MODEL 43B

PULSED FLUORESCENCE SO₂ ANALYZER

INSTRUCTION MANUAL

P/N 7672

DESC

MFG

LN

VD

32V, 371

Dana

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I. INTRODUCTION

Thermo Environmental Instrument's Model 43B pulsed fluorescence SO\textsubscript{2} air analyzer is an analytical instrument for continuous, real time measurement of sulfur dioxide. The Model 43B presents a new generation in pulsed fluorescence monitoring technology. The use of pulsed fluorescence for SO\textsubscript{2} monitoring, a technique pioneered by Thermo Environmental Instruments Inc., offers several advantages over other monitoring techniques:

- Specific to SO\textsubscript{2}
- No flames, consumable reactants, or bottles gases required
- Excellent stability
- Simple calibration
- Insensitive to change in flow and temperature
- Totally self contained
- Microprocessor based

The Model 43B has also incorporated a number of significant improvements over other fluorescence monitors currently on the market. These include the following:

- Greater sensitivity
- Lower noise
- Lower flow rate
- Less susceptibility to interference
- Improved optics - reflective filtering
- Optical and electronic span diagnostics

GENERAL THEORY OF OPERATION

Figure 3 illustrates the general principles of pulsed fluorescence SO\textsubscript{2} monitoring.

![Figure 3. Principles of Operation](image-url)
I. Introduction

Pulsating ultraviolet light is bandpass filtered and focused into a fluorescence chamber. Here it excites SO$_2$ molecules into higher energy states. As these states decay, the excited SO$_2$ molecules emit a characteristic radiation. A second filter allows only this radiation to fall on a photomultiplier tube, which converts the radiation into an electrical signal. This signal is then filtered and amplified by the electronics to levels appropriate for display. The physics of SO$_2$ fluorescence, the linearity of the photomultiplier tube, and good instrument design insure that this signal is linearly proportional to the SO$_2$ concentration.

DETAILED THEORY OF OPERATION

Sulfur dioxide absorbs light in three primary regions.

<table>
<thead>
<tr>
<th>Region</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>390 nm - 340 nm</td>
</tr>
<tr>
<td>2</td>
<td>320 nm - 250 nm</td>
</tr>
<tr>
<td>3</td>
<td>230 nm - 190 nm</td>
</tr>
</tbody>
</table>

The first region has not been characterized accurately due to a weak absorption and a heavy quenching of the fluorescent radiation. Sulfur dioxide molecules excited by radiation in Region 2 are strongly quenched by oxygen and nitrogen in air. Region 3 exhibits minimal quenching by air and most other molecules that would be found in polluted air. It is for this reason that the excitation for fluorescence is located in Region 3. The pulsed light source emits ultraviolet radiation at frequencies $\nu_1$. SO$_2$ molecules absorb at these frequencies, producing electronically excited SO$_2^*$.

$$ SO_2 + h\nu_1 \rightarrow SO_2^* $$

Here $h\nu_1$ is a quantum of energy absorbed by the SO$_2$ molecules and $I_a$ is the light intensity absorbed by these molecules. In terms of the incident light, $I_o$, $I_a$ is given by the following equation:

$$ I_a = I_o \left[1 - e^{-\alpha x(SO_2)}\right] $$

Here, $\alpha$ is the absorption coefficient of SO$_2$, $x$ is the path length, and SO$_2^*$ is the concentration of SO$_2$. Having absorbed this radiant energy and been raised to an excited state, the SO$_2$ molecules then release their excess energy and decay back towards their ground state. One such method of decay is fluorescence, in which the SO$_2$ molecules emit radiation at frequencies $\nu_2$ which are different from the absorption frequencies, $\nu_1$. 

I-2
Another method of decay is known as quenching. In quenching, a molecule in the background air collides with an excited SO₂ molecule, robbing the SO₂ molecule of some of its excess energy. This reaction can be expressed as follows:

\[ \text{SO}_2^* + M \xrightarrow{k_q} \text{SO}_2 + M \]

\( M \) is characteristic of the background air. A third method of decay is called dissociation. In this process, the SO₂ molecules actually split apart, as indicated in the following reaction:

\[ \text{SO}_2^* \xrightarrow{k_d} \text{SO} + O \]

Using the above reactions, an expression can be written representing the fluorescent intensity at a detector.

\[ F = \frac{Gk_fI_o \left[1 - e^{-\alpha x (\text{SO}_2)}\right]}{k_f + k_d + k_q [M]} \]

