C. SPECIFICATIONS

Ranges	0-1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 PPM
Noise	0.05 PPM RMS - with time constant of 30 seconds
Minimum Detectable Limit	0.10 PPM
Zero Drift, 24 hours	+/- 0.2 PPM
Span Drift, 24 hours	+/- 1% Full Scale
Rise, Fall Times (0-95%) (at 1 lpm flow, 30 second response time)	1 Minutes
Precision	+/- 0.1 PPM
Linearity	+/- 1%
Flow Rate	0.5 - 2 lpm
Rejection Ration	Negligible interference from water and CO2.
Operating Temperature	Performance specifications maintained over the range 15-35°C (may be operated safely over the range 5-45°C)
Power Requirements	105 - 125 VAC, 60 Hz 220 - 240 VAC, 50 Hz 100 Watts
Physical Dimensions	17"W x 8 3/4"H x 23"D
Weight	45 lbs.
Dual Outputs (Standard)	Individually selectable to 0-10mv, 0-100mv, 0-1V, 0-5V, 0-10V, digital display, 1 hour integrated value. Other outputs available upon request (4-20ma)

CHAPTER II INSTALLATION

The installation of the Model 48 GFC Ambient CO Analyzer includes unpacking the instrument, connecting sample, zero, span, and exhaust lines to the instrument, and attaching the dual analog outputs to a suitable recording device. Installation should always be followed by a multipoint calibration using the procedure outlined in Chapter IV.

A. UNPACKING

Thermo Environmental Instruments Inc. Model 48 GFC Ambient CO Analyzer is shipped complete in one container. If upon receipt of the instrument, there is obvious damage to the shipping container, notify the carrier immediately and hold for his inspection. the carrier, and not Thermo Environmental Instruments Inc. is responsible for any damage incurred during shipment.

In addition to the basic analyzer, a six-foot line cord, and an instruction manual has been packed in the shipping container.

To unpack the Model 48, follow the procedure outlined below:

1. Remove the Model 48 from the shipping container and set it on a table or bench which will allow easy access to both the front and rear of the instrument.

2. Snap open the four hold-down latches holding the cover to the instrument. Remove the cover from the main frame of the instrument to expose the internal components.

3. Check for possible damage during shipment.

4. Check that the printed circuit boards are tightly inserted in their connectors.

B. ASSEMBLY

1. Connect * the ambient air to be measured to the bulkhead connector labeled "SAMPLE" on the rear panel of the instrument (see Figure II-1). Care should be taken to ensure that the sample is not contaminated by dirty, wet, or incompatible materials in the sample lines. Teflon, borosilicate glass, or similar tubing with an OD of 1/4" and a minimum ID of 1/8" is required for all sample lines. The length of the tubing should be held to a minimum. For best results the tubing between the manifold and the analyzer should be less than ten (10) feet.

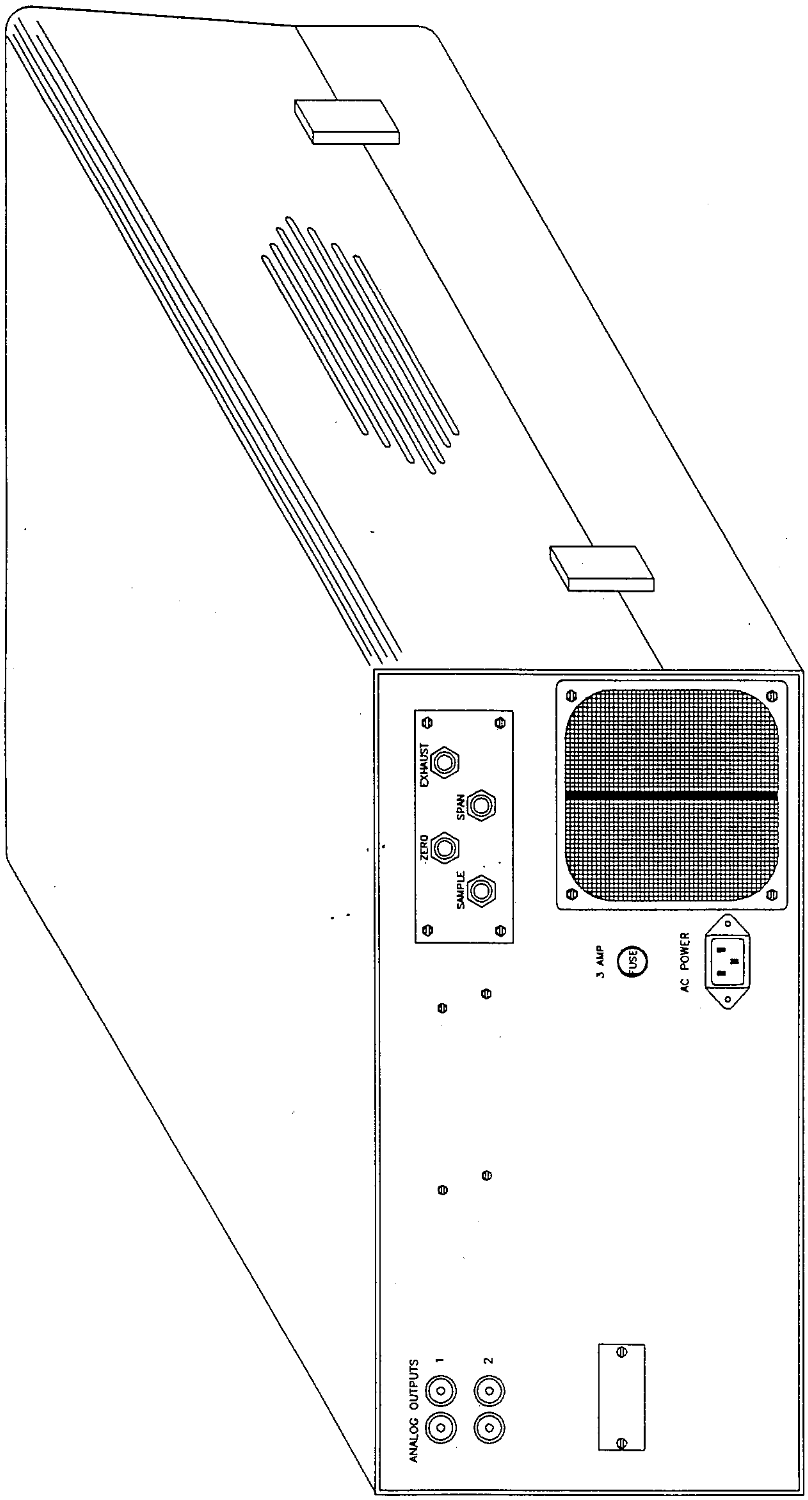

Figure II-1

Rear View

**** CAUTION ****

* SAMPLE GAS SHOULD BE DELIVERED TO THE INSTRUMENT AT ATMOSPHERIC PRESSURE. IT MAY BE NECESSARY TO EMPLOY AN ATMOSPHERIC DUMP BYPASS PLUMBING ARRANGEMENT TO ACCOMPLISH THIS.

2. Connect * (see caution above) a source of CO free air to the bulkhead connector labeled "ZERO" on the rear panel of the instrument (see Figure II-1). Generation of CO free air is discussed in Section IV-A.2.

3. Connect * (see caution above) a source of CO span gas to the bulkhead connector labeled "SPAN" on the rear panel of the instrument (see Figure II-1). See Section IV-A.2 for a discussion of suitable sources of span gases.

4. Connect the rear panel bulkhead labeled "EXHAUST" to a suitable vent. Take care to verify that there is no restriction in this line.

5. Connect a recording device to the output channels of the instrument. See Figure II-1 for the location of the recorder outputs. Unless otherwise specified, the recorder signals are 0-10 VDC.

6. Install the power cord to the rear of the instrument (see Figure II-1). Plug the male end into an appropriate outlet. Check for proper voltage requirements.

7. The Model 48 can be operated either with or without a particulate filter. If a filter is used, it should be a Teflon filter-holder with a 5-10 micron Teflon filter. In order to satisfy all EPA requirements for precision and level 1 span checks (see 40 CFR 58, Appendix A,B), it recommended that the filter be installed between the sample-span solenoid and the optical bench (see Figures I-3,4). The flow scheme of the Model 48 has been designed to allow for this type installation.

C. OPTIONAL EQUIPMENT

1. Rack mounting for standard 19-inch relay rack. Figure II-2 illustrates the installation of the rack mount option on the Model 48 Analyzer. The mounting hardware is installed on the analyzer at the factory. For installation on an existing instrument, detailed instructions will be provided when the rack mounting hardware is shipped.

2. Teflon particulate filter - (5-10 micron pore size - 2" diameter Teflon element). The particulate filter should be installed as discussed in B.7 above. If the particulate option is being used, all calibrations and precision and level 1 span checks must be performed through the particulate filter.

3. Remote activation of zero, span, and sample solenoids allows the user to control these solenoids remotely. This option is activated through contact closure to ground by use of a rear panel barrier strip. Instructions on the use of this option are given in Appendix F of this manual.

