STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME II

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

APPENDIX C

THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

MONITORING AND LABORATORY DIVISION

SEPTEMBER 1984

TABLE OF CONTENTS

APPENDIX C

THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

TABLE OF CONTENTS (cont.)

APPENDIX C

THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

APPENDIX C

THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

FIGURES

Page

TABLES

STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME II

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

APPENDIX C.1

STATION OPERATOR'S PROCEDURES

FOR

THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

MONITORING AND LABORATORY DIVISION

FEBRUARY 1984

C.1.0 GENERAL INFORMATION

C.1.0.1 THEORY

The Thermo Electron sulfur dioxide analyzer measures the amount of fluorescence given off by SO_2 after its absorption of ultraviolet light. The fluorescent measurement is proportional to the SO_2 concentration. A detailed discussion of the scientific basis of the analyzer measurement principle is contained in the Manufacturer's Instruction Manual.

This Appendix supplements the Manufacturer's Manual with the instructions for servicing and troubleshooting the analyzer. Separate appendices present acceptance test and calibration procedures for the analyzer.

C.1.0.2 ANALYTICAL CYCLE

The following procedure describes flows and analysis of an air sample entering the sample port (see Figure C.1.0.1).

The sample flows through the sample port to the tube side of the permeation dryer. Using the differential partial pressure of water and selective permeation, the dryer removes water without affecting the SO_2 concentration. Exiting the dryer, the sample flows through a pressure reducing capillary and on through the hydrocarbon cutter. The cutter removes aromatic hydrocarbons, which fluoresce at the same wavelength as SO_2. The sample then enters the fluorescent chamber.

Filtered and pulsed ultraviolet light is focused through an ultra- violet interference filter into the chamber. Here the light excites the SO_2 molecules causing them to give off their characteristic decay radiation. A bandpass filter allows only this radiation to fall on a photomultiplier tube (PMT) where it is converted into an electrical signal. The preamp integrates the current flow into a voltage waveform. The signal then proceeds through an electronic gate to filter out high frequency noise. This gate is switched on synchronously with the ultraviolet light source. An adjustable time response filter is provided before the signal goes to the PPM meter and recorder output. For calibration, the high voltage to the PMT or the gain on the final amplifier is adjusted to make the analyzer agree with known SO_2 concentrations. Signals resulting from scattered light, background radiation detected with no SO_2 present, are suppressed using the zero pot.

On leaving the chamber, the sample flows through the flowmeter, the vacuum regulator, the shell side of the dryer, the sample pump and out the exhaust. The vacuum regulator controls the absolute pressure in the chamber. The vacuum applied to the dryer shell is full pump vacuum (~20" Hg). For further details refer to the manufacturer's instruction manual.

C.1.0.3 CAUTIONS

1. Light from this analyzer's ultraviolet lamp can burn the eyes. Use protective glasses to view the lamp or look at it only for a few seconds at distances of two or more feet. Do not touch the lamp face.

2. The analyzer contains a 1000-volt direct current (VDC) power for supply for the UV lamp, a -1000 to -2000 VDC power supply for the photomultiplier tube, and 115 VAC at the input terminals to the PMT power supply. When working on this analyzer use all high voltage precautions.

3. Use a third wire ground on this analyzer.

4. The hydrocarbon cutter contains a specified amount of fine light green catalyst material. Do not disassemble the cutter, as material may be lost.

