and take corrective measures before the analyzer reaches the "action required" level.

An instrument reaches the action level when the automated QC check response for ozone varies more than ±7.1 percent, ±10.1 percent for carbon monoxide and sulfur dioxide, and/or ±15.1 percent for nitrogen dioxide, nitric oxide, or total oxides of nitrogen.

You **MUST** initiate corrective action when an instrument reaches the action level state. At the action level, calibration staff using certified transfer standards must verify that instrument drift is due to an instrument malfunction and not simply a bad automated QC check caused by a problem with the calibration system (i.e. faulty O3 generator or zero air supply). If it is determined that instrument malfunction or instrument drift is the problem, corrective actions must be taken to bring the instrument within acceptable control limits. Document all corrective actions on the instrument maintenance sheets and record all corrective action in the station log.

If an instrument has collected air-monitoring data where drift has been greater than the upper/lower "action level" control limits, you should invalidate the ambient data unless there is compelling evidence for not doing so. Code invalid data using the appropriate AQS null data qualifier code.

10.4 Troubleshooting Guide for Automated Calibrations

Response to Zero/Precision/Span checks on analyzers within $\pm$ 5.1 percent or appropriate zero limits.

- No action necessary

Response to Zero/Precision/Span check on analyzers varies more than $\pm$10.1 percent or $\pm$7.1 percent for ozone.

- Check for proper zero air supply.
- Check 4010 programming and operation.
- Check 4010 output tubing to probe and manifold.
- Check station by-pass pump, if applicable.

O3/NO2 OK; All other parameters (CO, SO2, THC, CH4) greater than $\pm$10.1 percent.

- Check certified station cylinder, regulator output, gas tubing.
- Check manifold connections and individual tubing.

O3/NO2 not OK, other parameters (CO, SO2, THC, CH4) OK.

- Check 4010 ozone generator.
- Check for proper zero total airflow supply.
- Check for proper zero airflow in O3 generator.
- Check individual tubing for O3/NO2 analyzers.
- Check for probe/manifold problems or contamination.
- Check dew point levels of zero air supply.

Table 4 below shows a troubleshooting matrix for gas concentration levels relative to other gases and system components that might be faulty.

CO/SO2	NO	NO2	O3	Probable Cause
Steady	Increasing	Increasing	Steady	NOx Instrument
Decreasing	Steady	Steady	Steady	CO/SO2 Analyzer
Steady	Steady	Increasing	Increasing	4010 Ozone Generator
Decreasing	Decreasing	Decreasing	Steady	MFC 2 (Gas Supply)
Decreasing	Decreasing	Decreasing	Decreasing	MFC 1 (Zero Air Supply)
No Response	No Response	No Response	No Response	4010 not operating
Steady	Steady	Steady	Decreasing	O3 Analyzer
Steady	Steady	Decreasing	Decreasing	4010 Ozone Generator
Steady	Decreasing	Decreasing	Increasing	NOx Analyzer or 4010

Table 4: Nightly Calibration Troubleshooting Guide.

APPENDIX A: AQSB Monthly Quality Control Maintenance Check Sheet 701

SABIO 4010 GAS CALIBRATOR

CALIFORNIA AIR RESOURCES BOARD
MONTHLY QUALITY CONTROL MAINTENANCE CHECK SHEET
SABIO 4010 GAS CALIBRATION SYSTEM

Location: ____________________ Month/Year: ____________________
Station Number: ____________________ Technician: ____________________
Property Number: ____________________ Agency: ____________________

OPERATOR INSTRUCTIONS:

1. Daily checks: Check power.
   Check 4010 display. Verify instrument set for auto calibration.
   Verify 4010 time and date.
   Review nightly auto calibration data.

2. Weekly Checks: Review zero, precision and span readings for all instruments and correct if control limits are exceeded.

3. Monthly Checks: Check and record gas cylinder output pressure (25 PSI)___________
   Check and record gas cylinder pressure (300 PSI) _______________
   Check and record gas-cylinder certification date _________________
   Verify that the cooling fan is operating.
   Inspect air and gas line connections. Replace or repair as necessary.
   Reorder gas cylinder when pressure drops below 300 PSI.