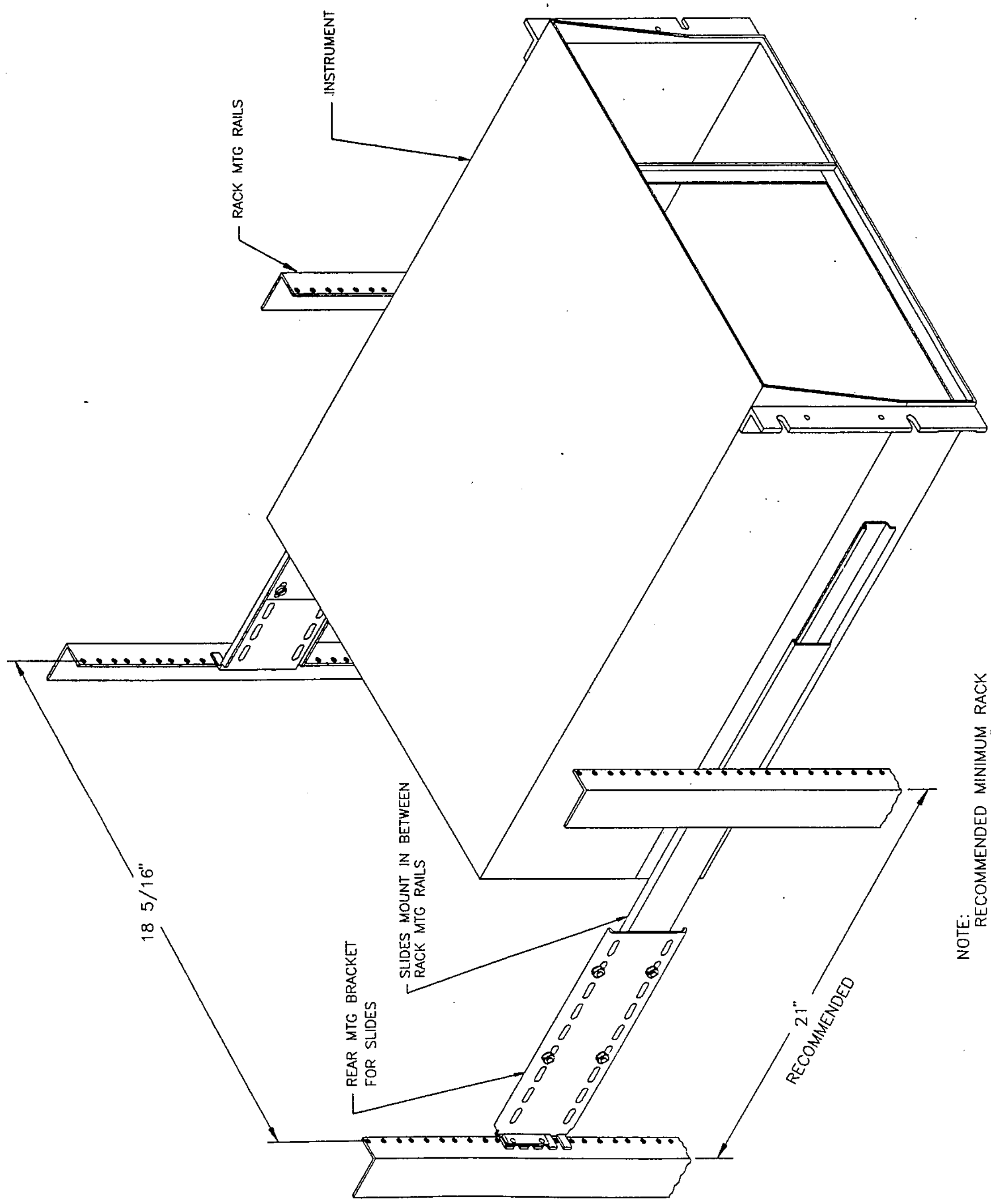

Figure II-2

Rack Mount Assembly (Option)

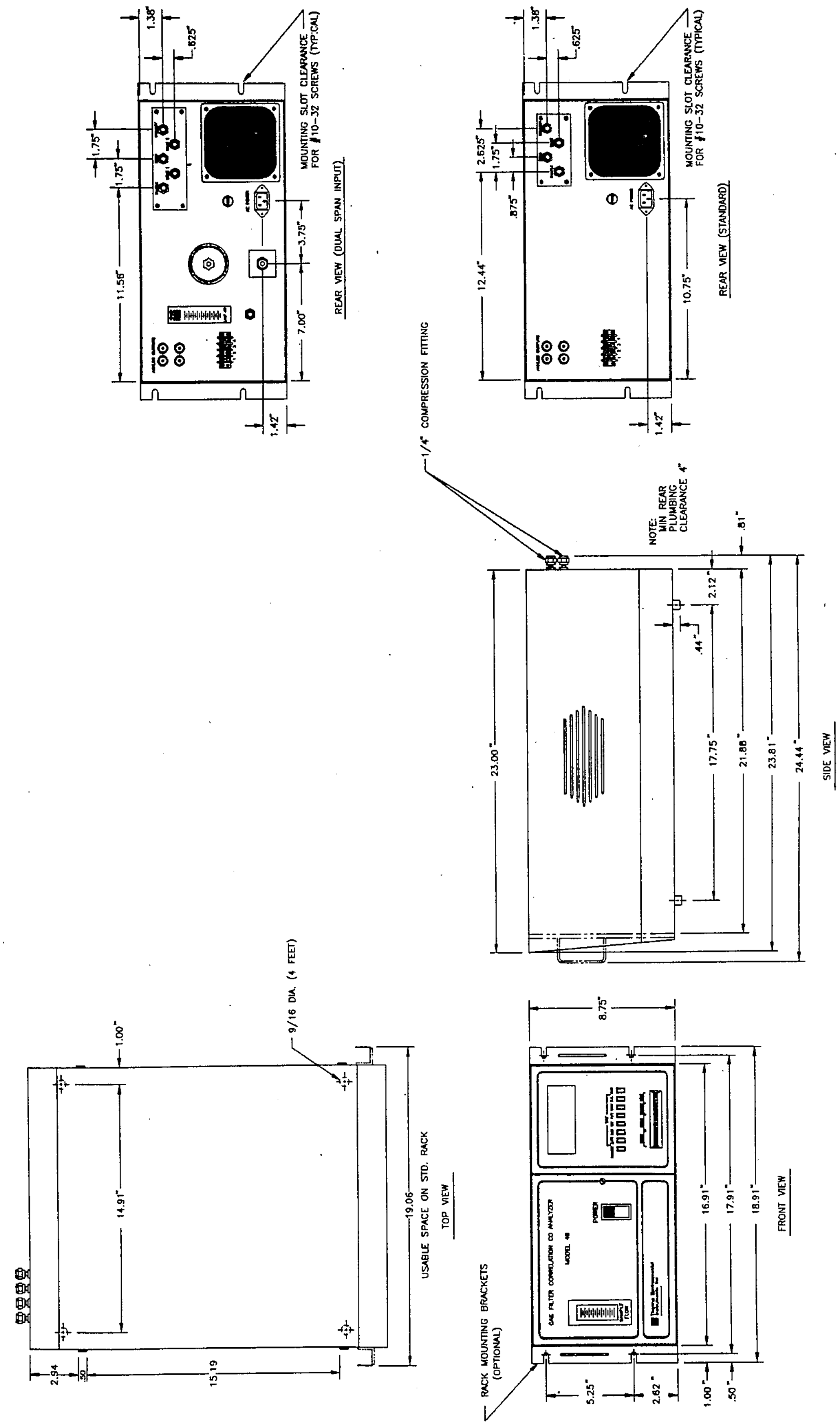

Figure II-3

General Dimensional Outline

CHAPTER III OPERATION

This chapter describes the operation of the Model 48 GFC Ambient CO Analyzer. It is assumed that the instrument has already been calibrated (see Chapter IV for the calibration procedure). First a description of the individual controls is given. Then the start-up procedure is outlined.

A. DESCRIPTION OF CONTROLS (Figure III-1)

1. Power Switch - Controls power to the electronic circuits, pump, chopper motor, and solenoid valves. When turned on, the power "ON" light integral with the switch will be lit; there also should be an audible sound from the pump. The instrument automatically goes into the start-up mode.

2. Sample Flow Meter - The flow meter shows the flow rate through the optical bench. The meter should read between 1/2 to 2 liters per minute (1-4 SCFH). The flow rate is set by a capillary. It can only be changed by using a different sized capillary.

3. LED Display - Depending upon the mode of operation, the display will show the CO concentration in PPM, 0 or FSCAlE, DAC ramp, detector frequencies, temperature in degrees Celsius, pressure in millimeters Hg, various status diagnostics, or the previous hourly average CO concentration. If in the troubleshooting mode (see Chapter VII), additional test diagnostics may also be displayed.

4. CO Run and Test Mode Entry Pushbuttons - Allows the operator to change the mode of operation of the instrument. A LED (light emitting diode) above the pushbutton indicates the active mode. There are eight (8) pushbuttons:

A. REMOTE Mode - This pushbutton is used to engage (LED above the pushbutton "ON") or disengage (LED above the pushbutton "OFF") the remote option if installed. This option is remote activation of the span, zero, and sample solenoids. This pushbutton is ignored if this option is installed.

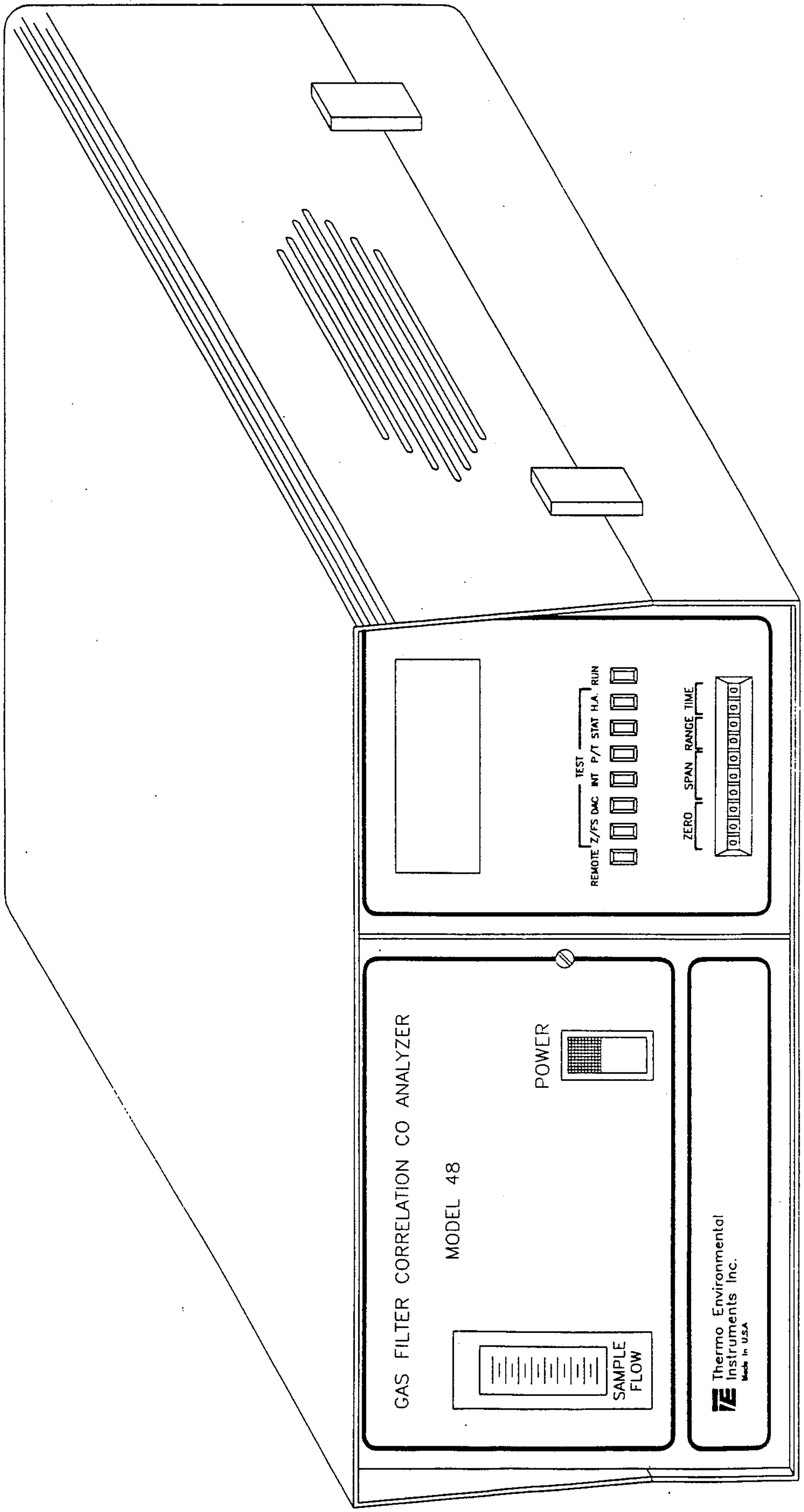

Figure III-1

Front Panel Controls

B. Test Z/FS (Zero/Full Scale) - First actuation into this mode sets the instrument to digital zero. The recorder output levels may then be adjusted to 0 Volts or to some offset level. Engaging the pushbutton a second time sets the instrument to digital full scale. The full scale levels of the recorder outputs can then be adjust.