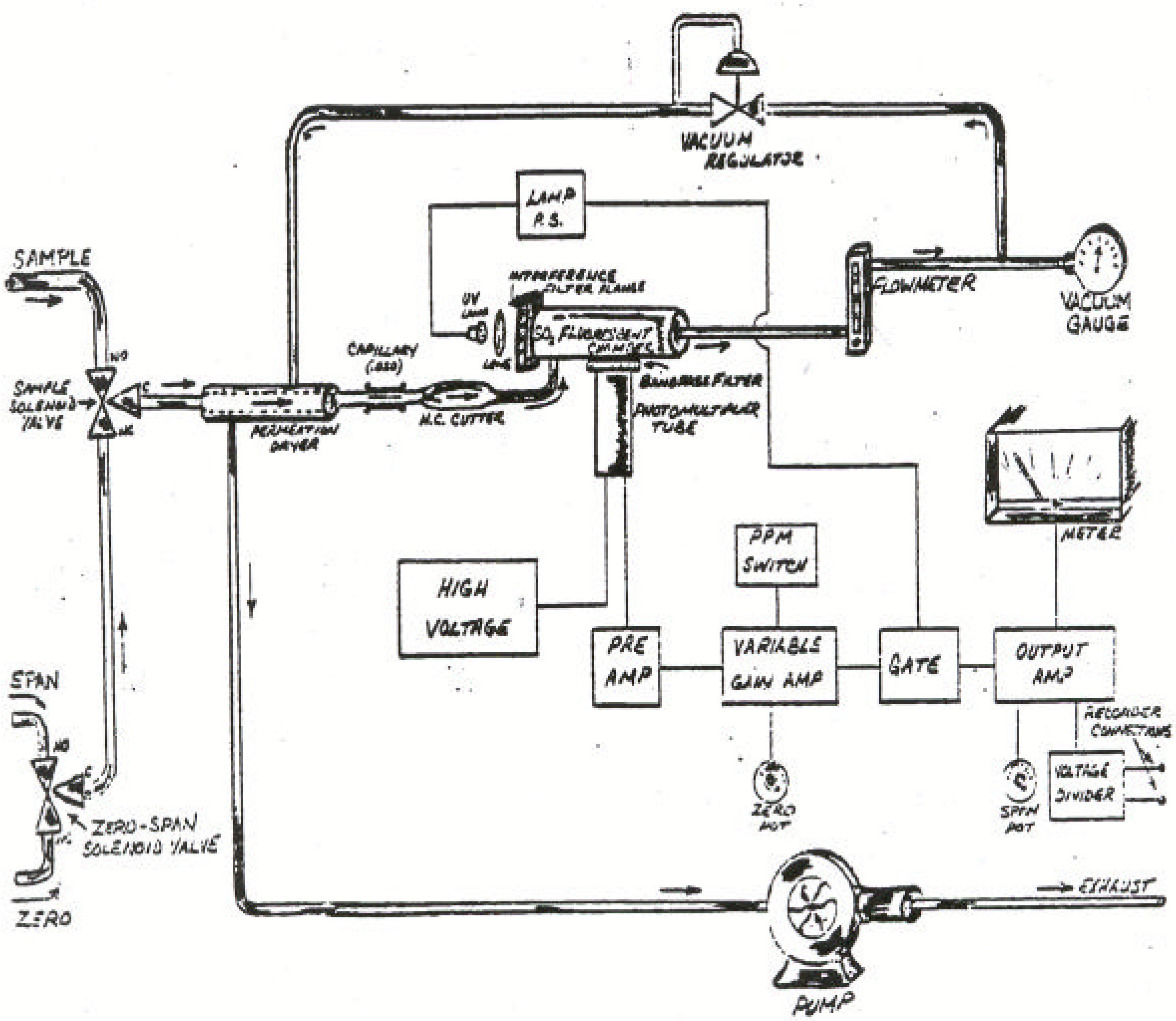

Figure C.1.0.1
Model 43 Gas Flow/Electronics Diagram

C.1.1 ROUTINE SERVICE CHECKS

C.1.1.1 GENERAL INFORMATION

Perform the following routine service checks using the attached schedule (Table C.1.1.1) and the procedures documented below and in Section C.1.2. Checks may be performed more frequently but should be performed at least at the prescribed intervals. Attached is a copy of the Monthly Quality Control Maintenance Checksheet (Figure C.1.1.1) which you should complete weekly and forward monthly to your supervisor. Use of control limits is explained in Section C.1.2.3.

C.1.1.2 DAILY CHECKS

1. Verify that the flow meter reads the correct flow as indicated on the most recent calibration report. Record the flow meter reading weekly.

2. Verify that the mode selector switch is in "SAMPLE".

3. Verify that the range selector switch is set to 0.5 ppm.

C.1.1.3 WEEKLY CHECKS

Record the as found and final readings on the Monthly Quality Control Maintenance Checksheet.

1. System Pressure - Check that the gauge pressure indicates -10.0 inches Hg. Adjust if necessary.

2. Leak Check - Perform a leak check of the analyzer using the procedure in Section C.1.2.1.

3. Sample Inlet Particulate Filter - At least once a week, replace the teflon sample particulate filter. Note the filter cleanliness and adjust the replacement frequency accordingly. Change the filter if even a slight particulate coating or discoloration is visible.

4. Scattered Light Level - Note the zero pot setting (when sampling zero air) and then turn the dial fully counterclockwise (000). Record the scattered light level, in ppm, on the checksheet, and then return the zero pot to its initial setting. If the scattered light level is greater than 0.15 ppm, replace

the UV interference filter. If this does not work, notify the Electronics Instrument Repair Lab in Sacramento for assistance, (916) 324-1847.

5. Zero and Span Check - Perform an analyzer zero and span check after the above weekly checks have been performed, using the procedures in Section C.1.2.3. At those sites without automatic daily calibration systems, complete the weekly portion of the checksheet. Record all PPM values in the lower part of the appropriate blocks and the pot settings in the upper part of the appropriate blocks (see Figure C.1.1.1). At those sites with automatic calibrators, the SO2 value is not to be recorded on the analyzer's checksheet since it appears on the calibrator checksheet.

C.1.1.4 MONTHLY CHECKS

1. Capillary and "O"-Ring -Remove the glass capillary and rubber "O"-ring. Replace the "O"-ring if it is cracked and/or deteriorated. Push a thin wire through the capillary to clear it of particulates. Then rinse the capillary with alcohol and let it dry. Reassemble the capillary and "O"-ring and record the date of inspection on the checksheet.

2. Electrical Span - Using the procedures in Section C.1.2.2, check the amplifier and output signal voltages. Adjust if necessary. Record the results and the date of the check on the checksheet.

3. Switch Positions - Check and record on the checksheet the positions of the response time switch, SW1, and photomultiplier tube (PMT) high voltage coarse gain switch. The response time switch should be set to the center position (four minute time response). The PMT voltage switch should be set in the position indicated on the most recent calibration report.

4. Multipoint Calibration - Monthly, record the date a multipoint calibration was last performed on the analyzer. Before six months have passed since the last analyzer calibration, contact your supervisor to arrange for a multipoint calibration.

C.1.1.5 SEMI-ANNUAL CHECKS

Cooling Fan and Filter - Remove the screws holding the metal filter screen to the rear panel. Remove the screen and soak it in a weak detergent solution to remove all particulates. Rinse with clean water and air dry. Wipe off the residue from the rear fan face with a clean cloth. Reassemble and record the date cleaned on the checksheet.

C.1.1.6 ANNUAL CHECKS

Replace the brominated charcoal filter (zero filter) used for zeroing the Model 43 once a year. Upon receipt of your new filter, return the old filter unit to the Sacramento Support Facility. Affix a date sticker to the new filter.

C.1.1.7 EIGHTEEN-MONTH CHECKS

Replace the hydrocarbon cutter. Upon receipt of your new cutter, return the old cutter to the Sacramento Support Facility. Affix a dated tag to the new cutter.

Table C.1.1.1

Thermo Electron Model 43 SO_2 Analyzer Service Schedule

	Daily*	Weekly	Monthly	Quarterly	Semi-Annually	Annually	18 Months
Sample Flow	X						
System Vacuum		X					
Leak Check		X					
Sample Inlet Particulate Filter		X					
Scattered Light Level		X					
Zero and Span		X					
Monthly Checksheet		X	X				
Capillary and "O"-Ring			X				
Electrical Span			X				
Switch Positions			X				
Cooling Fan and Filter					X		
Multipoint Calibration**					X		
Replace Zero Filter						X	
Replace H.D. Cutter							X
Replace U.V. Interference Filter		As Required					
Replace U.V. Lamp		As Required					
Replace Sample Pump		As Required					

*Or each day the operator services the analyzer

**Or as required after specific repairs listed in Troubleshooting, Section C.1.3.

CALIFORNIA AIR RESOURCES BOARD
MONTHLY QUALITY CONTROL MAINTENANCE CHECKSHEET
THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

Location: *Union Island* Month/Year: *April 1979*
Station Number: *39-261* Technician: *J. Thomas*
Analyzer Property Number: *2688* Agency: *ARB*

Date	Reading: Dial/Chart (ppm)				Sample Flow Setting	System Vacuum (“Hg)	Scattered Light Level (ppm)	Leak Check (T)	Replace Particulate Filter (T)
	Zero		Span						
	As Found	Final	As Found	Final	As Found	As Found			
3	226/.000	/	342/.400	/	2.4/	10.4/10.0	.082	T	T
10	226/.003	/	342/.388	/	2.4/	10.0/	.085	T	T
17	226/.006	232/.000	342/.370	/	2.4/	10.0/	.088	T	T
24	232/.000	/	342/.355	390/.400	2.4/	10.0/	.088	T	T
	/	/	/	/	/	/	/		
	/	/	/	/	/	/	/		
	/	/	/	/	/	/	/		