In this equation, \( k_f, k_d, \) and \( k_q \) refer to rate constants of the respective process given above and \( G \) represents a geometric factor which is a function of the fluorescence chamber design. When the SO₂ concentration is relatively low and the path length of exciting light is short, the above expression can be approximated by:

\[ F = \frac{Gk_fI_o\alpha x (\text{SO}_2)}{k_f + k_d + k_q [M]} \]

\( k_f, k_d, \) and \( k_q \), remain relatively constant over a wide range of temperatures and background atmosphere. \( I_o \) can, with proper design, be made constant as well. Since \( G \) and \( x \) depend
I. Introduction

only on the mechanical design of the chamber, they too are constant, permitting the equation to be rewritten as a direct proportionality:

\[ F = K(SO_2) \]

This shows that the fluorescent radiation impinging upon a detector is directly proportional to the concentration of SO\(_2\). This direct proportionality is the basis for the measurement technique used in the Model 43B.

The above derivation did not take into account the effect of other substances besides SO\(_2\) which mimic its fluorescence activity. Chief among these interferents are large organic molecules, such as aromatic hydrocarbons. By careful design and through the use of a Hydrocarbon "Kicker" (developed by RIVM, Netherland, 1984), Thermo Environmental Instruments Inc. has all but eliminated the effects of these interferents.

DESCRIPTION OF ANALYZER

The analyzer section is concerned with the gas flow within the instrument. Figure 4 is a flow schematic of the Model 43B. There is just one inlet port, labeled SAMPLE, on the rear panel of the instrument.

![Gas Flow Schematic](image)

Figure 4. Gas Flow Schematic

The gas flows through the tube side of a Hydrocarbon "Kicker," which removes hydrocarbons from the gas stream while leaving the SO\(_2\) concentration unaffected. It operates on a selective permeation principle, allowing only hydrocarbons molecules to pass through the tube wall. The driving force for the hydrocarbon removal is the differential partial pressure across the wall. This differential pressure is produced within the instrument.
by passing the sample gas through a capillary tube to reduce its pressure and feeding it into the shell side of the Hydrocarbon "Kicker." Exiting the tube side of the "Kicker," the sample flows into the fluorescence chamber, where it undergoes analysis. Since the chamber is at atmospheric pressure, the instrument is insensitive both to small leaks and to moderate variations in flow rate. A flow meter reading greater than 0.4 LPM is satisfactory. The flow rate may be adjusted by changing the capillary. A vacuum gauge is provided to monitor the differential pressure across the Hydrocarbon "Kicker." A differential pressure of at least 10 inches Hg is required to remove all interfering hydrocarbons.

Much attention has been paid to keeping the sample gas in its original condition until analysis. Sample lines are constructed from FEP Teflon. No flow or pressure control hardware is located in the sample line prior to analysis, and the sample flow rate is high, thus minimizing absorption effects.

DESCRIPTION OF OPTICS

The optics section (see Figure 5) begins with a hermetically sealed lamp which is pulsed at a rate of 10 times per second. The lamp is operated in the pulsed mode for six major reasons.

- Long life
- High optical intensity - improved signal to noise ratio
- Small size
- Low power requirements - less than 1 watt
- Long term stability
- Chopped signal processing - no dark current drift

Figure 5. Optics System Schematic
I. Introduction

The light from this lamp is focused with a condensing lens into the mirror assembly. A set of four mirrors selectively reflects only those wavelengths which are of use in exciting SO₂ molecules. This reflective filtering allows the radiation reaching the detection chamber to be both more intense and more stable throughout the lifetime of the instrument. After this reflective filtering, the light passes through a relay lens and into the reaction chamber. A circular baffle helps keep stray light from entering the actual detection volume.

The main detector assembly is located at a right angle to the incoming light. A condenser lens collects and focuses light from fluorescing SO₂ molecules. The light then passes through a bandpass filter which restricts the light reaching the photomultiplier tube to the SO₂ fluorescence wavelengths only.

Facing the light source, at the opposite side of the reaction chamber, is a light trap, which prevents light from reflecting back into the detection volume. At the center of this trap, a hole allows light to reach the photodetector located at the back of the reaction chamber. This photodetector continuously monitors the incident light. It is connected to a circuit which automatically compensates for fluctuations in the flash lamp output.

DESCRIPTION OF ELECTRONICS

The electronics in the Model 43B consists of signal processing, power supply, microcomputer, and temperature control circuits. Referring to Figure 6, the Model 43B electronics block diagram, the photomultiplier tube transforms the light intensity into a current. A preamplifier converts the current into a voltage and this voltage is amplified according to the range setting. From here, the signal passes through an electronic gate which is switched synchronously with the flash lamp pulses. The microcomputer generates the signals used to initiate both the flash trigger and the sampling of the signal.