C. Test DAC (Digital to Analog Converter) - This function is used to test for proper operation of the analog outputs and any recorder which may be connected. Actuation of this pushbutton results in the generation of a "ramp" on the analog outputs. Initial entry into this mode displays -23 PPM and outputs -2.3% full scale on the analog outputs for 30 seconds. The DAC is then caused to change its output sequentially through all its possible states causing the digital display to count from -23 to +1000 PPM while the analog outputs change from -2.3% full scale to +100% full scale in steps of 0.1% FS. this process takes approximately seven minutes for completion. A straight line ramp on the recorder chart indicates proper functioning of both the instrument <u>and</u> recorder. Both the digital display and analog output ramp can be stopped at any intermediate value by engaging the pushbutton a second time. Engaging the pushbutton a third time causes the ramp to continue. This allows calibration of the recorder at any of the intermediate values.

D. Test INT (Intensity) - Actuation of this button causes the instrument to display the infrared light intensity in Hz measured by the IR detector. The initial actuation displays the intensity as digitized by the first V-F (voltage to frequency) converter. The second engagement displays the intensity as digitized by the second V-F converter. Both readings should be nominally the same, reading at least 10,000 Hz. A low reading is an indication of either a weak IR source or of low reflectance of the mirrors in the optical bench. Therefore the need to clean the optics and the status of the V-F converters can be ascertained without dismantling any part of the instrument.

E. Test P/T (Pressure/Temperature) - Initial entry into this mode caused the pressure to be displayed in millimeters Hg. If this pushbutton is engaged a second time, the temperature in degree Celsius will be displayed.

F. Test STAT (Status) - This function allows the user to determine which options have been selected by the internal circuit board switches without the need to open the instrument and interpret the switch settings. Successive engagement of the pushbutton indicates the full scale ranges in PPM of analog outputs #1 and #2, the time responses of analog outputs #1 and #2, the status (whether ON or OFF) of the eight internal SPST DIP switches on PIA board 48-3, and additional status functions if in the troubleshooting mode (see Chapter VII).

G. Test H.A. (Hourly Average) - First actuation of this button displays the average CO concentration for the previous hour whether the hourly average analog output interrupts are engaged or not. The second actuation displays the minutes past the hour presently assumed by the instrument. If the pushbutton is then held in, the timer will increment, allowing the user to set the beginning time of the average.

H. RUN - This pushbutton cancels all test diagnostic modes and put the instrument into the sample monitoring mode. If no diagnostic tests are desired, use of this button is all that is required to "drive" the instrument. The digital display shows the CO concentration in PPM. There are three RUN modes, indicated by lights and labels in the display, and operated by successive engagements of the pushbutton:

1. Run-Zero - the solenoids switch so that zero gas flows into the optical bench.

2. Run-Span - the solenoids switch so that span gas flows into the optical bench.

3. Run-Sample - the solenoids switch so that sample gas flows into the optical bench.

Note that "Run-Sample" is the default mode. Thus when the instrument is first turned on (or when power comes on again after a power failure) the instrument automatically goes into the "Run-Sample" mode. If the Model 48 is inadvertently left in a diagnostic or calibration mode, data will be lost for only one hour since the instrument will automatically default to the "Run-Sample" mode one hour after the last actuation of any switch (unless DIP switch #8 is ON - see Chapter VII).

5. ZERO - When calibrating the instrument, three thumbwheel switches are used to set the zero reading of the Model 48.

6. SPAN - Three thumbwheel switches are used to set the instrument to the concentration of a span gas source. If the instrument is zeroed first, use of the span switches will not affect the zero setting.

7. RANGE - The Model 48 has two independent analog outputs with independently selectable ranges and time responses. The first range thumbwheel switch selects the range for output #1 (the upper terminals on the rear panel), while the second switch selects the range for output #2. The number code on the thumbwheel switches correspond to the following ranges:

Switch Setting	Fullscale Range (PPM)
0	1
1	2
2	5
3	10
4	20
5	50
6	100
7	200
8	500
9	1000

The selected FS ranges can be displayed by use of the Test STAT function.

8. Time - These two thumbwheel switches select the time response/hourly averaging options for analog outputs #1 and #2 respectively. The number code on the thumbwheel switches corresponds to the following:

Setting	Time Response (60 Hz)	Time Response (50 Hz)
0	10 sec. CO average	12 sec. CO average
1	20 sec. CO running average	24 sec. CO running average
2	30 sec. CO running average	36 sec. CO running average
3	60 sec. CO running average	60 sec. CO running average
4	90 sec. CO running average	96 sec. CO running average
5	120 sec. CO running average	120 sec. CO running average
6	300 sec. CO running average	300 sec. CO running average
7	1 hr. CO continuous average (c.H.A.)	1 hr. CO continuous average (c.H.A.)
8	1 hr. and 60 sec. integrated CO averages, time multiplexed 60 sec. averages periodically blanked (b.H.A.)	1 hr. and 60 sec integrated CO averages, time multiplexed, 60 sec. averages periodically blanked (b.H.A.)
9	1 hr. and 60 sec. integrated CO averages, time multiplexed 60 sec. averages delayed (d.H.A.)	1 hr. and 60 sec integrated CO averages, time multiplexed 60 sec. averages delayed (d.H.A.)

The selected time responses for analog outputs #1 and #2 can be displayed by use of the Test STAT function.

For time switch settings 0 through 6, the analog output updates every 10 seconds (12 seconds for 50 Hz). If the switch setting is 7, the analog output gives the CO average for the previous hour starting at the time when the minute timer (as displayed upon second actuation of the Test H.A. pushbutton) is equal to one.

If the switch setting is 8, the analog output gives during the first 10 minutes of every hour, the CO average for the previous hour, and during the remaining 50 minutes, updating every 60 seconds, the current 60 sec. CO integrated average.

If the switch setting is 9, the analog output gives during the first 10 minutes of every hour, the CO average for the previous hour, and during the remaining 50 minutes, sixty 60 second integrated CO averages for the present hour, time compressed in the ratio 5:6. Therefore even while the hourly average is being output, the Model 48 continues to monitor CO and stores the 60 second averages to be updated every 50 minutes of the hour. The hourly average routines are discussed more fully in Section F of this chapter.

The digital display indicates the CO average corresponding to the time specified by switch settings 0 through 6 for analog output #1, updating every 10 seconds (12 seconds for 50 Hz) as indicated by blinking decimal point. If the time switch for analog output #1 is set to 7, 8, or 9, the digital display indicates 60 second running averages updating every 10 seconds (12 seconds for 50 Hz).

B. STARTUP

Turn the power switch on. The Model 48 automatically enters the startup mode during which time the following occurs:

1. The source turns on, all electronics are turned on, the detector cooler goes on, the chopper motor and sample pump go on, the heater in the pressure transducer goes on, the program initializes itself.

2. During the few minutes it takes for the source etc. to stabilize, the following should be noted in a properly operating instrument:

   a. When the power switch is energized, the LED display first displays the word "HELLO" followed by the word "CO". During this time (approximately 2 minutes), the analog outputs will give 0 volts.

   b. The instrument will then automatically go into the "Run-Sample" mode.

3. The Model 48 has been designed so that the Test diagnostic modes can be utilized without disturbing the analog outputs. Therefore, if one enters the Test STAT or H.A. modes, the instrument continues to output the CO values at the analog outputs. Entering the Test Z/FS or DAC modes does affect the outputs as described in Section III-A above, however, the microcomputer continues to store the CO data for use when returning to the RUN mode. If one enters the Test INT or P/T modes, the Model 48 "latches" onto the current CO value and continues to output that value until the instrument is returned to the RUN mode. The Model 48 then enters a wait period of approximately 25 seconds before updating to the current CO value.

C. SHUTDOWN

De-energize the power switch on the front panel. The Model 48 is now powered down.

D. LOSS OF POWER

If a power failure occurs or if the Model 48 is turned off momentarily, the instrument automatically goes into the startup mode upon resumption of power. Note that if any of the hourly average modes are being used, upon power up the timer will be reset to zero, thus the average will not necessarily be in synchronization.

E. INTERNAL SWITCHES

On board 48-3 (PIA) there is an eight station SPST DIP switch (Figure V-3). These switches are used to engage certain options if desired. They have the following meaning:

1. If DIP switch #1 (left most switch) is ON, the REMOTE function is deactivated.

2. If DIP switches #2 and #8 are ON, the pressure and temperature transducer measurements are deactivated, and the pressure and temperature values are set to instrument standards of 750 mm Hg and 25°C. These values are then used to determine the apparent CO concentration and can be displayed by utilizing the Test P/T function on the front panel.

3. If DIP switch #3 is OFF, CO concentrations less than 200 PPM are displayed with one decimal digit. CO concentrations greater than or equal to 200 PPM are displayed with no decimal digits. If DIP switch #3 is ON, CO concentrations less than 20 PPM are displayed with 2 decimal digits, CO concentrations greater than or equal to 20 PPM but less than 200 PPM are displayed with 1 decimal digit, and CO concentrations greater than or equal to 200 PPM are displayed with no decimal digits. If DIP switches #3 and #8 are ON, CO concentrations up to approximately 328 PPM are displayed with 2 decimal digits. Above 328 PPM no decimal digits are displayed.

4. DIP switches #4, 5, and 6 are currently not being used.

5. If DIP switch #7 is ON, the ZERO and SPAN solenoids are disabled, i.e., successive engagement of the RUN pushbutton has no effect.

6. If DIP switch #8 is ON, the Test pushbuttons - INT, STAT, and H.A. can select additional functions for troubleshooting and the automatic default to the "Run-Sample" mode is deactivated (see Section VII-A).