SO_2 Compressed Gas Cylinder Number *CC 645* Concentration *0.40* ppm.
Operator Instructions:

1) Daily Checks: Air flow (record weekly); Mode switch on sample; Check chart traces.
2) Weekly Checks: Check system vacuum; Leak check; Zero and span; Replace particulate filter; Check scattered light level.
3) Monthly Checks: Inspect capillary and O-ring: Date last inspected: *4/3/79*.
   Check electrical spans: Date last checked: *4/3/79*.
   Amplifier output: As found *10.00* volts; Final____volts.
   Signal output: As found *10.05* mvolts; Final *10.00* mvolts.
   Switch positions: PMT (L M H); Response time (LEFT CENTER RIGHT).
4) Semi-Annual Checks: Clean cooling fan and filter: Date last cleaned: *2/8/79*.
   Calibration: Date last calibrated: *3/25/79*.
5) Annual Checks: Replace zero filter: Date last replaced: *2/8/79*.
6) 18 Month Check: Replace H. C. cutter; Date last replaced: *11/7/78*.

Date	Comments or Maintenance Performed
3	*Reset signal ouput, cleaned capillary. No change in sample flow.*

Reviewed By: *L. Mills* Date: *5/3/79*

Figure C.1.1.1
Monthly Quality Control Maintenance Checksheet

C.1.2 DETAILED MAINTENANCE AND ADJUSTMENT PROCEDURES

C.1.2.1 LEAK CHECKS

Place the mode selector switch on "ZERO". With a swagelok plug, cap the bulkhead zero input port. Wait two minutes. The flow meter should now read zero. If the flow meter shows flow and no lines are broken and all fittings are tight, check the appropriate solenoid valve(s) (refer to Figure C.1.0.1). Isolate the leak and replace any valves or fittings as necessary. Remove the plug from the zero port and place it on the span port. Place the mode selector switch on "SPAN" and check as above. Remove the plug from the span port and place it on the sample port. Place the mode selector switch on "SAMPLE" and check as above.

C.1.2.2 ELECTRICAL SPAN ADJUSTMENTS

1. Amplifier PC Board - Slide the electronic section forward to expose the printed circuit boards (see Figure C.1.2.1.). Locate the following components on the amplifier board: R19 full-scale pot and SW2 calibrate toggle switch. Make adjustments as follows:

    a. Attach a digital voltmeter between the 10-volt output terminal on the Output PC Board and ground.

    b. Place the calibrate toggle switch (SW2) on the amplifier board in the "full scale" (or right) position.

    c. Record the as found DVM voltage on the checksheet. Then, if necessary, adjust the R19 full-scale pot until the DVM indicates 10 $\pm$ .01 volts. Record the final DVM voltage on the checksheet.

    d. Return the SW2 switch to the "operate" (or left) position.

2. Output PC Board - After performing the above, adjust the 1 volt signal output as follows:

    a. Verify that the jumper wire on the output PC board is connected from the center terminal position to 1 volt.

    b. Put the SW2 calibrate switch in the "full scale" (or right) position.

c. Adjust the "P6 Meter Adjust" pot so that the front panel PPM meter is at full scale.

d. Attach the digital voltmeter leads to the recorder output terminals at the rear of the analyzer.

e. Record the "as found" reading on the checksheet. If necessary, adjust pot P9 so that the DVM reads 1 $\pm$ .001 V. Record the "final" reading on the checksheet. Check that the strip chart recorder indicates the same value as the DVM. If the difference is greater than 0.5% of full scale (1/2 chart division) check out the recorder and/or the recorder leads and make corrections as required.

f. Return the calibrate switch SW2 to the "operate" (or left) position.

NOTE: If a digital voltmeter capable of 1 volt is not available, use the strip chart recorder.

C.1.2.3 ANALYZER ZERO AND SPAN CHECKS

This section describes the procedure for performing Model 43 analyzer zero and span checks and adjustments. The analyzers are zeroed and spanned daily with CSI calibrators at satellite stations and daily at stations equipped with Dasibi Model 1005 C_2 Gas Calibration systems. Adjustments of analyzer zero and span settings are made whenever the specified control limits are exceeded. Flash lamp deterioration with time causes decreased analyzer sensitivity of 1 to 2 percent per week. Sudden shifts in zeros and spans should be thoroughly investigated and your supervisor notified before any span and zero adjustments are made. In the event the specified control limits are exceeded and zero and span adjustments are required, they shall be performed after the monthly checks in Section C.1.1.4 are repeated.

1. Determining Quality Control Limits - To maintain the Model 43 within acceptable calibration tolerances it is necessary to establish upper and lower control limits. Exceeding the upper control limit (UCL) necessitates troubleshooting of the analyzer as it is most probably caused by an analyzer malfunction. Exceeding the lower control limit (LCL) generally represents flash lamp decay and only necessitates resetting the analyzer span. For satellite stations, reset the span if the "as found" span reading is more than 10% below the CSI's true SO_2 concentration. For stations with Dasibi calibrators, reset the span if two consecutive daily Timer Program

SO_2 readings are more than 10% below the predicted concentration. Mathematically, the control limits are calculated as follows:

For satellite stations,

UCL, ppm, = 1.10 x True Concentration
LCL, ppm, = 0.90 x True Concentration

For stations with Dasibi calibrators,

UCL, ppm, = 1.10 x Predicted Concentration
LCL, ppm, = 0.90 x Predicted Concentration

Case 1: Satellite Stations

Given: CSI's True SO_2 Concentration = .40 ppm

Calculate: Upper Control Limit, UCL, ppm
Lower Control Limit, LCL, ppm

UCL = 1.10 x .40 = .44 ppm
LCL = 0.90 x .40 = .36 ppm

Case 2: Stations with Dasibi Calibrators

Monthly, obtain the latest copy of the Dasibi Gas Calibration System - Monthly Statistical Analysis. Find the predicted SO_2 concentration under "true ppm" for the high concentration column of the auto program. Assuming the value found is 0.41 ppm,

UCL = 1.10 x .41 = .45 ppm
LCL = .90 x .41 = .37 ppm

2. Stations with CSI calibrators equipped with SO_2 permeation tubes, refer to Appendix I. Zero and span values are determined daily and tabulated on back of the CSI Monthly Checksheet (TSD- 50).