4. Semi-Annual: Perform 4010 calibration/verification. Date last cal: ______________

Date	Comments or Maintenance Performed:

Reviewed by: _____________ Date: _____________

AQSB Maintenance Form 701 (6/2020) Page 1 of 1

APPENDIX B: AQSB Calibration Form 701 (Calibration Summary Page)
SABIO 4010 GAS CALIBRATOR

CARB Calibration Report -- Sabio 4010 Gas Calibration System
Calibration Summary Page

ID Information:

Station Name:	Roseville
Site #:	06-061-0006
Station Address:	151 N Sunrise Ave
Agency:	CARB

Instrument:

Make:	Sabio
Model #:	4010
Property #:	20121939
Serial #:	09400713

Calibration:

"As Is"	X
"Final"	N/A
Calibration Date:	10/12/2019
Prev. Cal. Date:	N/A

Calibration Summary:

	Overall % from True:
Air Flow MFC	0.77%
Gas Flow MFC	0.25%
Sabio Photometer	0.43%
Sabio O3 Generator	2.80%

Meteorology:

Temp. (deg C):	27.2
Atm. Press. (mmHg):	750
Elevation (ft):	190

Station Autocal Gas Standard:

Cylinder #:	CC86172
Output Press. (psi):	33
Cyl. Press. (psi):	1200
CO Conc. (ppm):	498.9
CH4 Conc. (ppm):	5000
NO/NOx Conc. (ppm):	49.46
SO2 Conc. (ppm):	12.9
Analysis Date:	9/20/2014
Expiration Date:	9/30/2016

Expected Concentrations:

Pollutant:	Span Conc. (ppm):	Prec Conc. (ppm):
NO/NOx	0.400	0.100
CO*	4.035	1.009
SO2*	0.104	0.026
CH4*	40.437	10.109
O3 & NO2**	0.320	0.070

NO/NOx values based on Sabio set points

*** Values based on NO gas cylinder ratios to other gases**

**** O3 and NO2 expected based on O3 set points with**

Data Logger:

Make:	CARBLogger
Model:	R610
Barcode:	20061212
Ser. Num:	1362

Comments:	Installation calibration of 4010.
The instrument output plumbed to the station manifold in lieu of directing gas to roof top calibration line.	

Calibrated By:			**Reviewed By:**	

APPENDIX B: AQSB Calibration Form 701 (MFC Calibration Page)

CARB Calibration Report -- Sabio 4010 Gas Calibration System
MFC Calibration Summary Page

Flow Transfer Standard ID:

Make & Model:	4 in 1
Property #:	20081158
Cert. Date:	7/30/2014
Exp. Date:	7/30/2015

Calibration:

Cal. Type:	AS-IS
Calibration Date:	10/12/2019
Previous Cal Date:	N/A

Flow Transfer Standard Equation:

		m:			b:	
0 - 30 lpm MFC:	Air Flow =	0.2008	* Avg. Display	+/-	0.048	SLPM
0 - 100 cc MFC:	Gas Flow =	0.9995	* Avg. Display	+/-	0.495	SCCM

Air Flow Calibration Data -- 20 SLPM MFC:

Manual Flow Setpt.:	18.0	15.0	10.0	5.0	2.0
Sabio Output Flow (Display):	18.05	14.99	10.00	5.00	2.01
Transfer Std. (Display):	88.50	73.90	49.40	24.50	9.60
True Air Flow (SLPM):	17.82	14.89	9.97	4.97	1.98
Diff. from Set Point (SLPM):	0.18	0.11	0.03	0.03	0.02
Percent from Set Point (sccm):	1.01%	0.75%	0.32%	0.65%	1.22%

Gas Flow Calibration Data -- 100 SCCM MFC:

Manual Flow Setpt.:	92.0	82.0	50.0	22.0	12.0
Sabio Output Flow (Display):	92.000	82.000	50.000	22.000	12.000
Transfer Std. (Display):	90.90	82.00	49.20	21.40	11.50
True Air Flow (SLPM):	91.35	82.45	49.67	21.88	11.99
Diff. from Set Point (sccm):	0.65	-0.45	0.33	0.12	0.01
Percent from Set Point (sccm):	0.71%	-0.55%	0.66%	0.53%	0.09%

Air Flow Cal. -- 20 SLPM MFC:

Manual Flow Setpoint: (x)	True Air Flow: (y)	Line Calc.
18.0	17.82	17.85
15.0	14.89	14.88
10.0	9.97	9.92
5.0	4.97	4.97
2.0	1.98	2.00