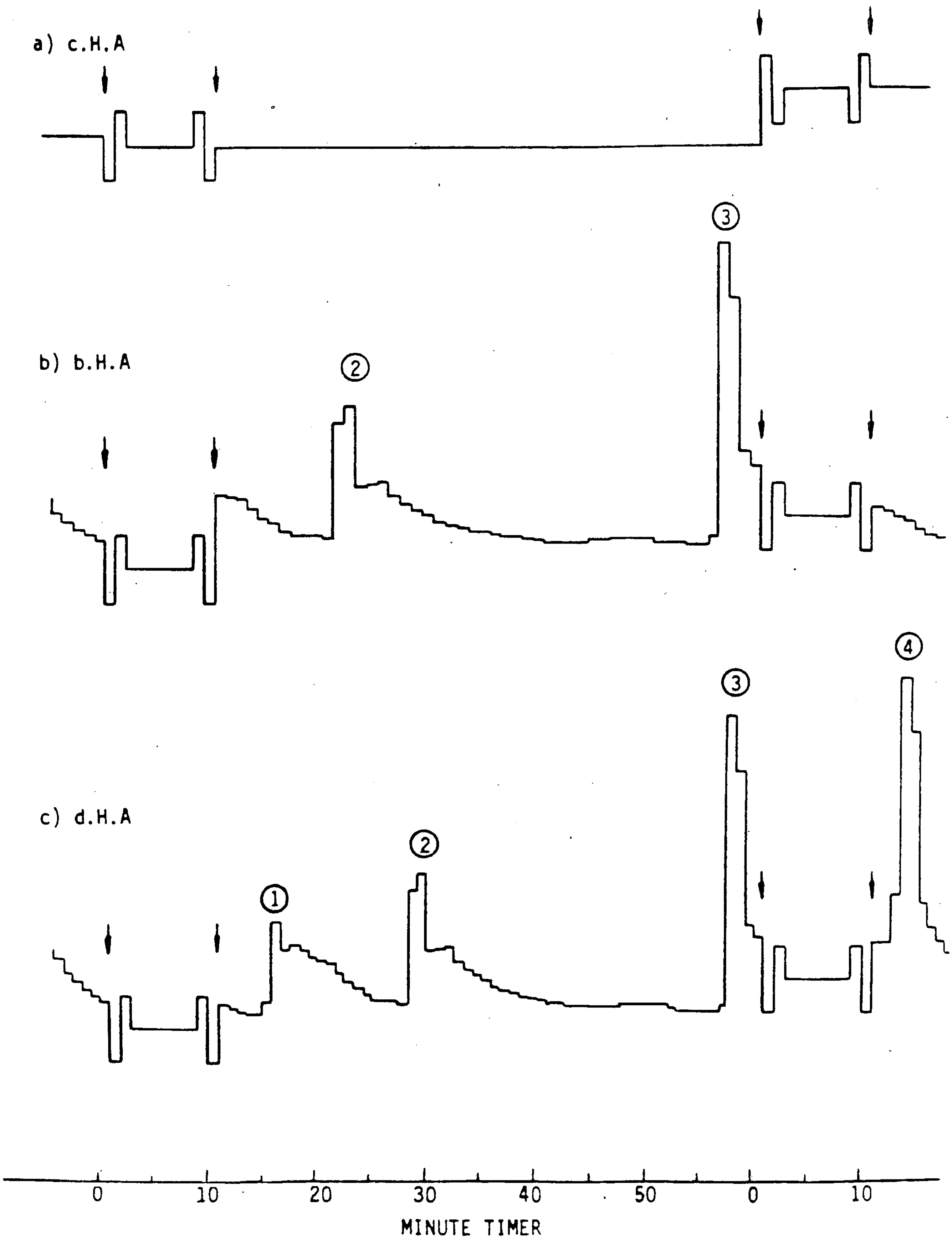

Figure III-2

Hourly Average Outputs

Note that under any condition where DIP switch #8 is ON, the LED indicating which front panel pushbutton is in use will be blinking.

F. HOURLY AVERAGE

All Model 48's include hourly average routines as standard user options. These options can be engaged by the use of time switches 7, 8, or 9 as described above in Section A.8. Using the standard dual analog outputs, the current CO value can be displayed on one output while the hour average value is being displayed on the second output.

Figure III-2 shows the types of hourly average outputs available using time switches 7, 8, or 9.

If it is desired to set the minute during the hour that the average begins, e.g., on the hour, engage the Test H.A. pushbutton twice to display the time in minutes. Now hold the pushbutton in until the time corresponds to the current time in minutes, e.g., if it is currently 0923, hold the button in until the display reads 23. The hourly average will now be display on the hour. Note however, that the first average will not be complete, since it will only include 37 minutes of data.

If the time switch is set to 7, continuous hourly average, an output as in Figure III-2.a is obtained. A separation signal is given at the beginning of the hour (minute timer at 1) and after 10 minutes (minute timer at 11) to indicate the updated hourly average. The separation signals consist of two 50 second steps 5% of FS above and below the hourly average value. These are indicated by arrows in the figure. The output for the remainder of the hour is the CO average concentration for the previous hour. When the timer resets to 1 minute, a new separation signal and hourly average value are output as shown.

Figure III-2.b indicates the analog output obtained for the same CO values as in a.) using switch setting 8 - blanking hourly average. During the first ten minutes of the hour (minute timer 1 to 11), the CO average concentration for the previous hour is given between the separation signals as indicated by the arrows. The output is the same as obtained in the continuous hourly average mode, but only for the first 10 minutes of the hour. For the remaining 50 minutes of the hour, fifty 60 second CO integrated average concentrations are given. Note CO concentration peaks labeled #2 and #3 at 23 and 57 minutes respectively. When the timer resets to 1 minute, a new separation signal and hourly average value are output.

Figure III-2.c indicates the analog output obtained using switch setting 9 - delayed hourly average. During the first 10 minutes of the hour, the CO average concentration for the previous hour is given, the same output as in a) and b). However, during the remaining 50 minutes, sixty 60 second integrated CO averages are given, time compressed in the ratio 5:6, that is, for 50 seconds each. The microcomputer in this case saves the 60 second integrated CO averages which are blanked out in the first ten minutes of the hour if using switch 8. Therefore, no data is lost and all the CO averages are output, however, they are delayed and compressed in time. Note the CO peaks #2 and #3 in the d.H.A. mode correspond to those same labeled peaks in the b.H.A. mode, however they appear to occur later in time, at 29 and 58 minutes respectively. Note also that CO peaks labeled #1 and #4 are now seen because the data which occurred while the hour average was being output was saved and then output.

CHAPTER IV CALIBRATION

This chapter describes the procedure for performing the multipoint calibration of the GFC CO Analyzer. The information described here is more than adequate to perform the calibration. However, if greater detail is desired, the user is referred to the Quality Assurance Handbook for Air Pollution Measurement Systems (1).

A. EQUIPMENT REQUIRED

1. CO Concentration Standard

Cylinder of CO in air containing an appropriate concentration of CO suitable for the selected operating range of the analyzer under calibration. The assay of the cylinder must be traceable either to a National Bureau of Standards (NBS) CO in Air Standard Reference Material (SRM) or an NBS/EPA approved gas manufacturer's Certified Reference Material (CRM). A recommended protocol for certifying CO gas cylinders against a CO, SRM or CRM is given in the Quality Assurance Handbook (1). The CO gas cylinder should be recertified on a regular basis determined by the local quality control program.

2. Dilution Gas (Zero Air)

Air, free of contaminants which will cause a detectable response on the CO analyzer. The zero air should contain < 0.01 PPM CO. Since the Model 48 is virtually interference free, it is only necessary to insure that CO has been removed. It should be noted that zero air as supplied in cylinders from commercial suppliers typically contain CO concentrations in the 0.1 - 0.3 PPM range. Thus cylinder zero air should be scrubbed of the residual CO prior to its use in the Model 48 as a dilution gas or a zero standard. Room air which has been scrubbed of CO can be used as the zero air source. It is not necessary to remove SO2, NO, NO2, CO2, water vapor, or hydrocarbons, since the Model 48 does not respond to these molecules. If water vapor is not removed, it might be necessary to correct the flow measurement data when calculating the dilution ratio of the span CO reference (see below).

A platinum on alumina catalyst, operated at 250^{o}C, has been found to be a convenient oxidizer to convert CO to CO2.

If it is desired to remove water vapor, SO2, etc., a photolytic ozone generator can be used to convert NO to NO2. This can be followed by a heatless air drier to remove water vapor, NO2, SO2, hydrocarbons, and ozone. The oxidizer should then be used to remove the CO. An alternative to the heatless air drier could be followed by silica gel, followed by activated charcoal. It has also been reported that a substance sold as Purafil (2) is successful in removing NO, and can be substituted for the ozonator. When using any of these chemical scrubbers, they must be periodically charged. Check with the manufacturer for proper interval times.

3. Flow Meter(s) and Controller(s)

In order to obtain an accurate dilution ratio, in the dilution method used for calibration, the flow rates must be regulated to 1%, and be measured to an accuracy of at least 2%. The meter and controller can be two separate devices, or combined in one device. The users manual for the meter should be consulted for calibration information. Additional information on the calibration of flow devices can be found in the Quality Assurance Handbook (1). It should be noted that all flows should be corrected to 25°C and 760 mm Hg, and that care should be exercised in correcting for water vapor content.

4. Pressure Regulator for CO Standard Cylinder

The regulator used must have a nonreactive diaphragm and internal parts, as well as a suitable delivery pressure.

5. Mixing Chamber

A chamber constructed of glass, Teflon (R), or other nonreactive material, and designed to provide thorough mixing of CO and diluent air for the dilution method.

6. Output Manifold

The output manifold should be constructed of glass, Teflon (R), or other nonreactive material, and should be of sufficient diameter to insure an insignificant pressure drop at the analyzer connection. The system must have a vent designed to insure atmospheric pressure at the manifold and to prevent ambient air from entering the manifold.

B. CHECKOUT OF THE MODEL 48 GFC CO ANALYZER

Prior to calibration, it should be ascertained that the Model 48 is operating properly. The Model 48's internal diagnostics makes this a quick and simple process. Turn on the instrument and allow it to stabilize for one hour. Perform the service checks of Chapter V.

C. STEP-BY-STEP CALIBRATION OF THE MODEL 48 GFC AMBIENT CO ANALYZER

1. Connect Instrument

Connect the Model 48 to be calibrated, and the equipment of Section IV-A as shown in Figure IV-1. If an optional sample line filter is used, the calibration must be performed through this filter. Insure that the flowrate into the output manifold is greater than the total flow required by the analyzer and any other flow demand connected to the manifold.