3. Stations with Dasibi calibrators, zero and span the analyzer as follows:

   a. Review the daily Timer program zero data. If the zero data exceeds $\pm$ .005 ppm, reset the analyzer zero using the following procedure. Push "MANUAL ZERO" on the calibrator, set the

"AIR" thumbwheel to 15.0, and allow the analyzer to sample zero gas until you obtain a stable zero trace. Record the "as found" PPM value and zero pot setting on the checksheet.

b. Reset the zero pot to zero on the chart. Record the "final" PPM value and zero pot setting on the checksheet. Return the calibrator to "STOP".

c. Once a week, check the Timer Program net span value, in PPM, against the predicted SO_2 concentration. If this value exceeds the lower control limit and troubleshooting the analyzer reveals no malfunctions, the analyzer span pot should be reset to the correct SO_2 value. Push "MANUAL NO" on the calibrator, set the "AIR" thumbwheel to 15.0 and the "GAS" thumbwheel to 99.0. Allow the analyzer to sample span gas until a stable trace is obtained. Record the "as found" PPM value and the span pot setting on the checksheet.

d. Reset the analyzer to the predicted SO_2 concentration using the front panel span pot. If there is insufficient range in the span pot, notify your supervisor and request a multipoint calibration. Record the "final" PPM value and span pot setting on the checksheet. Return the calibrator to "STOP".

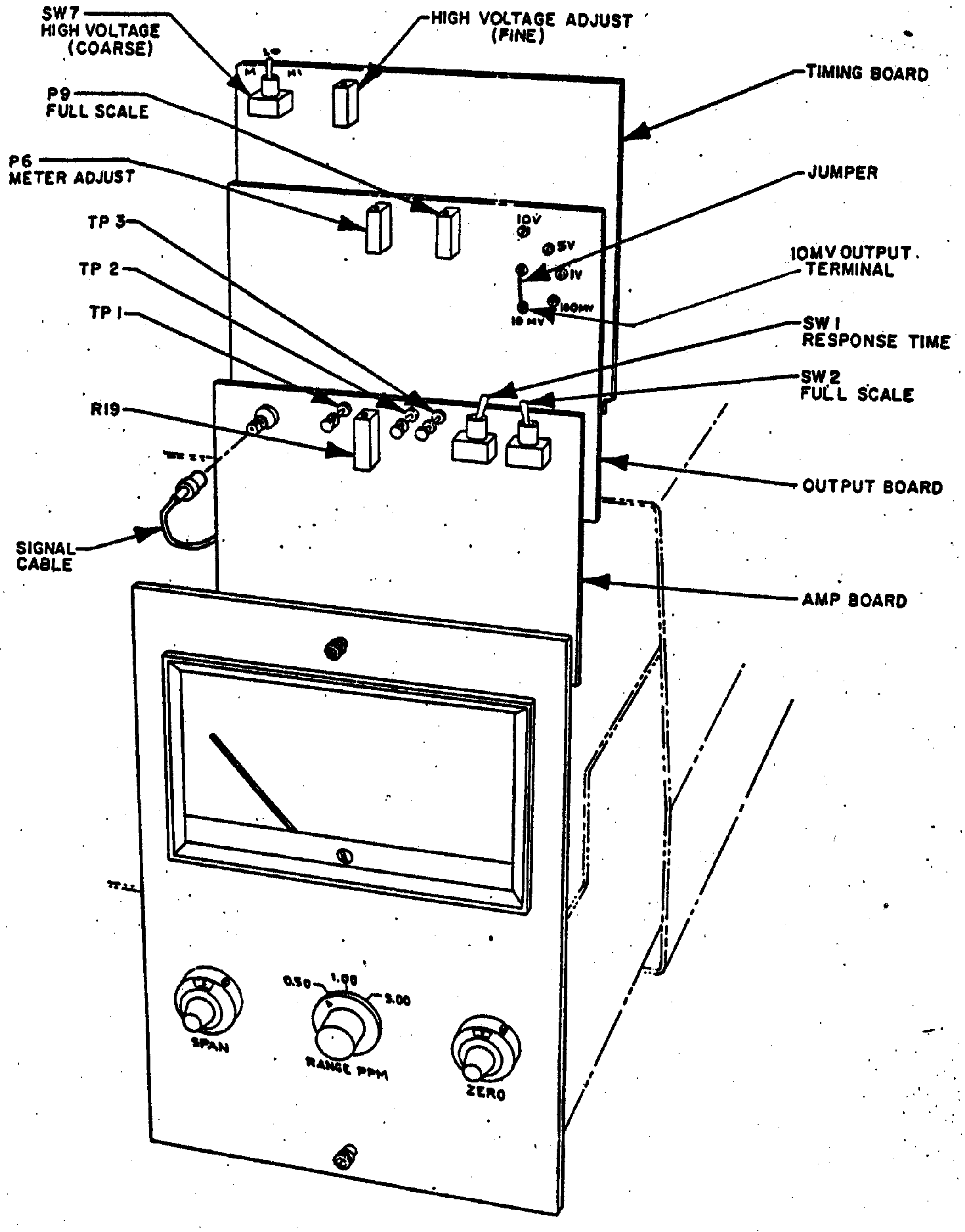

Figure C.1.2.1
Model 43 Electronics P.C. Boards

C.1.3 TROUBLESHOOTING

C.1.3.1 GENERAL INFORMATION

The Manufacturer's Instruction Manual contains information pertaining to troubleshooting and should be your first source of information. Additional problems which have occurred are outlined below. Space is provided on the Monthly Quality Control Checksheet for recording malfunctions, causes, fixes and actions taken to prevent recurrence.

NOTE: Cautions listed in Section C.1.0.3 should be observed while performing troubleshooting or maintenance on the analyzer.

C.1.3.2 ELECTRONIC MALFUNCTIONS

Problem	Probable Cause	Fix
Negative zero Erratic zero	Dirty UV lamp	Wipe clean with alcohol
	Defective shock mount on sample pump	Replace shock mount
	Flash lamp P.S.	*Replace flash lamp power supply
	Defective PMT high voltage power supply	*Replace PMT high voltage power supply
Blows electronics fuse	Flash lamp power supply	*Replace flash lamp P.S. and fuse
Noisy output	Defective 15 VDC supply	Replace power supply
	Erratic flash lamp	*Replace flash lamp
No PMT output and cannot zero meter	Defective PMT	*Replace PMT
Abrupt zero shifts	Dirty contacts-amp PC board	Clean contacts and check zero
	Defective permeation dryer	Replace dryer

*Requires multipoint calibration after this operation.