Air Flow Regression Equation:

TAF (Slope):	0.9907
Setpt. (Intercept):	0.0165

Air Flow Deviation from True:

Sum of Corrected TS Avg:		
	S1:	49.6167
Sum of Photometer Avg:		
	S2:	50.0000
Percent Deviation:		0.77%

Previous Air Calibration Comparison:

Previous TAF (Slope):	1.0000
Percent Change:	0.94%

Gas Flow Cal. -- 100 SCCM MFC:

Manual Flow Setpoint: (x)	True Air Flow: (y)	Line Calc.
92.0	91.35	91.16
82.0	82.45	81.25
50.0	49.67	49.55
22.0	21.88	21.81
12.0	11.99	11.90

Gas Flow Regression Equation:

TAF (Slope):	0.9984
Setpt. (Intercept):	-0.0470

Gas Flow Deviation from True:

Sum of Corrected TS Avg:		
	S1:	257.3475
Sum of Photometer Avg:		
	S2:	258.0000
Percent Deviation:		0.25%

Previous Gas Calibration Comparison:

Previous TAF (Slope):	1.0000
Percent Change:	0.16%

Comments:			
Calibrated by:		Reviewed by:	

AQSB Cal Form 701 (Sabio 4010) Page 2 of 3 October 2019

APPENDIX B: AQSB Calibration Form 701 (Ozone Generator Page)

SABIO 4010 GAS CALIBRATOR

CARB Calibration Report -- Sabio 4010 Calibration System
O3 Gen/Photometer Calibration Summary Page

Ozone Transfer Standard ID.#:

Make & Model:	Tanabyte 322	Span Dial Number:	NA
Property #:	20092667	P/T (On/Off):	On
Serial #:	120	P/T Corr. Value:	NA
Gas Press. (mmHg):	778.00	Air Flow (volts):	NA
Gas Temp. (C):	23.6	Gas Flow (volts):	NA
Air Flow (SLPM):	0.0	Certification Date:	11/26/2014
Air Flow Setting:	0.0	Expiration Date:	5/27/2015

Calibration Info:

Cal. Type:	As-Is
Calibration Date:	10/12/2019
Prev. Calib. Date:	N/A

Sabio Diagontics:

Ozone Block Temp (C):	50.6
Air Flow (SLPM):	10
Ozone Gen. Press. (PSIA):	22.4
Ozone Flow (CCM):	507.9

True Ozone Correction Factor (TOCF):

	m:			b:	
True O3 =	0.9972	* Avg. Display	+/-	0.0001	ppm O3

Calibration Data:

Number	Pre-Zero	1st	2nd	3rd	4th	5th	Post-Zero
Sabio Ozone Gen. Set Point:	0.000	0.400	0.320	0.160	0.070	0.050	0.000
Sabio O3 Lamp Current:	0.62	11.75	11.51	10.39	9.44	9.13	0.63
Sabio Photometer Reading:**	0.000	0.395	0.311	0.153	0.069	0.049	0.000
Transfer Standard Display:	0.000	0.392	0.312	0.155	0.068	0.048	0.000
O3 Std True Ozone (ppm):		0.391	0.311	0.155	0.068	0.048	
O3 Set Pt. from True (%):		2.30%	2.82%	3.45%	3.08%	4.24%	
O3 Set Pt. Diff. from True (ppb):		9	9	5	2	2	

** Reading with Servo mode OFF

Ozone Cal. Summary:

Setpoint: (X)	True O3: (Y)	Best Fit Line calc.
0.400	0.391	0.390
0.320	0.311	0.312
0.160	0.155	0.155
0.070	0.068	0.067
0.050	0.048	0.048

Overall O3 Gen from True:

Sum of Corrected TS Avg:	
S1:	0.9728
Sum of O3 Generator Values:	
S2:	1.0000
Percent Deviation:	2.80%

Overall Photometer from True:

Sum of Corrected TS Avg:	
S1:	0.9728
Sum of Photometer Avg:	
S2:	0.9770
Percent Deviation:	0.43%

Ozone Regression Values:

TOF (Slope):	0.9784
Intercept:	-0.0011

Previous Calibration Comparison:

Previous TOF (Slope):	0.9724
Percent Change:	-0.61%

Comments:			
Calibrated By:		**Reviewed By:**	

AQSB Cal Form 701 (Sabio 4010) Page 3 of 3 October 2019

APPENDIX C: AQSB Calibration Form 701-1 (Interactive MFC)

SABIO 4010 GAS CALIBRATOR

ARB Calibration Report -- Sabio 4010 (Interactive Calibration)

MFC Interactive Calibration Data:

Flow Transfer Standard ID:

Make & Model:	Tylan 4 in 1
Property #:	20003921
Cert. Date:	6/15/2019
Exp. Date:	6/31/2020

Calibration:

Cal. Type:	Interactive
Calibration Date:	12/6/2019
Previous Cal Date:	N/A

Flow Transfer Standard Equation:

		m:			b:	
0 - 30 lpm MFC:	Air Flow =	1.0456	* Avg. Display	+/-	-0.524	SLPM
0 - 100 cc MFC:	Gas Flow =	0.9928	* Avg. Display	+/-	0.3373	SCCM

MASS FLOW CONTROLLER INTERACTIVE CALIBRATION DATA

AIR Mass Flow Controller (LPM)

Control (V)	Monitor (V)	Target SLPM	Transfer Std Display	Xfr Std True Flow Rate	Difference	Accuracy
0.5	0.5043	2.00	2.50	2.09	-0.09	-4.3%
1.0	1.0056	4.00	4.00	3.66	0.34	9.3%
1.5	1.5037	6.00	6.00	5.75	0.25	4.4%
2.0	2.0055	8.00	8.00	7.84	0.16	2.0%
2.5	2.5042	10.00	10.00	9.93	0.07	0.7%
3.0	3.0046	12.00	12.00	12.02	-0.02	-0.2%
3.5	3.5028	14.00	14.00	14.11	-0.11	-0.8%
4.0	4.0044	16.00	16.00	16.21	-0.21	-1.3%
4.5	4.5034	18.00	18.00	18.30	-0.30	-1.6%
	Sigma S1 =	90.00	Sigma S2 =	89.91		

Overall Accuracy:	0.10%	Average Diff. (ppb)	0.010
Correlation:	0.9997	Average Diff. (%)	0.912%
Slope:	4.1127		
Intercept:	-0.2916		

GAS Mass Flow Controller (ccm)

Control (V)	Monitor (V)	Target SCCM	Transfer Std Display	Xfr Std True Flow Rate	Difference (ppb)	Difference (%)
0.5	0.5043	10.0	10.0	10.27	-0.27	-2.6%
1.0	1.0056	20.0	20.0	20.19	-0.19	-1.0%
1.5	1.5037	30.0	30.0	30.12	-0.12	-0.4%
2.0	2.0055	40.0	40.0	40.05	-0.05	-0.1%
2.5	2.5042	50.0	50.0	49.98	0.02	0.0%
3.0	3.0046	60.0	60.0	59.91	0.09	0.2%
3.5	3.5028	70.0	70.0	69.83	0.17	0.2%
4.0	4.0044	80.0	80.0	79.76	0.24	0.3%
4.5	4.5034	90.0	90.0	89.69	0.31	0.3%
	Sigma S3 =	450.0	Sigma S4 =	449.80		

Overall Accuracy:	0.05%	Average Diff. (ppb)	0.023
Correlation:	1.0000	Average Diff. (%)	-0.331%
Slope:	19.8560		
Intercept:	0.3373		

Comments:			
Calibrated by:		Reviewed by:	

APPENDIX C: AQSB Calibration Form 701-1 (Interactive Ozone Generator)

SABIO 4010 GAS CALIBRATOR

ARB Calibration Report - Sabio 4010 (Interactive Calibration)

Ozone Generator Interactive Calibration Summary:

Ozone Transfer Standard ID.#:

Make & Model:	Environics 6103	Span Dial Number:	NA
Property #:	20021227	P/T (On/Off):	On
Serial #:	2878	P/T Corr. Value:	NA
Gas Press. (mmHg):	14.69	Air Flow (volts):	NA
Gas Temp. (C):	30.2	Gas Flow (volts):	NA
Air Flow (SLPM):	2.5	Certification Date:	5/16/2019
Air Flow Setting:	2.5	Expiration Date:	8/15/2020

Calibration Info:

Cal. Type:	Interactive
Calibration Date:	12/6/2019
Prev. Calib. Date:	N/A

Sabio Diagontics:

Ozone Block Temp (C):	
Air Flow (SLPM):	
Ozone Gen. Press. (PSIA):	
Ozone Flow (CCM):	

True Ozone Correction Factor (TOCF):

	m:			b:	
True O3 =	1.0199	* Avg. Display	+/-	0.0008	ppm O3

Ozone Generator Interactive Calibration Data:

Diluent Flow = 10 LPM

Sabio O3 Control Voltage	O3 Monitor Voltage (actual)	Transfer Standard Display (ppb)		Entered Corrected Ozone Value (ppb)
0.2	0.1979	22.3		22.7
0.4	0.3993	63.9		65.2
0.6	0.5996	103.8		105.9
0.8	0.8004	144.5		147.4
1.0	1.0017	184.5		188.2
1.2	1.2012	224.4		228.9
1.4	1.4022	263.1		268.3
1.7	1.7029	315.7		322.0
2.0	2.0059	372.8		380.2
2.3	2.3043	429.5		438.0
2.9	2.9057	540.7		551.5
3.5	3.5096	651.9		664.9
Sigma (S5) =		3317.1	Sigma (S6) =	3383.1

Overall Accuracy:	-1.95%
Correlation:	0.9998
Slope:	193.8335
Intercept:	-8.8236

Comments:				
Calibrated By:			**Reviewed By:**	

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APPENDIX C: AQSB Calibration Form 701-1 (Interactive Photometer)

SABIO 4010 GAS CALIBRATOR

ARB Calibration Report - Sabio 4010 (Interactive Calibration)

Photometer Interactive Calibration Summary:

Ozone Transfer Standard ID.#:

Make & Model:	TAPI 750	Span Dial Number:	NA
Property #:	20021227	P/T (On/Off):	On
Serial #:	2878	P/T Corr. Value:	NA
Gas Press. (mmHg):	14.69	Air Flow (volts):	NA
Gas Temp. (C):	30.2	Gas Flow (volts):	NA
Air Flow (SLPM):	2.5	Certification Date:	5/16/2019
Air Flow Setting:	2.5	Expiration Date:	5/15/2020

Calibration Info:

Cal. Type:	Interactive
Calibration Date:	12/6/2019
Prev. Calib. Date:	N/A

Sabio Diagontics:

Ozone Block Temp (C):	
Air Flow (SLPM):	
Ozone Gen. Press. (PSIA):	
Ozone Flow (CCM):	

True Ozone Correction Factor (TOCF):

	m:			b:	
True O3 =	1.0199	* Avg. Display	+/-	0.0008	ppm O3

Photometer Interactive Calibration Data:

Diluent Flow = 10 LPM

Sabio O3 Control Voltage	O3 Monitor Voltage (actual)	Sabio Photometer Display (ppb)	O3 Transfer Standard Display (ppb)	Entered Corrected Ozone Xfer Value (ppb)	Difference (ppb)	Accuracy (%)
0.2	0.1979	22.5	22.0	22.4	0.1	0.3%
0.4	0.3993	64.5	64.0	65.3	-0.8	-1.2%
0.6	0.5996	103.8	102.0	104.0	-0.2	-0.2%
0.8	0.8004	144.5	143.0	145.8	-1.3	-0.9%
1.0	1.0017	184.5	183.0	186.6	-2.1	-1.1%
1.2	1.2012	224.4	220.0	224.4	0.0	0.0%
1.4	1.4022	263.1	258.0	263.1	0.0	0.0%
1.7	1.7029	315.7	310.0	316.2	-0.5	-0.1%
2.0	2.0059	372.8	367.0	374.3	-1.5	-0.4%
2.3	2.3043	429.5	422.0	430.4	-0.9	-0.2%
2.9	2.9057	540.7	534.0	544.6	-3.9	-0.7%
3.5	3.5096	651.9	640.0	652.7	-0.8	-0.1%
Sigma (S5) =		3317.9	Sigma (S6) =	3330.0		

Overall Accuracy:	-0.36%	**Average Diff. (ppb)**	-1.238
Correlation:	1.0000	**Average Diff. (%)**	-0.409%
Slope:	1.0026		
Intercept:	0.2774		

Comments:			
Calibrated By:		**Reviewed By:**	

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