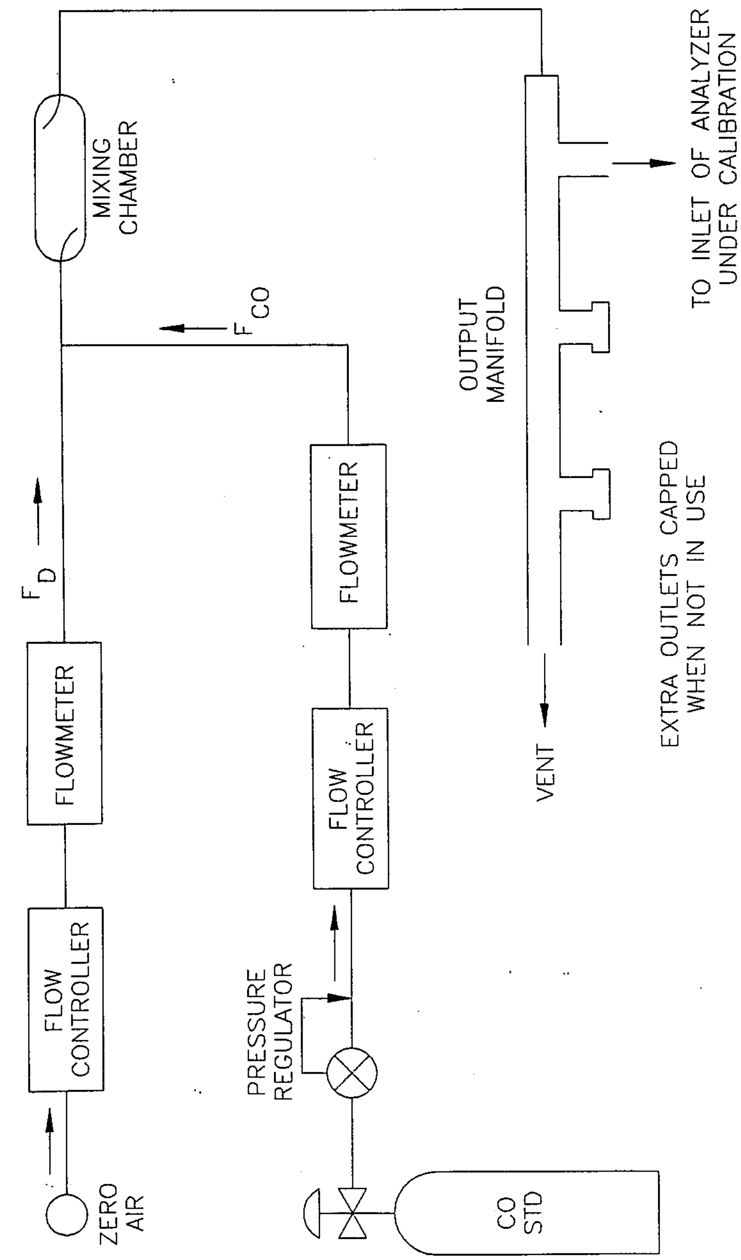

Figure IV-1

Calibration Flow Schematic

2. Zero Adjust

a. Allow sufficient time for the Model 48 to warm up and stabilize.

b. Adjust the dilution system of Figure IV-1 so that zero air alone is present in the manifold. Since not all flow controllers have a positive shut off, it might be necessary to disconnect the CO input line and cap it. Allow the Model 48 to sample zero air until a stable reading is obtained and adjust the zero of the Model 48 using ZERO thumbwheel switches (Figure III-1). Adjust for an average reading of zero.

If a strip chart recorder is used to obtain a record of the analog output, it is recommended that the system (i.e., either the Model 48 or the recorder) be adjusted to obtain a zero trace at 5% of scale. This is to allow observation of zero drift and/or zero noise. This offset can be achieved in one of two convenient manners as follows:

i. Use the zero offset capability of the recorder if it has such a capability.

ii. Adjust the analog output of the Model 48 to obtain the desired offset, by following the directions in Section V-G.

c. Record the stable zero air response as Z.

3. Span Adjust

a. Select the operating range of the Model 48. The full scale analog outputs of the Model 48 are given in Section III-A.7.

b. Adjust the zero air flow and the CO flow from the standard CO cylinder to provide a diluted CO concentration of approximately 80% of the upper range limit (URL) of the analyzer. The total air flow must exceed the total demand of the analyzer connected to the output manifold to insure that no ambient air is pulled into the manifold vent. The exact CO concentration is calculated from:

$$[CO]_{out} = ([CO]_{std} \times F_{co})/(F_d + F_{co}) \quad (1)$$

Where:

$[CO]_{out}$ = diluted CO concentration at the output manifold, PPM
$[CO]_{std}$ = concentration of the undiluted CO standard, PPM
F_{co} = flow rate of the CO standard corrected to $25^{o}C$ and 760 mm Hg, liters per minute
F_d = flow rate of the dilution air corrected to $25^{o}C$ and 760 mm Hg, liters per minute

Allow the Model 48 to sample this CO concentration standard until a stable response is obtained.

c. Adjust the Model 48 SPAN thumbwheels to obtain a recorder response as indicated from:

recorder response (percent scale) = (([CO]out x 100)/URL) + Zco (2)

Where:

URL = nominal upper range limit of the Model 48's operating range
Zco = Model 48's response to zero air, %scale

As noted earlier, if the instrument is zeroed first, use of the span switches will not affect the zero setting.

d. Record the CO concentration and the Model 48's response.

4. Additional Concentration Standards

Generate several additional concentrations (at least five others are suggested) by decreasing Fco or increasing Fd. Be sure the total flow exceeds the Model 48's total flow demand. For each concentration generated, calculate the exact CO concentration using Equation (1). Record the concentration and the Model 48's response for each concentration.

5. Calibration Curve

Plot the Model 48's response versus the corresponding CO concentrations. Connect the experimental points using a straight line, preferably determined by linear regression techniques. The calibration curve is used to reduce subsequent ambient data.

6. Frequency of Calibration

In order to generate data of the highest confidence, it is recommended that a multipoint calibration be performed every three (3) months, any time any major disassembly of components is performed, or any time the zero or span checks give results outside the limits described in Section D below.

D. PERIODIC ZERO AND SPAN CHECKS

In order to achieve data of the highest confidence, it is suggest that periodic zero and air span checks be performed. These checks can be performed by:

1. Periodically challenging the Model 48 with zero air. The output of the zero air supply should be greater than the flow demand of the Model 48. In addition, an atmospheric dump bypass should be utilized to ensure that the zero air gas flow is being delivered at atmospheric pressure. Record the Model 48's response in percent of scale as Ao. Compute the zero drift from the following equation:

$$\text{Zero Drift } \% = Ao - Z$$

where Z is the recorder response obtained at the last calibration for zero air, % scale. For convenience, zero air can be plumbed directly to the zero air input bulkhead port, and the zero check performed by engaging the "Run-Zero" pushbutton.

2. Periodically challenging the Model 48 with a CO level of approximately 80% of the URL. The 80% URL level may be obtained by dilution of a higher level of CO using a system similar to that of Figure IV-1, or by using a low level cylinder of CO containing CO in air at a concentration of approximately 80% of the URL. In either case the cylinder of CO should be checked against an SMR or CRM. It should also be true for a cylinder of low level CO. The Quality Assurance Handbook (1) should be referred to for the procedure of checking the cylinders. Record the Model 48's response in % of scale as A80. Compute the span error from the following equation:

$$\text{Span Error, } \% = ([(A80 - Z)URL/100] - [CO]) \times 100/[CO]$$

Where:

Z = Recorder response obtained at the last calibration for zero air, % scale.

[CO] = Span concentration

For user convenience the span gas can be plumbed directly to the span input bulkhead fitting. By engaging the "Run-Span"pushbutton, span gas will flow into the instrument.

3. The latest copy of the Quality Assurance Handbook for Air Pollution Measurement Systems (1) should be consulted to determine the level of acceptance of zero and span errors.

4. For detailed guidance in setting up a quality assurance program, the user is referred to the Code of Federal Regulations (3) and the EPA Handbook on Quality Assurance.

1. QUALITY ASSURANCE HANDBOOK FOR AIR POLLUTION MEASUREMENT SYSTEMS, Volume II - Ambient Air Specific Methods EPA 600/4-77-027a, May 1977 and 40 CFR 50, Appendix C.

2. Available from Purafil, Inc., POB 80434, Atlanta, GA 30366.

3. 40 CFR 58, Appendix A, B.

CHAPTER V PERIODIC MAINTENANCE AND SERVICE CHECKS

This chapter describes the periodic maintenance procedures that should be performed on the Model 48 to ensure proper, uninterrupted operation. Certain components such as the sample pump, solenoid valves, and source have a limited life and should be checked on a regular calendar basis and replaced if necessary. Other operations, such as cleaning the optics and checking the calibration of the pressure and temperature transducers should also be performed on a regular basis. What follows is a check and/or cleaning procedure for these elements. Replacement procedures for components found to be defective by these checks are given in Chapter VIII, Corrective Maintenance.

A. CLEANING OF THE OPTICS

Best results will be obtained if the optics are cleaned prior to recalibration. The cleanliness of the mirrors should also be checked any time the Test INT frequencies give a result less than 10,000 Hz, since one source of low output is light attenuation due to dirt on the mirrors.

To clean the mirrors, follow the procedure outlined below:

1. Turn off power and disconnect power line.

2. Remove field mirror (Figure V-1), (the field mirror is the rear mirror), by removing the four Allen head screws holding it to the main bench (use a 9/64 Allen wrench). Remove the relay mirror (Figure V-1), (the relay mirror is the front mirror, accessible through the front door), by removing the three Allen head screws holding it to the main bench (use a 9/64 Allen wrench).

3. Carefully clean each mirror using a "Q-Tip" and methanol. Rinse with distilled or deionized water. Dry by blowing clean dry air over the mirror.