Problem	Probable Cause	Fix
High positive zero drift	Defective UV interference filter	*Replace UV interference filter
High negative span drift	Defective flash lamp	*Replace flash lamp
Sudden positive zero and span shift	1000V lamp power supply defective resulting in high voltage to UV lamp	*Replace lamp power supply
Zero reading higher than recent ambient concentrations	Charcoal zero filter faulty	Replace zero filter and check zero
	Interference flange not properly coated	*Replace interference filter flange

C.1.3.3 FLOW MALFUNCTIONS

Problem	Probable Cause	Fix
Zero/span solenoid valve leaking, or no flow	Defective zero/span solenoid valve	**Replace solenoid valve
Zero SO_2 ouput when monitoring ambient air	Pump stopped or ouput PC board out of socket	**Check the power to pump and change the pump if necessary. Reinstall ouput PC board if necessary.
Flowmeter reading decreases weekly/slow analyzer response	Leak in sample solenoid	**Replace solenoid valve
	Cutter clogging	**Replace cutter
	Capillary clogging	Clean the capillary
	Faulty pump	**Reset vacuum pressure or change the pump if necessary
	Faulty inlet particulate filter	Replace inlet filter

*Requires multipoint calibration after this operation.
**Requires span check after this operation. If the span check indicates a response change of more than 10%, a multipoint must be performed.

STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME II

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

APPENDIX C.2

ACCEPTANCE TEST PROCEDURES

FOR

THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

MONITORING AND LABORATORY DIVISION

APRIL 1979

C.2.0 ACCEPTANCE TEST PROCEDURES

C.2.0.1 GENERAL INFORMATION

Before beginning acceptance testing of the analyzer, read the manual thoroughly. Then, initiate an instrument log book and an Acceptance Test Mini-Report (Figure C.2.0.1).

C.2.0.2 PHYSICAL INSPECTIONS

Unpack the analyzer and check for physical damage. Remove the top cover from the analyzer and perform the following checks:

1. Pull out the electronics drawer and remove and reinsert the printed circuit boards.

2. Check for correct power cord phasing; standard wiring configuration has the black wire connected to the brass terminal of the plug, white to copper and green to earth ground. Verify the analyzer chassis is grounded to earth ground.

3. With the analyzer power one, and observing the flow meter at the front of the analyzer, leak check the entire flow system using the procedure outlined in Appendix C.1.2.1.

4. Verify that the analyzer is complete upon receipt (i.e., manuals, rackmount slides).

C.2.0.3 OPERATIONAL TESTS

Perform the following operational checks and record the results on the strip chart and mini report. As a permanent record of the tests performed, file the charts and test report in the Air Quality Surveillance files under the ARB property number.

1. Electronics and Gas Flow

    a. Connect the power cord to the analyzer and turn on the power. Place the input mode switch on "zero" and the range PPM switch to 0.5 ppm. Slide the electronics drawer forward in its housing by loosening the fasteners and locate the two toggle switches on top of the first PC board (see Figure C.1.2.2). The front panel meter should indicate a full scale reading if the toggle switch to the right hand side of the PC board, SW2, is moved to the right position. Return switch SW2 to the left position (operating position). The left hand toggle switch, SW1, adjusts the time response and should be set to the center position (4 minute response time).

b. With the power switch on, verify that the cooling fan, pump, and UV lamp are now powered. using a 0-3 SLPM Vol-o-Flo, verify that the flow through the sample port is approximately 1.0 SLPM. Check that the flow meter indicates approximately 1 SLPM. Measure the air flow through the zero and span ports, also. Verify that the flow through the zero and span ports and flow meter readings are identical to the flow through the sample port.

c. Open the front panel analyzer section door. Verify that the vacuum reading on the pressure gauge is -10 inches Hg. If necessary, adjust the pressure regulator on this interior panel so that the gauge indicates 10" Hg.

d. Zero and span the analyzer using the procedure outlined in Appendix C.1.2.2.

2. Zero and Span Drift

a. Establish stable zero and span (~.4 PPM SO_2) traces on a strip chart recorder using appropriate repeatable sources.

b. At intervals of 24 hours and 72 hours, repeat the above zero and span points. Deviations should not exceed $\pm$1% F.S. for 24 hours or $\pm$2% F.S. for 72 hours.

3. Voltage Variation test - Vary the input line voltage to 105 VAC, 110 VAC, 115 VAC, 120 VAC, 125 VAC, 120 VAC, 115 VAC, while sampling a constant concentration (~.4 PPM SO_2). Remain at each step at least 10 minutes. Analyzer response changes due to voltage variations should not exceed $\pm$.01 ppm.

4. Temperature Variation - Place the analyzer in the environmental chamber. Establish a stable recorder trace utilizing a known concentration (~.4 PPM SO_2). Vary the ambient temperature from 4ºC to 44ºC in 5ºC intervals. Repeat the test while sampling zero air. Analyzer response changes due to temperature variation should be less than $\pm$.01 PPM for zero and less than $\pm$0.03 PPM for span.

5. Check the Flash Lamp Supply Voltage as follows:

a. Turn off the analyzer.

   b. Remove timing PC Board.

   c. Carefully remove flash lamp from socket.

   d. Turn the analyzer power on.

   e. Check the voltage at socket pin #6 to chassis for + 1000 VDC ±35 VDC.

   f. Turn off the analyzer.

   g. Reinsert the flash lamp and timing PC board.

6. With analyzer power on, check the Low Voltage Power Supply for +15 VDC ±0.2 VDC and -15 VDC ±0.2 VDC.

7. Measure the scattered light level using the procedure in Appendix C.1.1.3.4.

8. Linearity - Calibrate the analyzer using the NBS SO_2 permeation tubes. Record the percent FS deviation from true SO_2 concentrations at 80%, 60%, 40%, and 20% of FS on the Acceptance Test Mini-Report (Figure C.2.0.1) and appropriate calibration form.

9. Check the PMT High Voltage, as follows:

   a. Turn off the analyzer.

   b. Remove high voltage cable from the PMT housing.

   c. Turn the analyzer power on.

   d. Measure the voltage at the high voltage cable to chassis ground. The voltage should be -1000 VDC to -2000 VDC.

   e. Turn off the analyzer. Short the PMT control terminals on the PMT voltage supply. Turn the analyzer power on. The voltage from the high voltage cable to chassis ground should now be greater than -2000 VDC.

   f. Turn off the analyzer and remove the short.

   g. Reconnect the high voltage cable to the PMT.

10. Install a pretested Xonics particulate filter holder on the sample inlet port. (Particulate filters must be tested to assure that they do not remove SO_2 from the sample stream.)

11. Final Review - If the tests are satisfactory, complete an equipment relocation notification tag and record pertinent information such as flash lamp voltage, PMT high voltage, scattered light level, zero and span settings, etc. in the log book and on the mini report. The analyzer is now ready for field use.