The microcomputer used in the Model 43B utilizes a Motorola microprocessor. The microcomputer takes data from the input board, manipulates it according to the parameters chosen by the user, stores and remembers all variables and/or options, calculates calibration parameters, determines SO₂ concentrations, and outputs those concentrations to the front panel display and the rear panel analog terminals. It also offers the user a variety of status and troubleshooting outputs.

As noted, a photodetector monitors the light from the lamp. The signal from this detector is compared to a reference signal, and the difference is used to control the voltage to the lamp. In this way, a stable light intensity is maintained throughout the lifetime of the lamp. The lamp voltage may be monitored in the status list. This display indicates lamp voltages between 0 and 1200 volts. For more information about the troubleshooting mode, see Chapter IV, "Operation."
II. SPECIFICATIONS

Ranges
  Standard Mode
  High Range Mode

Signal Averaging Time For:
Noise (RMS value when sampling zero air)
Lower Detectable Limit (LDL)
Analyzer Response Time

Linearity

Precision

Zero Drift

Span Drift

Interferences per EPA levels
  NO
  M-Xylene
  H₂O

Temperature Dependence
  Zero
  Span

Flow

Standard Output

Optional: Two additional analog outputs

Optional: Digital Output

Line Power

Average Power Consumption

Maximum Steady A.C. Line Current

Size and Weight

<table>
<thead>
<tr>
<th></th>
<th>10 SEC</th>
<th>60 SEC</th>
<th>300 SEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 ppb</td>
<td>0.5 ppb</td>
<td>0.25 ppb</td>
<td></td>
</tr>
<tr>
<td>2.0 ppb</td>
<td>1.0 ppb</td>
<td>0.5 ppb</td>
<td></td>
</tr>
<tr>
<td>80 sec</td>
<td>110 sec</td>
<td>320 sec</td>
<td></td>
</tr>
</tbody>
</table>

±1 % of fullscale

1% of Reading or 1 ppb

Less than 1 ppb per day

± 1% per day

Less than LDL except for the following
  Less than 3 ppb
  Less than 2 ppb
  Less than 2% of reading

± 0.1 ppb/°C

± 0.1% / °C

0.5 LPM (Standard), 1 LPM (optional)

Dual: Selectable Voltage

Selectable Voltage, 4-20 mA isolated,
4-20 mA non-isolated

RS-232

115 V/60 Hz and 220 V/50 Hz versions

100 Watts

1.3 Amp (115 V)

17"W x 8 3/4"H x 23"D  44 lbs.
IV. OPERATION

This Chapter describes the operation of the Model 43B. There are three general modes of operation, the normal sampling mode, the troubleshooting mode, and the optional RS-232 communication mode. The instrument is typically operated in the normal sampling mode. The troubleshooting mode allows the user access to more detailed information concerning the instrument. This is useful when troubleshooting the instrument. In the optional RS-232 communication mode, the instrument is controlled remotely.

STARTUP

1. Push the power switch on the front panel of the instrument to the on position. The pump should now be powered, and the lamp should begin to flash within five minutes.

2. Open the front panel and verify that the vacuum reading on the gauge is greater than 17 inches Hg.

3. Allow approximately 30 minutes for the instrument to stabilize.

4. Before beginning actual monitoring, perform a multi-point calibration using the procedures outlined in Chapter V, "Calibration."

FRONT PANEL DISPLAY

The seven-segment displays are used to show SO₂ concentrations, instrument parameters, and messages. The decimal point blinks each time the SO₂ concentration is updated. There are also ten LEDs, the eight LEDs along the bottom of the display correspond directly with the pushbuttons below them. When a pushbutton is pressed, the corresponding LED will turn on, indicating the current instrument operation. A blinking LED means the instrument is in the troubleshooting mode. The remaining two LEDs are only used with the optional zero/span valves. These LEDs indicate which valve is activated.

FRONT PANEL PUSHBUTTONS

There are eight pushbuttons which enable the user to control the Model 43B.

Z/FS Pushbutton

The zero/fullscale pushbutton together with the trim potentiometers on the D/A board allow the analog outputs to be adjusted to agree with the front panel display. The outputs may be toggled between zero and fullscale, by pressing the Z/FS pushbutton. When the display reads zero, the output should be zero volts. This can be checked with a voltmeter and adjusted if necessary with potentiometers R1 and R3 on the D/A board (see Figure 13). When the display reads fullscale, the output should be 10 volts (for a standard instrument). Potentiometers R2 and R4 on the D/A board are used to adjust the output to fullscale. A
IV. Operation

DAC ramp may be generated by pressing the - or + pushbutton after first actuating the Z/FS pushbutton. To start the DAC ramp, the output must be at zero as displayed on the front panel. The ramp can be paused at any value between -2.3% fullscale and 100% fullscale, by pressing the - or + pushbutton. To resume the ramp in either direction, press the - or + pushbutton again.