4. Reassemble following the above procedure in reverse. It is not necessary to realign any mirror following cleaning.

5. Calibrate following the procedure of Chapter IV.

B. SOURCE REPLACEMENT

The source control system of the Model 48 has been designed to operate the wire wound resistor source conservatively in order to increase its life. Nevertheless, the source does have a finite life. Since the source is relatively inexpensive and easily replaced, (see Section VIII-A), it is recommended that the source be replaced after one (1) year of continuous use. This will prevent loss of data in the field due to source failure. If a source is to be replaced on an "as needed" basis, it should be replaced when any one of the following conditions hold:

ITEM	PART NO.	DESCRIPTION	QTY
		MATERIAL LIST	
1	7363	DETECTOR ASSEMBLY	1
2	7410	OPTICAL BENCH	1
3	7357	CHOPPER SOURCE ASSEMBLY	1
3A	4763 4762	MOTOR, BODINE 110V, 60HZ. MOTOR, BODINE 220V, 50HZ.	1
3B	7361	RESISTOR .15 ±5%	1
3C	7384	SOURCE COVER	1
3D	7385	SOURCE MOUNT	2
4	7411	RELAY MIRROR	1
5	7412	FIELD MIRROR	1
6	7414	EXIT MIRROR	1
7	7413	ENTRANCE MIRROR	1
8	4807	O-RING 2-035V	2
9	7380	FILTER INTERFERENCE ASSEMBLY	1
10	7415	APERTURE	1
11	4818	O-RING	1
12	5843	SCREW, FLT HD. 4-40 X 3/8"	2
13	4443	MALE BRANCH TEE	1
14	7331	THERMISTOR	1
15	7362 7352	TEMP. CONTROL BD. ASSEMBLY (110V) TEMP. CONTROL BD. ASSEMBLY (220V)	1
16	4826	O-RING	1
17	7360	OPTICAL SWITCH ASSEMBLY	1
18	7416	MOUNT, OPTICAL SWITCH	1
19	7358	FILTER WHEEL ASSEMBLY	1
20	8544	SHOCK MOUNT	4
21	7379	SPACER	4

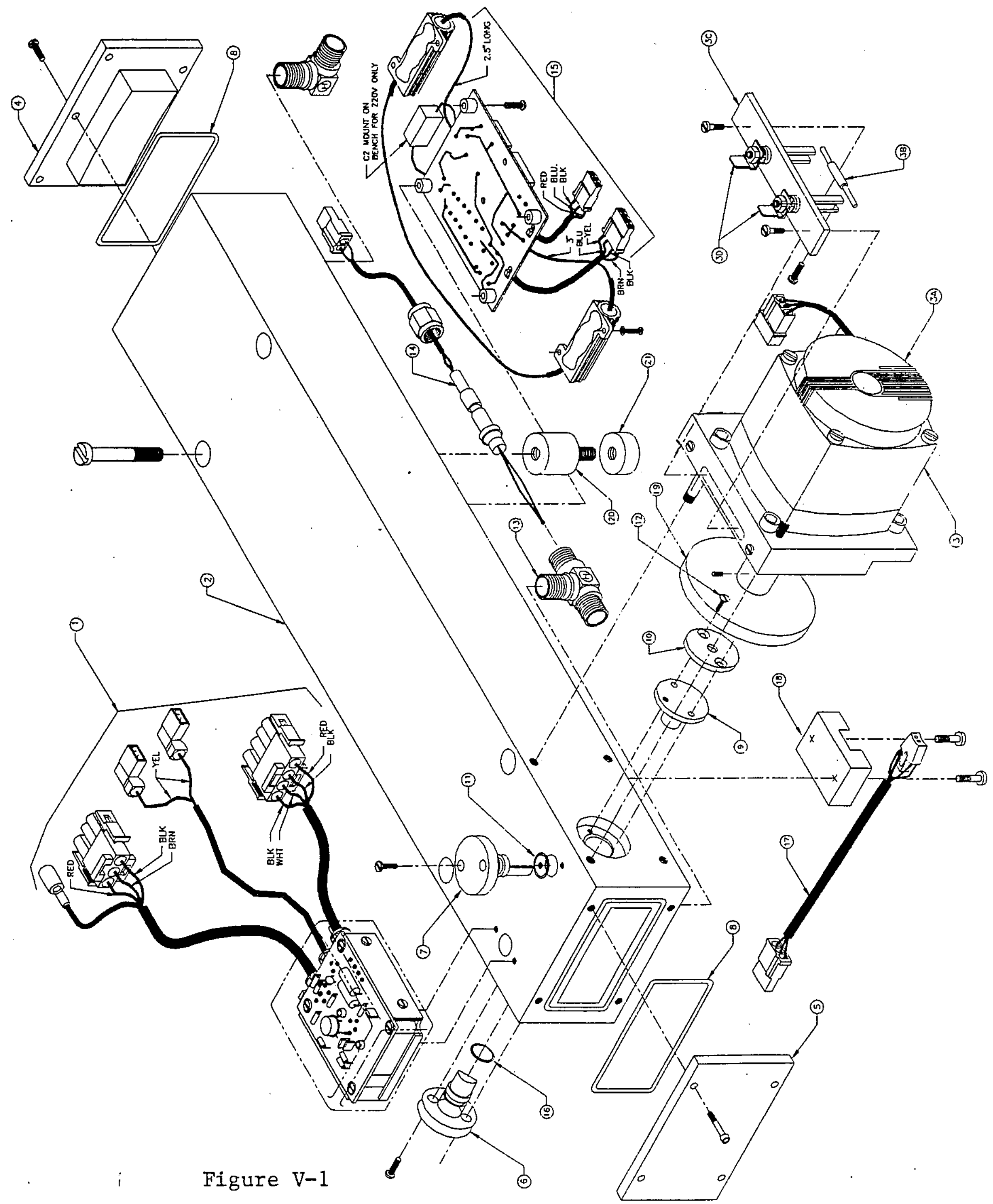

Figure V-1

Optical Bench Assembly

1. No light output.

2. If after cleaning the optics, the Test INT frequencies remain below 10,000 Hz.

Since the Model 48 is a ratio instrument, and since replacing the source does not affect the calibration, it is not necessary to recalibrate the Model 48 every time the source is replaced.

C. DETECTOR FREQUENCIES

The Model 48 measures intensity ratios and not absolute values. Therefore a large range of detector output frequencies are acceptable for proper operation of the instrument. The nominal values are between 10,000 and 30,000 Hz. These frequencies can be monitored by energizing the Test INT pushbutton.

Degradation of detector frequencies below the acceptable range indicates either a dirty mirror or a weak source (or a malfunction - see Troubleshooting Section). If cleaning the mirrors does not increase the detector frequencies to their proper range, replace the source.

D. PRESSURE TRANSDUCER

By energizing the Test P/T pushbutton, the LED display will show the pressure in mm Hg as determined by the pressure transducer. The pressure transducer has a zero and span adjust. The zero can be adjusted by disconnecting a vacuum pump known to produce a vacuum less than 1 mm Hg. The zero potentiometer (Figure V-2) is then adjusted for a reading of zero mm Hg. If the pump is then disconnected, but the transducer not connected to the bench, the display does not agree with a known accurate barometer, adjust the span potentiometer. Note that if the expected pressure changes are small (i.e., the only changes expected are barometric weather changes and not altitude changes) and error in the zero setting will not introduce a measurable error if the span is adjusted correctly. Thus if only a barometer is available, and not a vacuum pump, only adjust the span. If a barometer is not available, a pressure from the local weather station or airport. Since these pressures are usually reported corrected to sea level, it might be necessary to correct to local pressure by subtracting .027 mm Hg. per foot of altitude. Do not try to calibrate the pressure transducer unless the pressure is known accurately. Note that it is possible for the atmospheric barometric pressure from room to room or in a building to be different from the outside atmospheric pressure as a result of the positive pressure developed by the air-conditioning and/or heating systems.

E. TEMPERATURE TRANSDUCER

By energizing the Test P/T pushbutton twice, the LED display will show the temperature in degrees Celsius. The transducer used is a thermistor.

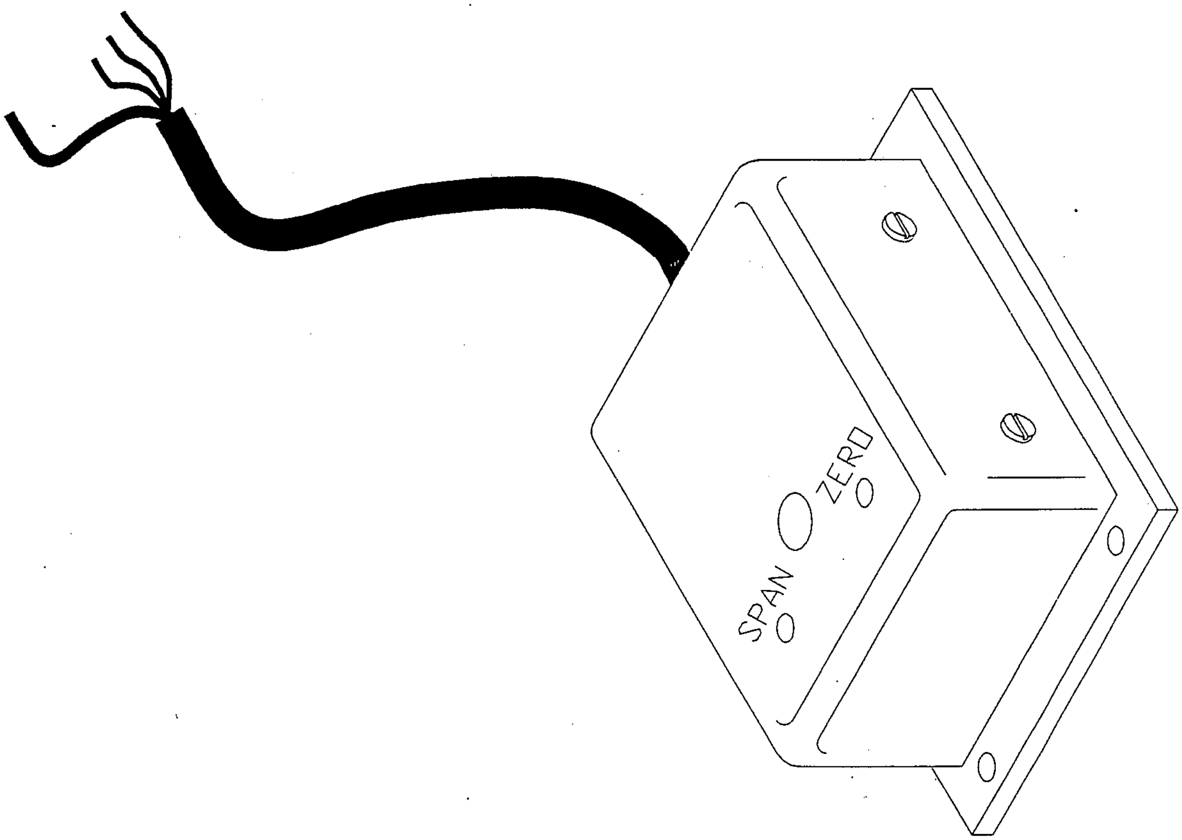

Figure V-2

Pressure Transducer

In order to calibrate the temperature transducer, remove it from the bench and tape it to a calibrated thermometer. Adjust the temperature adjustment potentiometer R71 on the Counter board (Figure V-3) so that the LED displayed value agrees with the value on the calibrated thermometer. Since the thermistors used on the Model 48 are interchangeable to an accuracy of +/-.2 degrees Celsius, and have a value of 10K ohms at 25 degrees Celsius, an alternative procedure is to hook up an accurately known 10K resistor to the thermistor input on the mother board, and adjust R71 for a reading of 25 degrees Celsius on the digital display. Note that a 1 degree Celsius change corresponds to a +/-5% change in resistance, thus this alternative procedure can be quite accurate as a check; however, it clearly is not NBS traceable.

F. SYSTEM LEAKS AND PUMP CHECK OUT

There are two major types of leaks, external leaks and leaks across the solenoid seals.