THERMO ELECTRON MODEL 43 SO_2 ANALYZER
ACCEPTANCE TEST "MINI REPORT"

Date *11/28/78* Serial No. *ASM-7539-93* Reviewed By *J.Smith*
By *G.Marks* ARB No. *2688* Date of Acceptance *12/28/78*

		Passed	Failed	Final OK
I.	Physical Inspections			
	A. Checked for shipping damage	✓		
	B. Checked all electrical wiring		✓	✓
	C. Checked all plumbing for leaks	✓		
	D. Analyzer complete upon receipt	✓		
II.	Operational Checks			
	A. Checked operation of valves, controls, meters, pumps switches indicator lamps, etc.	✓		
	B. Set electrical zero and span	✓		

	Tests Performed (Attach Charts)	%FS Dev	Range	Pass	Fail	Final OK
III.	A. Voltage variation (105 VAC to 125 VAC @ *0.40* ppm)	*<+/-1.0*	*0.5*	✓		
	B. 24 Hour Zero Drift	*+0.2*	"	✓		
	C. 24 Hour Span Drift@ *0.40* ppm	*+0.2*	"	✓		
	D. 72 Hour Zero Drift	*+0.5*	"	✓		
	E. 72 Hour Span Drift@ *0.40* ppm	*-1.0*	"	✓		
	F. Linearity (%FS Dev. from true SO_2)					
	80% Full Scale: *.403* ppm	*+0.6*	"	✓		
	60% Full Scale: *.303* ppm	*+0.6*	"	✓		
	40% Full Scale: *.211* ppm	*+0.2*	"	✓		
	20% Full Scale: *.100* ppm	*0*	"	✓		
	G. Temperature variation					
	Zero Shift: Step 1 *21* °C to *30* °C	*0*	"	✓		
	*Step 2 *25.5* °C to *44* °C	*+2.0*	"	✓		
	Step 3 *4.5* °C to *26* °C	*0*	"	✓		
	Span @ *0.40* ppm					
	Step 1 *21* °C to *30* °C	*+1.5*	"	✓		
	Step 2 *25.5* °C to *44* °C	*+4.5*	"	✓		
	Step 3 *4.5* °C to *26* °C	*-3.0*	"	✓		

H. Fianl Analyzer Readings
Flash lamp voltage *+999.2* ; Low voltage supply *+15.185* VDC; *-15.126* VDC
PMT High Voltage *-1530* VDC; w/o control *-2160* VDC
Flow: *0.90* SLPM@ *2.2* Flow setting PMT switch: Low **(Medium)** High

IV. Special Tests

V. Comments/Maintenance Performed

Rewired power cord and receptacle to standard configuration (black to brass).
**III G: No shift at zero up to 35 °C; shift starts at ~37 °C.*

Figure C.2.0.1
Acceptance Test Mini-Report

STATE OF CALIFORNIA

AIR RESOURCES BOARD

AIR MONITORING QUALITY ASSURANCE

VOLUME II

STANDARD OPERATING PROCEDURES

FOR

AIR QUALITY MONITORING

APPENDIX C.3

CALIBRATION PROCEDURES

FOR

THERMO ELECTRON MODEL 43 SULFUR DIOXIDE ANALYZER

MONITORING AND LABORATORY DIVISION

SEPTEMBER 1984

C.3.0 CALIBRATION PROCEDURES

C.3.0.1 INTRODUCTION

The Air Resources Board calibrates sulfur dioxide (SO_2) analyzers using a precise quantitative dilution, with air, of a compressed cylinder of SO_2 gas. A compressed gas cylinder of SO_2 with a concentration in the range 20 to 50 PPM is diluted with zero air. Zero air is mixed with the SO_2 using a calibrated dilution apparatus to provide five concentrations from 0 to 90% of the analyzer's operating range. The SO_2 standard is initially certified against a NBS-SRM (either cylinder gas or permeation source) and thereafter recertified at six month intervals. The dilution apparatus (mass flow meters, etc.) are also certified and recertified every three months against laboratory flow standards. The procedures described herein were written for the Thermo Electron Model 43 analyzer but may be adapted to any fluorescent SO_2 analyzer.

C.3.0.2 APPARATUS

Figure C.3.0.2, a schematic of a typical SO_2 dynamic calibration system. Connections between components in the calibration system downstream from the SO_2 cylinder should be of glass, FEP Teflon*, or other non-reactive material.

1. Dilution apparatus including two calibrated mass flow controllers (MFCs), two digital panel meters (DPM), manual or solenoid valves for positive gas shut-off, such as a Dasibi 1009 MC Calibrator or equivalent.

2. SO_2 standard - Compressed gas cylinder containing 20 to 50 PPM SO_2 in oxygen free N_2 with less than 0.005 PPM H_2S, less than 0.005 PPM oxides of nitrogen (NO plus NO_2), less than 1.0 PPM (each) of total hydrocarbons, CO, and, CO_2, and having a maximum dew point of -40°C. The cylinder must be traceable to a National Bureau of Standards SO_2 Standard Reference Material.

3. Zero Air - Air, free of contaminants which cause a detectable response on the SO_2 analyzer or which might react with SO_2; provided by the Aadco zero air system, CSI calibration unit, or zero air cylinder.

4. One-quarter or one-eight inch FEP Teflon tubing for airflow connections. All fittings in contact with SO_2 must be made of 316 stainless steel or FEP Teflon.

5. Calibration Datasheet (Figure C.3.0.1).

* Trademark of Dupont Corporation.

CALIFORNIA AIR RESOURCES BOARD
DYNAMIC SO_2 CALIBRATION DATASHEET

Site Name *Glendora* Calibration: As Is *x* Final___
Site No. *70-591* Date *12-29-83* Log No. *ARB 83-363*
Site Temperature *21.5 ℃* Barometric Pressure *759.6* Site Elevation *900ft*

INSTRUMENT: Make and Model *TECO 43* Property No. *ARB 2434*
Serial No. *ASM-6361-84* Span *390L* Zero *275* Range *0.5PPM* Airflow *0.88*l/min at *1.35* setpoint
Reaction Chamber Vacuum *10.0*"Hg Electronic Span *100* %F.S.
Primary DAS: Make and Model *Monitor Labs 9302* Property No. *ARB 5291* Serial No. *ML137*

TRANSFER STANDARD: Make and Model *Dasibi 1009MC* Property No. *ARB2434*
Serial No. *041* Date Certified *12-9-93* Cert. Expires *3-9-84*
0-100 sccm MFC: Airflow = *1.008* x Display ± *0.26* sccm (SO_2 gas)
0-10 slpm MFC: Airflow = *0.996* x Display ± *0.070* slpm (dilution)

COMPRESSED GAS CYLINDER: Cylinder No. *JJ8698* Property No. *ARB 5151* Assay *20.5*ppm.
Date Certified *6-2-83* Cert. Expires *6-2-84* Outlet Pressure *20* psi