CAL Pushbutton

The calibration pushbutton is used to enter zero and span values during calibration of the instrument. When the CAL pushbutton is pressed, the display continues to show the SO$_2$ concentration, except that it represents the 300 second moving average instead of the averaging interval used in the sampling mode. This reading should be allowed to stabilize after a known concentration of zero or span gas is introduced into the instrument. The - and + pushbuttons are used to enter the SO$_2$ concentration, by counting up or down to the desired value. The ENT pushbutton accepts the known value and the computer calculates and applies the appropriate correction. The LED above the CAL pushbutton turns off and the instrument returns to the sampling mode displaying a "Store" message. The ENT pushbutton is used to store the correction. For detailed information about calibration, see Chapter V, "Calibration."

ENT Pushbutton

The enter pushbutton has several functions. One function is to accept parameters that have been selected using the - and + pushbuttons, such as offset levels. This pushbutton is also used to toggle modes, such as the Troubleshooting mode in the status list and to initiate a store command, when prompted.

-/+ Pushbuttons

The increment and decrement pushbuttons are used to select operating parameters. There are two ways these pushbuttons are used; (1) to go up or down in a pre-programmed list of parameter values, such as those for range and time constant, (2) to enter a parameter by counting up or down to the value desired, such as span and offset values.

DISP Pushbutton

The display pushbutton is used when in the status list or performing a calibration. This pushbutton allows the display to be scrolled back one level.

STAT Pushbutton

The status pushbutton displays the current operating parameters set for the Model 43B. It is used to change and/or check the parameters under which the instrument is operating. These parameters are displayed upon successive engagement of the STAT pushbutton (see Figure 12). The DISP pushbutton can be used to recall the previously displayed parameter.
<table>
<thead>
<tr>
<th>STATUS LIST</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BASIC</strong></td>
<td><strong>EXTENDED</strong></td>
</tr>
<tr>
<td>FSCALE</td>
<td>remote status (DIP switch 1 on)</td>
</tr>
<tr>
<td>XXXX</td>
<td>fullscale message</td>
</tr>
<tr>
<td>1. XXXX</td>
<td>fullscale range 1</td>
</tr>
<tr>
<td>2. XXXX</td>
<td>fullscale range 2 (DIP switch 5 on)</td>
</tr>
<tr>
<td>SEC.</td>
<td>averaging time message</td>
</tr>
<tr>
<td>1. XXXX</td>
<td>averaging time for output 1</td>
</tr>
<tr>
<td>2. XXXX</td>
<td>averaging time for output 2</td>
</tr>
<tr>
<td>trb. on</td>
<td>troubleshooting mode</td>
</tr>
<tr>
<td>b. XXXX</td>
<td>zero background</td>
</tr>
<tr>
<td>SF. XXXX</td>
<td>span factor 1</td>
</tr>
<tr>
<td>F1. XXXX</td>
<td>span factor 2 (DIP switch 5 on)</td>
</tr>
<tr>
<td>LED off</td>
<td>optical test LED</td>
</tr>
<tr>
<td>L. XXXX</td>
<td>lamp voltage</td>
</tr>
<tr>
<td>XXXXX</td>
<td>lamp intensity</td>
</tr>
<tr>
<td>r.c. XXXX</td>
<td>reaction chamber temperature</td>
</tr>
<tr>
<td>r. c. XX</td>
<td>temperature correction control (DIP switch 4 on)</td>
</tr>
<tr>
<td>t. on</td>
<td>pressure correction control (DIP switch 4 on)</td>
</tr>
<tr>
<td>Pr. on</td>
<td>internal instrument temperature (DIP switch 4 on)</td>
</tr>
<tr>
<td>P. C. XXXX</td>
<td>internal instrument pressure (DIP switch 4 on)</td>
</tr>
<tr>
<td>Q. 00</td>
<td>analog offset voltage</td>
</tr>
<tr>
<td>dFRULT</td>
<td>default command</td>
</tr>
<tr>
<td>rECALLL</td>
<td>recall command</td>
</tr>
<tr>
<td>Store</td>
<td>store command</td>
</tr>
<tr>
<td>dS. 1-B</td>
<td>DIP switch status</td>
</tr>
<tr>
<td>XXXXXXX</td>
<td>program number</td>
</tr>
</tbody>
</table>

Figure 12. Status List

Remote Status. If the remote option is installed in the instrument, this item is at the beginning of the status list. The remote status allows the remote option to be turned on and off, through the use of the ENT pushbutton.
**Fullscale Message.** The fullscale message is included in the status list to indicate that the following one or two (depending on mode) items is the fullscale range parameter(s).