1. External leaks - In order to test for the presence of leaks around the fittings, disconnect the sample input line and plug the sample fitting. The flow as read on the rotameter should slowly decrease to zero. The pressure as read on the LED display should drop to below 250 mm Hg. If the pump diaphragm is in good condition and the capillary not blocked, it should take less than one minute from the time the inlet is plugged to the time the reading below 250 mm Hg. is obtained.

2. Leaks across the solenoid valve - In order to check for leaks across the solenoid valves plug the span inlet line, engage the "Run-Span" pushbutton and leak check following the procedure of Section V-F.1 above. If the pressure drops below 250 mm Hg. the valve associated with the span line is okay. Repeat for the valve associated with the span line is okay. Repeat for the valve associated with the zero line by plugging the zero inlet, engaging the "Run-Zero" pushbutton, and leak checking following the procedure of Section V-F.1 above. If the pressure drops below 250 mm Hg. the valve associated with the zero line is okay.

G. DIGITAL TO ANALOG CONVERTER TEST

By energizing the Test DAC pushbutton, the analog outputs will track the digital output from -23 PPM to 1000 PPM going from -2.3% full scale to +100% full scale. If a recorder trace is made, giving a straight line, the analog outputs are operating properly. Any excursions from a straight line indicate a probable lost bit or bad recorder (see Troubleshooting Section).

To adjust the zero on a recording device, enter the Test Z/FS mode. This will output zero volts on the analog outputs. To adjust the span on a recording device, engage the button a second time. This will output the full scale voltage (10.000 V unless otherwise specified) on the analog outputs.

To adjust the zero and span on the D/A board, monitor the analog outputs with an accurate voltmeter. Enter the Test Z/FS mode and adjust R21 (for analog output #1) on the D/A board (see Figure V-3) for zero volts, or any small offset voltage desired. Do the same for analog output #2 by adjusting R22. Now engage the Test Z/FS pushbutton a second time and adjust R23 (analog output #1) for 10.000 volts (or for 10.000 volts plus the zero offset). Do the same for analog output #2 by adjusting R24.

If a full scale output other than 10 volts has been supplied, adjust R23 (and/or R24) for the supplied full scale output (or full scale plus zero offset.)

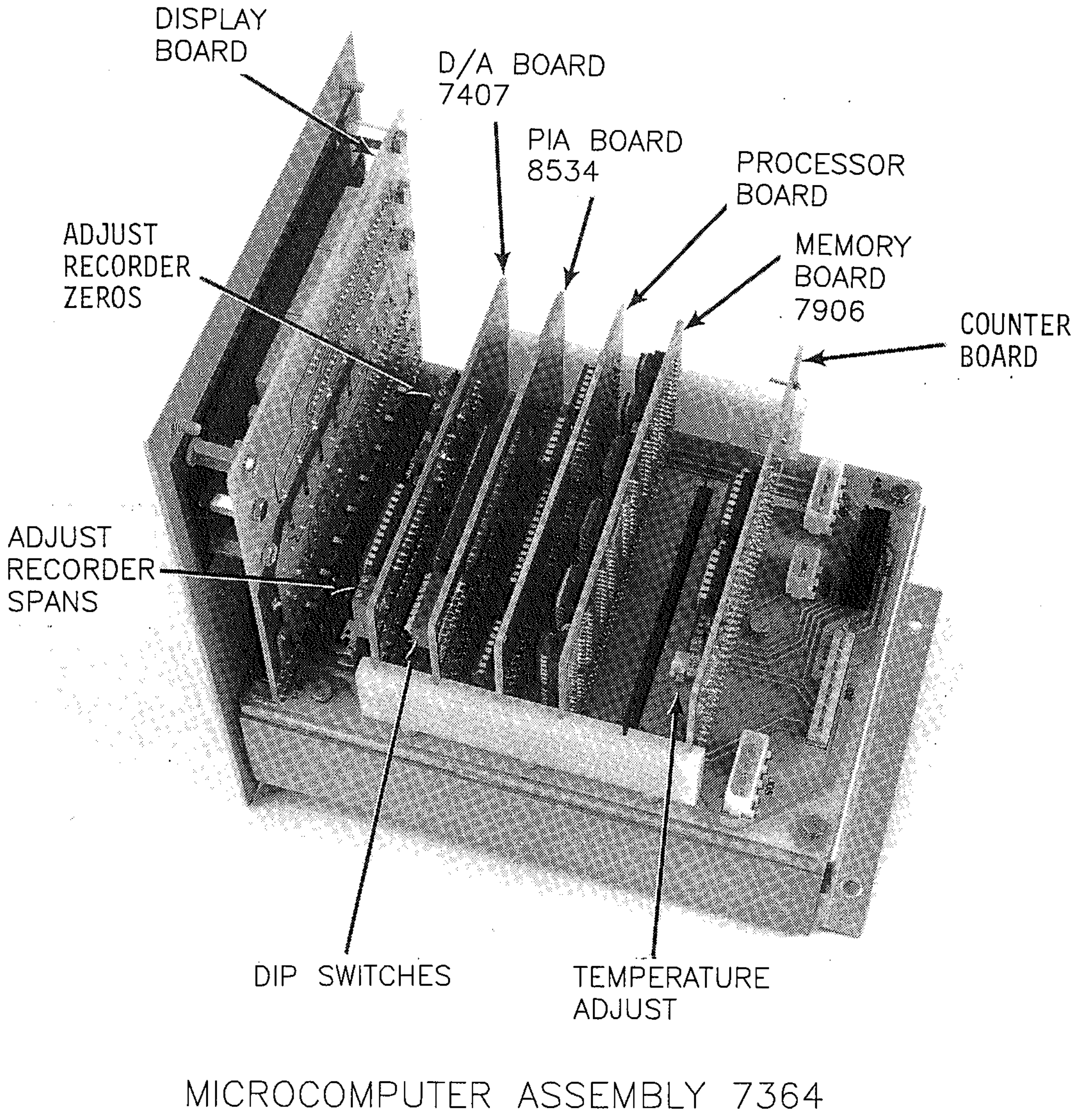

Figure V-3

Microcomputer Electronics

CHAPTER VI DESCRIPTION OF ELECTRONICS AND SOFTWARE OF MODEL 48

In order to understand the operation of the Model 48, a general knowledge of the electronics and software is necessary.

A. ELECTRONICS

The electronics can conveniently be broken down into the following subassemblies:

1. DC power supply and solenoid driver
2. Bias, source, and cooler power supply
3. Detector and preamplifier
4. Input signal conditioning board
5. Digital electronics
6. Temperature controller

A brief description of each follows. Note that all of the figures with the schematics are given in Appendix E. Also note that Figure E-16 is a schematic of the entire signal processing system.

1. DC Power Supplies (Figure E-1) - The DC power supply outputs the regulated and unregulated DC voltages necessary to operate the digital electronics, the bias supply, the detector and preamplifier, the input signal conditioning board, and the temperature controller. The transformer used is field jumpable for 110 and 220 volt service. It outputs +24 volts unregulated and +/-15 volts and +5 volts regulated. Regulation is achieved by use of monolithic voltage regulators. The DC board also contains the driving circuit necessary to energize the solenoids. The logic on/off signals are received from the microcomputer.

2. Bias, Source and Cooler Power Supplies (Figures E-2 and 3) - The solid state detector used needs a bias voltage of approximately -100 volts DC. Both the cooler and source need a high current, low voltage source. The bias supply (Figure E-2) contains a high current 18 volt regulated power supply. this 18 volts is passed through the source and cooler in series (see Figure E-3). The 18 volts is also used for an oscillator, the output of which goes to a step-up transformer, T101 of the bias supply, to generate the high voltage. This high voltage then passes through a rectifying circuit to form the -100 volt bias needed for the detector.

3. Detector and Preamplifier (Figure E-3) - The detector used on the Model 48 is a Photo Conductive, Lead-Selenide (PbSe) device, with an internal thermoelectric cooler. The PbSe detector operates through use of the internal photoelectric effect.

That is, its conductivity is proportional to the high intensity hitting it. One characteristic of this device is that it has a high conductivity even with no light. The background conductivity increases with increasing temperature. Thus in order to reduce the background conductivity, the detector is cooled. In order to distinguish the signal from background, the source is chopped. Thus the output of the detector includes an AC component due to the light signal, superimposed upon a DC component due to the background conductivity. It should be noted that the AC component is very small compared to the DC component.

The output of the detector passes through a coupling capacitor C2 and C3 of the preamplifier board (Figure E-3), which only passes the AC component. The AC component is then amplified by the op-amp IC-1. The output signal is an AC signal, with a low frequency component and a high frequency component. The low frequency component is at 30 Hz*, and is due to the 30 Hz rotation of the correlation wheel. The high frequency component is at 360 Hz and is due to the mask on the correlation wheel which divides the wheel into 12 sectors. The output of the preamplifier is fed through a shielded cable to the input signal conditioning board.

4. Input Signal Conditioning Board (Figure E-4) - The input signal conditioning board contains the circuitry necessary to operate the AGC (automatic gain control), the rectifier, and the demodulation circuitry. In addition, it includes the necessary components to digitize the signal output.

The output of the detector is fed to IC-121, which acts as a control gain amplifier. The control sensing element for the AGC feedback is the resistor CK2145, acting with IC-124 to feedback the gain information to the control gain amplifier, IC-121. IC's 127 and 123 are used to energize or de-energize the AGC, depending upon information received from the computer on Pin 15 of the input.

The output of the control gain amplifier passes through op-amp IC-124, which acts as a buffer. This information is then fed to IC-123, which detects when the AC signal crosses the origin. This information is fed to IC-127, which generates a 360 Hz square wave exactly in phase with the 360 Hz signal output of the detector. This 360 Hz signal ("chop clock" signal) is used for rectification and demodulation. IC's 126 and 129 act as a precision rectifier. Op-amp IC-129 is used in a unity gain, either inverting or noninverting mode. The mode of operation is set by switch IC-126. IC-126 switches in synchronization with the "chop clock" signal. Thus coming out of IC-129, one has a rectified signal. This signal is digitized by use of the V-F's IC-1212 and 1213. In order to separate the reference and sample signal, one V-F is used for the sample, the second for the reference. Which V-F is being used is determined by switch IC-128. In order to eliminate the effects of any long term drifts of the V-F's, the roles of the V-F's are interchanged every 5 seconds.

The Test INT signal, which is used to determine which V-F is being used, is generated by phase locking the "chop clock" signal with the output of the synch-generator optical switch. The optical switch output is at 30 Hz, due to the chopping frequency of the correlation wheel. Since this output might not be exactly in phase with the 360 Hz "chop clock" signal, both the output of the optical switch and the "chop clock" signal are fed into an LS74 flip-flop (IC-1210), which generates a 30 Hz signal exactly in phase with the "chop clock" signal ("sample (high)/reference (low)" signal). In order to switch IC-128 every 5 seconds*, exactly in phase with the "chop clock" signal, the "sample (high)/reference (low)" signal, and the "CTRL O" signal from the computer are fed to the LS74 flip-flops (IC's 1210 and 125) and the exclusive-or gate IC-1211.