DILUTION AIR: Source *AADCO* Property No. *ARB 5582* Outlet Pressure *30* psi

Trasfer Standard					$[SO_2]_{OUT}$ (ppm)	Instrument		
SO_2 Gas Flow		Dilution Flow		Total Flow		Chart (%FS)	DAS (ppm)	Net DAS
Display	sccm	Display	sccm	sccm				
vented	----	*4.11*	*4024*	----	*0*	*0.1*	*.000*	
80.1	*81.0*	*4.11*	*4024*	*4105*	*.402*	*77.5*	*.391*	*.391*
40.0	*40.6*	*4.11*	*4024*	*4065*	*.201*	*39.7*	*.201*	*.201*
20.0	*20.4*	*4.11*	*4024*	*4044*	*.103*	*20.3*	*.101*	*.100*
10.0	*10.3*	*4.11*	*4024*	*4034*	*.052*	*10.5*	*.052*	*.051*
vented	----	*4.11*	*4024*	----	*0*	*0.3*	*.001*	
				Σ	*.758*		Σ	*.743*

Percent deviation from true: $\left(\frac{\Sigma SO_2 \text{ Net DAS}}{\Sigma[SO_2]_{OUT}} - 1\right) \times 100\% = \left(\frac{.743}{.758} - 1\right) \times 100\% = -2.0\%$

Linear regression: Analyzer response (ppm), = (*.975*) ($[SO_2]_{OUT}$) ± (*.001*)ppm
Slope Intercept

As is change from previous calibration, dated________________:

$\left(\frac{\text{As Is Slope - Old Slope}}{\text{Old Slope}}\right) \times 100\% = (\qquad) \times 100\% =$ ______

Comments: *Leak Check = O.K. Electronic F.S. = 100.0%*

Calibrated by: *D. Smith* Checked by: *G.R.*

Figure C.3.0.1
Dynamic SO_2 Calibration Datasheet

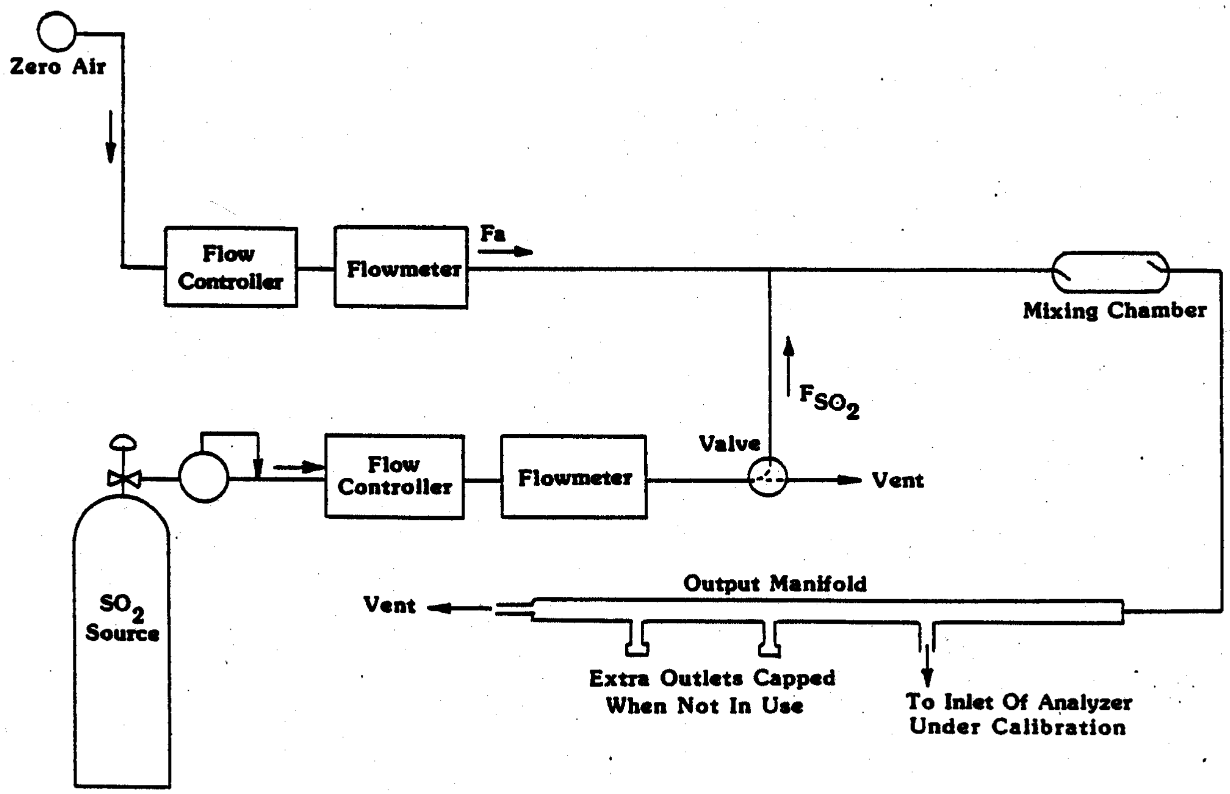

Figure C.3.0.2
Diagram of Typical SO_2 Dynamic Calibrations System

C.3.0.3 AS-IS CALIBRATION

Other than routine daily checks, analyzer repairs or adjustments should not be made prior to the (As-Is) calibration.

1. Record analyzer parameters and site conditions on the Calibration Datasheet (Figure C.3.0.1).

2. Precautions must be taken to remove contaminants from the SO_2 pressure regulator:

   a. Purge the regulator and delivery system with SO_2 to a safe vent after opening the cyling valve.

   b. If possible, leave the regulator on the cylinder between calibrations (only if there is no transport involved).

3. Select the correct SO_2 operating range (range PPM switch at 0.5 ppm). Perform the appropriate analyzer electronic checks as outlined in Section C.1.2.

4. Using FEP Teflon tubing, connect the SO_2 and zero air to the appropriate inlet fittings on the Dasibi 1009 MC.

5. Disconnect the analyzer's sample probe at the station's sampling manifold and connect it to the outlet manifold of the dilution apparatus. Cap the open port on the station's sampling manifold.