**Fullscale Range.** There will be two ranges displayed in the status list unless the dual range mode is disabled (DIP switch 5 is off). If the dual range mode is disabled, then only one fullscale range will be displayed and used. The dual range mode allows the sample to be analyzed at two different fullscale ranges. For example analog output 1 could have a fullscale range of 10 ppm while analog output 2 could have a fullscale range of 5 ppm. The - and + pushbuttons are used to select the fullscale range. The ranges available are 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, and 10.0 ppm (if DIP switch 2 is off, the above ranges are multiplied by 10).

**Averaging Time Message.** The averaging time message is included in the status list to indicate that the two following items are the averaging time intervals (in seconds).

**Averaging Time.** The analog output is presented as a rolling average. The averaging time is user selectable. The analog output is updated every ten seconds for all averages. This is indicated by the blinking decimal point. The - and + pushbuttons are used to select the available averaging times of 10, 20, 30, 60, 90, 120, and 300 seconds.

**Troubleshooting Mode.** The troubleshooting mode can be toggled on and off with the ENT pushbutton. This mode provides an extended list of parameters and messages in the status list that may be helpful in troubleshooting.

**Zero Background.** The zero background is given in ppm. This background is determined during calibration of the instrument. Typical values are below 0.050 ppm.

**Span Factor.** The Span Factor is the correction factor for span gas determined during calibration. It normally is set near unity. As the instrument is operated, the Span Factor tends to increase as a result of window, filter, and lamp degradation.

**Optical Test LED.** The optical test LED can be used to check the viability and condition of both the reaction chamber optics and the PMT. The optical test LED is located within the fluorescence chamber of the Model 43B. It may be toggled on or off through the use of the ENT pushbutton. The LED emits a light intensity that simulates a particular concentration of SO₂. The optical test LED intensity can be adjusted by potentiometer R5 on the counter board (see Figure 13).

**Lamp Voltage.** The lamp voltage reading gives a measure of the voltage being supplied to the flash lamp. The Model 43B is equipped with a lamp voltage control circuit, which automatically corrects for the degradation of the flash lamp with age. As the light output from the lamp falls, the lamp voltage control circuit causes the lamp to be driven with a higher voltage, thereby keeping the light intensity constant. The lamp voltage is factory set at 800 volts, but after several years of use, the lamp will likely have degraded to the point that it is being driven with the maximum voltage (1200 V) that the power supply can deliver. It will be necessary at this time to either replace the lamp or adjust the lamp voltage control
circuit. For the procedure on adjusting the lamp voltage control circuit, see Chapter VIII, "Servicing."

*Lamp Intensity.* The Lamp Intensity gives a measure of the brightness of the lamp. Typical lamp frequencies exceed 10,000 Hertz. Below this level, the lamp voltage needs to be adjusted, or the lamp replaced.

*Reaction Chamber Temperature.* The reaction chamber is heated to approximately 45°C. The status display gives the chamber temperature in °C. Readings below or above this value may be the result of a faulty thermistor or the heater control circuit.

*Temperature Correction Control.* By monitoring the internal temperature of the analyzer, additional temperature stability can be achieved. Although the Model 43B does not require temperature compensation for EPA equivalency, for special applications, or when operating the instrument outside the designated temperature range, this compensation can be used. The temperature correction can be toggled on or off using the ENT pushbutton.

*Internal Instrument Temperature.* The internal temperature display is typically about 5 °C above ambient temperature. With temperature correction set off, a standard temperature of 30 °C is used.

*Analog Offset Voltage.* The analog output zero voltage can be offset by a user selected percentage. This is useful when a recorder does not have offset capability, or when doing long term drift studies. The fullscale output will be decreased by the same percentage as the zero offset.

*Default Command.* The default command enters default instrument parameters to the computer, through the use of the ENT pushbutton. Default values for the zero background of 0 ppm, and 1.000 for the span factor are used.

*Recall Command.* The Recall function allows the user to recall the most recently stored parameters. If the user is experimenting with time settings, ranges, etc. but then wishes to go back to original settings, this function should be used in combination with the ENT pushbutton.

*Store Command.* The Store function is used to store instrument parameters. After calibrating the analyzer or any instrument parameters have been changed, the user should use this function, in combination with the ENT pushbutton to save (store) the new parameters.

*DIP Switch Settings.* The DIP switch settings on the PIA board are given by the flashing LEDs over the eight pushbuttons. If the LED is on, the corresponding DIP switch is on. See "Internal DIP Switch," later this chapter for more information about the DIP switch functions.
**IV. Operation**

*Program Number.* The last message gives the number of the program used in the analyzer. Prior to contacting the factory, the user should note this number.