6. If using a zero air cylinder, attach and flush the zero air regulator, being careful not to introduce contamination.

7. Once the dilution air flow rate is chosen, determine the required flow of SO_2 gas to obtain approximately 90% of full scale. (Use the following equation and those provided with the mass flow meter transfer standards. Record the mass flow meter equations on the Calibration Datasheet.) Do not adjust either MFC to less than 10% of full scale.

$$F_{SO2} = \frac{(Co)\,(F_a)}{C_{cyl} - Co}$$

where: F_{SO2} = SO_2 flow, sccm
F_a = Air flow, sccm

C_{cyl} = compressed SO_2 cylinder concentration, ppm

Co = desired concentration (diluted SO_2 concentration, ppm)

8. Turn the Teco 43's mode switch on the front panel to "Sample". Open the air regulator outlet valve on the dilution apparatus; set the flow so that when the SO_2 gas flow rate is at its maximum, the diluted SO_2 concentration is calculated to be approximately 90% full scale. The total flow must exceed the total demand of the analzyer(s) connected to the calibrator's output manifold to insure that no ambient air is pulled into the manifold vent (see caution note below). Allow the analyzer to sample zero air until a stable zero response is obtained. Adjust the analyzer's zero control to obtain the required zero set point on the chart recorder and again allow the analyzer to stabilize. Obtain approximately 10 minutes of stable recorder trace and record the response on the Calibration Datasheet.

9. Adjust the SO_2 gas flow (F_{SO2}) to the value calculated in Step 7 with the MFC potentiometer set to obtain approximately 90% full scale. It may require an hour or more for the reading to stabilize as the MFC, dilution apparatus, and analyzer must be conditioned to the calibration gas.

   CAUTION: Vent or scrub the excess SO_2 from the outlet manifold to the outside using a large diameter vent line.

10. After the recorder chart response has stabilized, record the MFC displays and calculate actual sccm--for the SO_2 gas flow and dilution air flow, and the recorder chart response on the Calibration Datasheet.

11. Reset the SO_2 MFC potentiometer to obtain responses of approximately 50%, 20%, and 10% of full scale. After the analyzer has stabilized for each test point, record the MFC displays and calculate actual sccm and the corresponding recorder chart response on the Calibration Datasheet.

12. Repeat the zero reference point (Step 8). Allow the zero trace to stabilize on the recorder chart. The zero response should reproduce the original zero to within 1% of full scale. If it does not, determine the cause and correct the problem before continuing (refer to Section C.1.3.2, Electronic Malfunctions).

13. Calculations:

   NOTE: The calculations assume that the SO_2 analyzer is linear, i.e., the calibration curve of the net chart recorder versus concentration is a straight line within 1% of full scale at each point. If it is not, troubleshoot the analyzer and calibration system and correct the problem before continuing.

a. Calculate the SO_2 and dilution air flow rates, sccm, using the certification equations provided.

b. Using the flow rates calculated for Steps 7 and 11, in sccm, calculate the true SO_2 concentration for each calibration point. Record under "[SO_2] " on the Calibration Datasheet.

$$\text{True } SO_2 \text{ conc (ppm)} = \frac{C_{cyl} \times F_{SO2}}{F_{SO2} + F_a}$$

c. Determine the net DAS response in PPM by subtracting the average DAS zero response.

d. Calculate the deviation from true:

$$\% \text{ Dev} = \left[\frac{3 \; SO_2 \text{ Net DAS}}{3 \; [SO_2]_{OUT}} - 1 \right] \times 100\%$$

Where Net DAS = Net Data Acquisition System

NOTE: Data for the above equations are recorded on the Calibration Datasheet.

e. Calculate the least squares linear regression coefficients (slope and intercept) using all calibration points including zero points and record on the Calibration Datasheet.

$$y = mx + b$$

where x = true SO_2 concentration, PPM = $[SO_2]_{OUT}$
y = Net DAS, ppm
m = slope (unitless)
b = y intercept, ppm

f. Calculate the (As-Is) change from the previous calibration:

$$\frac{\text{As-Is Slope} - \text{Old Slope}}{\text{Old Slope}} \times 100\%$$

g. Plot the SO_2 calibration curve, Net DAS or net chart versus $[SO_2]_{OUT}$.

h. If the slope, m, is between 0.95 and 1.05, and b agrees with the zero reading within 1% of full scale, then the analyzer is in calibration and no further adjustments are needed.

C.3.0.4 FINAL CALIBRATION

If the slope, m, calculated in Step 13e is less than 0.95 or greater than 1.05, an adjustment and (final) calibration are necessary. Adjust the SO_2 analyzer to correct the deviation as follows:

1. Repeat the 90% of full scale span concentration (Section C.3.0.3, Steps 9 and 10).

2. Adjust the front panel span pot until the analyzer reads the true SO_2 concentration.

   NOTE: Increasing the span pot increases the analyzer's response. Decreasing the span pot decreases the analyzer's response.

3. Repeat the zero reference point (Section C.3.0.3, Step 8), readjusting the front panel zero control as necessary.

4. Repeat Steps 1 to 3 in this section until no further adjustments are needed.

5. Repeat calibration points (90%, 50%, 20%, and 10% of full scale) for the final calibration. Complete the Calibration Datasheet and a calibration curve.

6. If there is insufficient range in the span control potentiometer to set the span, perform the following adjustments:

   a. Adjust the Amplifier PC Board and the Output Board (see Figure C.1.2.1 for locations) and refer to Section C.1.2.2.- "Electrical Span Adjustments".

   b. Verify that the pressure indicated on the pressure gauge inside the front panel is at -10 inches Hg. If it is not, check the capillary (refer to Section C.1.1.4), then adjust the regulator to obtain this value. This should be done with the front panel switch in the sample position.

   c. Locate the printed circuit card that has the three-position toggle switch (M-L-H) for high voltage course adjustment of the PMT and a high voltage potentiometer for fine gain adjustment (refer to Figure C.1.2.1).

      (1) Adjust the front panel span control to a setting of 300.

(2) Repeat the 90% full scale span concentration (Section C.3.0.3, Steps 9 and 10). Adjust the high voltage potentiometer so the analyzer obtains the true SO_2 concentration $\pm$.010 ppm.

(3) If the adjustment of the high voltage potentiometer does not bring the analyzer within the true SO_2 concentration $\pm$.010 ppm, put the high voltage toggle switch in a higher (or lower) position and repeat Step (2).

d. Repeat the zero reference point. Readjust the front panel zero control until the analyzer is zeroed.

e. Repeat Steps c and d until the true SO_2 concentration and a good zero are obtained.

f. Adjust the analyzer's front panel span control until the SO_2 response is exactly the concentration being supplied.

g. Repeat the calibration points for the final calibration (0 to 90% of full scale), completing a Calibration Datasheet and a calibration curve.

7. If the analyzer span still cannot be adjusted to provide the necessary corrections, then the analyzer may be in need of maintenance (i.e. faulty PMT tube or flash lamp). Trouble- shoot for possible electronic malfunctions (refer to Section C.1.3, Troubleshooting). Recalibrate after maintenance is performed, repeating Steps 1 to 5 of Section C.3.0.4.