**RUN Pushbutton**

The run pushbutton cancels any operation which the instrument may be performing and returns the instrument to the normal sampling mode.

**INTERNAL DIP SWITCH**

The PIA board (see Figure 13) contains an eight station SPST DIP switch. Viewing from the front panel, this DIP switch is located at the top right-hand side of the board.

![Diagram of Microcomputer Assembly](image)

Figure 13. Microcomputer Assembly
V. CALIBRATION

This chapter describes the procedures for analog output adjustments, multi-point calibrations, two-point calibrations, and zero and span checks. The Model 43B requires initial and periodic calibration according to the procedures described herein. The instrument user should have a quality control plan which allows for modification of the frequency and number of points required for calibration depending upon calibration, span, and zero check data collected over a period of time. Such a quality control program is essential to ascertain the accuracy and reliability of the air quality data collected and to alert the user if the accuracy or reliability of the data should become unacceptable. The data compiled for such a program might include items such as dates of calibration, atmospheric conditions, control settings and other pertinent data. For more detailed quality assurance guidelines, see the *Quality Assurance Handbook for Air Pollution Measurement Systems*, published by the U.S. EPA, Research Triangle Park, NC, 27711.

There are a number of conditions which should be met prior to a calibration or a zero/span check. First of all, the instrument should have had at least a half hour to warm up and stabilize. In addition, the range used during the calibration or zero/span check should be the same as that used during normal monitoring. Thirdly, all operational adjustments to the instrument should have been completed prior to calibration. Fourthly, all parts of the gas flow system, such as sample lines, particulate filters, etc., which are used in normal monitoring should also be used during calibration. Finally, it is recommended that the recording devices and outputs used during normal monitoring be calibrated prior to the instrument calibration and that they be used during the calibration or the zero/span check.

ZERO GAS GENERATION

An SO$_2$-free (<0.0005 ppm) air supply is required for the proper calibration and checkout of the monitor. There are several methods that are acceptable to generate this "zero air."

Commercial Heatless Air Dryers

Commercial heatless air dryers filled with a mixed bed of activated charcoal and a 13X molecular sieve have been found effective in removing SO$_2$ from compressed air. The use of this type of "zero air" system is recommended when minimum maintenance is of prime importance. This system requires a source of compressed air. Refer to the manufacturer's recommendations for installation of such a system.

Absorbing Column

An absorbing column packed with specially prepared iodated or brominated activated charcoal (TEI P/N 4146) has been found to be acceptable for scrubbing SO$_2$ from ambient air. Ambient air is forced through a laboratory gas absorption column packed with the special charcoal and the SO$_2$ is removed to acceptable (<0.0005 ppm) levels. The charcoal should be changed every 6 months or more frequently depending on local conditions.
V. Calibration

SPAN GAS GENERATION

The span gas generator must be capable of providing an accurate, stable, and reliable concentration of SO\textsubscript{2} for at least 5 concentrations equally spaced between zero and full scale. It must provide a flow of at least 0.8 LPM for an instrument with the standard flow (instruments with higher flowrates will require a higher minimum flow). There are several methods available for such a span gas generator.

Precision Dilution System

Commercial precision dilution systems are available which reliably and accurately dilute a high concentration gas mixture to provide a reliable span gas. A high concentration (50 ppm) of SO\textsubscript{2} in air is precisely diluted to the concentration range required. The Thermo Environmental Instruments Inc. Model 146 Multigas Calibration System is one such system for precision dilution.

Permeation Tube System

Permeation tube systems which will precisely maintain a set temperature to within 0.1 °C and hold a zero air flow rate to within 0.5% can be used for generation of span gas. The flow rate of the permeation system must be at least 0.8 LPM for proper operation. Commercial permeation systems, such as the Thermo Environmental's Model 143 Multipoint Permeation Tube Calibrator and Model 146 Multigas Calibration System, are available for this requirement. Refer to the instrument manufacturer's instructions for proper use of such systems.

CALIBRATION GAS GENERATION

The calibration gas generator should be capable of providing accurate levels of SO\textsubscript{2} calibration gas between zero and 80% of the full scale range. It must provide a flow rate of at least 0.8 LPM for an instrument with the standard flow (instruments with higher flowrates will require a higher minimum flowrate). All calibration gas should be, or should be derived from local or working standards (eg., cylinders of compressed gas or permeation devices) that are certified as traceable to an NIST primary standard.

ANALOG OUTPUT ADJUSTMENT

Check that the front panel meter indicates the same value as the rear panel recorder outputs. If the values differ by greater than 1%, the recorder outputs should be adjusted. The following procedure adjusts the recorder outputs:

1. Press the Z/FS pushbutton once. Using a small screwdriver, adjust potentiometers R1 and R3 on the D/A board, so that zero volts appears at the recorder outputs.

2. Press the Z/FS pushbutton a second time. Adjust potentiometers R2 and R4 on the D/A board, so that the fullscale voltage appears at the recorder outputs.
MULTI-POINT CALIBRATION

This procedure should be performed:

- When the instrument is newly installed
- When the instrument is moved to a new location
- Upon interruption of normal instrument operation for more than a few days
- After any major repair
- Whenever span and zero shift by more than 15%
- At least once a quarter (four times a year) as per EPA regulations

1. Connect a source of zero air to the appropriate bulkhead (see Figures 8 and 9), SAMPLE in the standard instrument and ZERO in instruments with the solenoid valve option. Gas must be supplied to the instrument at atmospheric pressure, it may be necessary to employ an atmospheric bypass plumbing arrangement to accomplish this (see Figure 7). If a filter is used, the gas must enter the analyzer through the filter. If the zero/span valve option is installed, the RUN pushbutton is used to activate the zero and span valves. The "zero" and "span" LEDs on the front panel display indicate which valve is activated.

2. Check the flowmeter for a flow of about 0.5 LPM and check the vacuum gauge for a reading of greater than 17 inches Hg.

3. Sample zero air and wait for the instrument to come to a stable reading (usually 5 - 8 minutes).

4. Press the CAL pushbutton to display the five minute average. This reading should agree with the reading in the sampling mode. Press the CAL pushbutton again to display the zero prompt and press the ENT pushbutton. The computer will calculate, apply, and store a zero background correction. The LED above the CAL pushbutton will turn off and the instrument will display a "Store" message. Press the ENT pushbutton to store the correction. The instrument will then return to the normal sampling mode and will be displaying the corrected zero concentration.

5. Connect SO₂ span gas (80 % of fullscale range) to the appropriate bulkhead (see Figures 8 and 9), SAMPLE in the standard instrument and SPAN in the instruments with the solenoid valve option. Gas must be supplied to the instrument at atmospheric pressure, it may be necessary to employ an atmospheric bypass plumbing arrangement to accomplish this. If a filter is used, the gas must enter the analyzer through the filter. If the zero/span valve option is installed, the RUN pushbutton is used to activate the zero and span valves. The "zero" and "span" LEDs on the front panel display indicate which valve is activated.

6. Again, check the flowmeter for a flow of about 0.5 LPM and check the vacuum gauge for a reading greater than 17 inches Hg.
V. Calibration

7. Sample span gas and wait for the instrument reading to stabilize.

8. Adjust the PMT high voltage using the PHOTOMULTIPLIER GAIN potentiometer on the test panel so that the instrument reads the known SO₂ concentration.

9. Repeat steps 1 to 8 until no adjustments is required to have the instrument read the known concentration.

10. Allow instrument to come to a stable reading (approximately 10 minutes).

11. For the final adjustment, press the CAL pushbutton once to display the five minute average. This reading should agree with the reading in the normal sampling mode. Press the CAL pushbutton two more times. Now the span concentration can be entered into the computer. The + and - pushbuttons are used to increment/decrement the concentration. Once the correct value is being displayed, the ENT pushbutton is used to enter the value to the computer. The computer will calculate, apply, and store a span correction. The instrument will return to the normal sampling mode and will now display the corrected span concentration.

12. Generate five SO₂ concentrations equally spaced between zero and the concentration above.

13. Record instrument reading after allowing time for both gas generation system and instrument to stabilize.

14. Repeat steps 12 and 13 for all concentration points.

15. Put instrument in zero mode as in step 1. Allow the instrument to come to a stable reading and record as zero.

16. Plot a graph of instrument reading against the SO₂ concentrations generated. This is the instrument calibration curve.

17. All future measurements should be interpreted using this curve.

TWO-POINT CALIBRATION

This procedure should only be performed when operating the Model 43B in a non-EPA conformance application.

1. Connect a source of zero air to the appropriate bulkhead (see Figures 8 and 9), SAMPLE in the standard instrument and ZERO in instruments with the solenoid valve option. Gas must be supplied to the instrument at atmospheric pressure, it may be necessary to employ an atmospheric bypass plumbing arrangement to accomplish this (see Figure 7). If a filter is used, the gas must enter the analyzer through the filter. If the zero/span valve option is installed, the RUN pushbutton is used to activate the zero and span
solenoid. The "zero" and "span" LEDs on the front panel display indicate which valve is activated.

2. Check the flowmeter for a flow of about 0.5 LPM and check vacuum gauge for a reading of greater than 17 inches Hg.

3. Sample zero air and wait for the instrument to come to a stable reading (usually 5 to 8 minutes).

4. Press the CAL pushbutton to display the five minute average. This reading should agree with the reading in the sampling mode. Press the CAL pushbutton again to display the zero prompt and press the ENT pushbutton. The computer will calculate, apply, and store a zero background correction. The LED above the CAL pushbutton will turn off and the instrument will display a "Store" message. Press the ENT pushbutton to store the correction. The instrument will then return to the normal sampling mode and will be displaying the corrected zero concentration.

5. Connect SO$_2$ span gas (80% of full scale range) to the appropriate bulkhead (see Figures 8 and 9), SAMPLE in the standard instrument and SPAN in the instruments with the solenoid valve option. Gas must be supplied to the instrument at atmospheric pressure, it may be necessary to employ an atmospheric bypass plumbing arrangement to accomplish this. If a filter is used, the gas must enter the analyzer through the filter. If the zero/span valve option is installed, the RUN pushbutton is used to activate the zero and span valves. The "zero" and "span" LEDs on the front panel display indicate which valve is activated.

6. Again, check the flowmeter for a flow of about 0.5 LPM and check the vacuum gauge for a reading greater than 17 inches Hg.

7. Sample span gas and wait for the instrument reading to stabilize.

8. Adjust the PMT high voltage using the PHOTOMULTIPLIER GAIN potentiometer on the test panel so that the instrument reads the known SO$_2$ concentration.

9. Repeat steps 1 to 8 until no adjustments is required to have the instrument read the known concentration.

10. Allow instrument to come to a stable reading (approximately 10 minutes).

11. For the final adjustment, press the CAL pushbutton once to display the five minute average. This reading should agree with the reading in the normal sampling mode. Press the CAL pushbutton two more times. Now the span concentration can be entered into the computer. The + and - pushbuttons are used to increment/decrement the concentration. Once the correct value is being displayed, the ENT pushbutton is used to enter the value to the computer. The computer will calculate, apply, and store a span correction. The instrument will return to the normal sampling mode and will now
display the corrected span concentration.

**ZERO/SPAN CHECK**

This section describes the procedure for performing zero and span checks. This procedure is normally performed before and after a sampling period and any time a quick check of the accuracy of the instrument is desired. Normally, zero and span are checked daily. As the user gains experience with the analyzer, the frequency of these checks can be adjusted accordingly. The span gas concentration used in the span check should be between 70% and 90% of the fullscale range. The zero and span drift should be measured and recorded prior to making any adjustments. In this, zero and span drift can be verified.

1. Connect a source of zero air to the appropriate bulkhead (see Figures 8 and 9), SAMPLE in the standard instrument and ZERO in instruments with the solenoid valve option. Gas must be supplied to the instrument at atmospheric pressure, it may be necessary to employ an atmospheric bypass plumbing arrangement to accomplish this (see Figure 7). If a filter is used, the gas must enter the analyzer through the filter. If the zero/span valve option is installed, the RUN pushbutton is used to activate the zero and span solenoid. The "zero" and "span" LEDs on the front panel display indicate which valve is activated.

2. Check the flowmeter for a flow of about 0.5 LPM and check vacuum gauge for a reading of greater than 17 inches Hg.

3. Sample zero air and wait for the instrument to come to a stable reading (usually 5 to 8 minutes).

4. Record the measured SO₂ value as the zero drift since the last adjustment. If the zero has changed by more than ± 0.015 ppm, it is recommended that a new multi-point calibration be performed.

5. Connect SO₂ span gas (80 % of fullscale range) to the appropriate bulkhead (see Figures 8 and 9), SAMPLE in the standard instrument and SPAN in the instruments with the solenoid valve option. Gas must be supplied to the instrument at atmospheric pressure, it may be necessary to employ an atmospheric bypass plumbing arrangement to accomplish this. If a filter is used, the gas must enter the analyzer through the filter. If the zero/span valve option is installed, the RUN pushbutton is used to activate the zero and span valves. The "zero" and "span" LEDs on the front panel display indicate which valve is activated.

6. Again, check the flowmeter for a flow of about 0.5 LPM and check vacuum gauge for a reading of greater than 17 inches Hg.

7. Sample span gas and wait for the instrument reading to stabilize.

8. Record the difference between the measured SO₂ value and the actual SO₂ span
concentration used. This is the span drift since the last adjustment. If the
calibration has changed by more than ± 10%, a new multi-point calibration should
be performed.