The 30 Hz "sample (high)/reference (low)" signal is also used to generate a 10 Hz pulse signal by use of IC's 127 and 125, resistor R1231, and capacitor C1217. This signal ("external reset") is fed to the microcomputer, and is used as the master clock signal.

5. Microprocessor System - The microcomputer system is a multiboard system interconnected by use of a mother board (Figure E-5). The boards are broken up into functional forms as follows:

a. Microprocessor (Figure E-6)
b. Memory (Figure E-7)
c. Counter (Figure E-8)
d. Peripheral Interface (Figure E-9)
e. Display Driver (Figure E-10)
f. Digital/Analog (Figure E-11)
g. Switch (Figure E-12)
h. Span-Zero Buffer Board (Figure E-14)

A simplified discussion of these boards is a follows:

a. Microprocessor Board - The microprocessor used on the Model 48 is a Motorola 6800. This processor is operated at a frequency of 1 MHz, which is generated by the MC6875 two-phase clock generator. 10 times a second the 6800 receives a reset pulse generated by the input signal conditioning board. This reset pulse is used to generate the master timing signal used throughout the system i.e., ten such pulses determine one second, etc. Each time a reset occurs, the processor goes into a service routine during which time it reads the counters, increments the clock, and checks the status of the pushbuttons. IC-44 is used as a chip select. Depending upon the status of address lines A12, A13, and A14, one of eight different IC's can be chosen as shown on the pin outputs 7, and 9-15.

b. Memory Board - Two types of memories are used on the Model 48:

i. A RAM which can be thought of as a scratch pad for the microcomputer system. It is on this memory that the microcomputer stores intermediate values. The microcomputer can read and write onto this memory.

ii. An electrically programmable read only memory (EPROM). This memory contains the resident programs that are necessary for the Model 48 to operate. These programs are loaded in at the factory. The microcomputer can only read from this memory. The program is permanently stored and is not lost when power is removed.

Two 1K x 4 bit RAMS are used with IC-52 storing the most significant bit (MSB) and IC-51 storing the least significant bits (LSB) of the 8-bit words. Thus up to 1024 8-bit words can be stored in the RAM. The exact location being read or written into is determined by the status of address lines AO-A9. whether the data being transferred over the data bus is being read or written is determined by the status of the R/W (read/write) line.

The EPROM's used in the Model 48 contain 2048 8-bit words. The address being read is determined by the address lines AO-A10. Which of the three EPROM's is being used is determined by the status of the address line A11.

c. Counter Board - The pulse train output of the V-F's on the input signal conditioning board feed into counter 1 and 2 of a programmable timer module (PTM) (6840-IC-74), which contains three 16-bit binary counters. The third counter of the PTM is multiplexed by use of IC-73. During part of the time cycle, the pulse train output of the pressure transducer is fed directly to counter three, while during the other part of the time cycle, the voltage developed across the thermistor (which is directly related to its resistance) is fed into a V-F converter, which in turn is fed into counter three. The linearization of the thermistor output is performed by the software. These counters are under software control through the microprocessor.

d. Peripheral Interface Board - The PIA board contains the PIA (peripheral interface adapter). The PIA provides an extremely convenient way of interfacing peripheral equipment to the 6800 microprocessor to the peripherals through the peripheral data bus and control lines. The functional configuration of the PIA is determined by the software which is programmed into the EPROMs. The use of the PIA allows a high degree of flexibility in the overall operation of the interfacing, with very few external logical devices necessary.

e. Display Driver Board - The display driver board includes the display driver IC-11. Data to be displayed is outputted from the PIA onto the output peripheral bus B. It is read by the display driver which as an 8 x 8-bit memory (IC-11). IC-11 then drives the 3-dual digit LED's and LED 14-LED 113 using the data stored in its memory until new data is read into its memory.

f. Digital/Analog Board - The digital/analog board contains two latches, IC-24 and 25, which latch the output from lines PA0, PA1, and PB0-7 of the PIA. The latched data is fed directly to a 10-bit D/A converter for outputting to the analog outputs. R21 and R22 are adjusted for zero readings at zero input and R23 and R24 are adjusted to give the proper full scale outputs. By proper choice of R5, R6, and R7, which are contained on a component carrier, different full scale voltages are selected.

g. Switch Board - The thumbwheel switches on the front panel are used to input data into the microprocessor through the PIA to be used to change the zero, span, full scale analog outputs, and time responses.

h. Span Zero Buffer Board - The buffer board includes the buffers necessary to remotely activate the span and zero solenoids. Buffers are necessary since the data and address busses must be isolated from the outside world.

6. Temperature Controller (Figure E-13) - Two 50 watt 100 ohm resistors (400 ohm for 220 V) mounted on the optical bench are used to heat the optical bench above the dew point, to avoid moisture condensation on the mirrors. A thermistor is used to determine the bench temperature, with op-amp IC-131 and the solid state relay K131 used as the control elements to control the current into the heaters.

B. SOFTWARE

The software package that controls the Model 48 is resident on the EPROM's, IC's 53, 54, and 55 of board 48-5 (Figure E-7). The program resident in the instrument supplied with this manual is noted on the title page.

Ten times a second the 6800 receives a reset pulse. This forces the program into the reset mode, during which time the status of all pushbuttons are checked, the counters are read, the timer incremented, etc. If for any reason this does not occur, e.g., if the source burns out, the chopper motor stops, the optical switch fails, etc., the program will hang up. If this were to occur, there would be no new update of data, or if the Model 48 were just turned on, the display will only show "HELLO". It is important to understand this for troubleshooting.

Ten pulses equal one second. The Model 48 operates on a ten second cycle. Thus 100 reset pulses corresponds to one full cycle. Every five seconds a signal is sent to the input signal conditioning board changing which V-F receives the sample signal and which one the reference signal. After ten seconds, the program determines the running count for the last forms a ratio of these two signals. Using this information, as well as the pressure and temperature information determined from the pressure and temperature transducers, and the information in the span and zero thumbwheel switches, the Model 48 program determines a linearized, temperature and pressure corrected CO concentration. Every ten seconds this new information is displayed on the digital display and analog outputs, if a time constant of 10 seconds is set. Note, the past 30 measurements are stored in memory, thus the values for the past 300 seconds available.

If a time constant other than 10 seconds is set, the program takes the average over the proper number of values. Thus if a time constant of 60 seconds is set, the program will retrieve the past six measurements, take the average, and output this information to the digital and analog outputs.

Note, however, that a new update still occurs every ten seconds, with the latest computed concentration being added to the average, and the earliest one being dropped. Thus every ten seconds, there will be an updated average of the past six current computed concentrations.

Whenever the program enters the RUN mode from the Test INT or P/T modes, there is an approximately 25 second waiting period. if a time constant of ten seconds is set, the value displayed after the waiting period will be correct, if, however, a time constant other than ten seconds is set, one full time constant must be waited before the output concentration is completely updated.

Whenever the program enters the Test INT mode, the signal that interchanges the V-F's every five seconds is disarmed. Instead, the reference signal goes to one V-F without changing and the sample signal goes to the other V-F without changing. If the same test pushbutton is engaged a second time, the roles of the two V-F's are interchanged.

Anytime a pushbutton other than "Run-Sample" is engaged, a delay timer is reset. if the delay timer determines that one full hour has passed since the last pushbutton has been engaged, the program will automatically default to the "Run-Sample" mode. However, this automatic default is deactivated if DIP switch #8 on PIA board 48-3 is set ON.

The program of the Model 48 also keeps a running average of the computed CO concentrations forming an hour average to be output to the analog outputs if this option is active. Note, even while the hour average is being output, the Model 48 keeps on monitoring for CO and is storing these current values to be used in the next hour average.

* Note that for a Model 48 operated at 50 Hz, all frequencies should be multiplied by the factor 5/6, and times should be multiplied by the factor 6/5, e.g., the correlation wheel rotates at 25 Hz rather than 30 Hz, and the Model 48 operates on a twelve second cycle rather than a ten second one.

CHAPTER VII TROUBLESHOOTING

The Model 48 has been designed to achieve a high level of reliability. Only premium components are used, thus complete failure is rare. In the event of problems or failure, use of the TROUBLESHOOTING mode (DIP switch #8 on PIA board 48-3 ON) and/or the troubleshooting chart outlined in this chapter should be helpful in isolating the fault(s). The Service Department at Thermo Environmental Instruments Inc. can also be consulted in the event of problems at (508) 520-0430. In any correspondence with the factory, please note the program written on IC's 53, 54, and 55 on the Memory board 48-5, and also the Serial Number of the instrument.

WARNING

THIS INSTRUMENT CONTAINS 120V (OR 220 V). NORMAL PRECAUTIONS SHOULD BE USED WHEN WORKING ON THE INSIDE OF THE INSTRUMENT WITH THE POWER CONNECTED.

A. TROUBLESHOOTING

To enter the TROUBLESHOOTING mode of the Model 48, set DIP switch #8 on PIA Board 48-3 ON. Under this condition, the LED indicating which front panel pushbutton is in use will be blinking. DIP switch #8 is used to engage several options which include:

1. If DIP switch #2 <u>and</u> #8 are ON, the pressure and temperature transducer measurements are deactivated, and the pressure and temperature values are set to instrument standards of 750 mm Hg and 25^{o}C (see Chapter III-E.2).

2. If DIP switch #3 <u>and</u> #8 are ON, CO concentrations up to approximately 328 PPM are displayed with 2 decimal digits (see Chapter III-E.3).

3. Whenever DIP switch #8 is ON, the automatic one hour default to the "Run-Sample" mode is deactivated.

4. If DIP switch #8 is ON, the Test pushbuttons - INT, STAT, and H.A. - can select additional functions for troubleshooting. These functions are:

   a. Test INT - The <u>third</u> actuation of this pushbutton causes the instrument to display the infrared light intensity as digitized by the first V-F converter with the AGC (automatic gain control) circuit in operation.

This circuit is used to optimize the noise and resolution levels of the Model 48. The <u>fourth</u> actuation of the pushbutton displays the intensity as digitized by the second V-F converter with AGC circuit engaged. Both readings should be nominally the same, giving approximately 34,000 Hz. The readings should always be around this value, over the entire range of INT 1 and INT 2 values (10,000 - 30,000 Hz). If the AGC circuit is inoperable, the readings will be below this value.

b. Test STAT - As discussed in Chapter III-A.4, successive engagement of this pushbutton normally indicates the full scale ranges in PPM of analog outputs #1 and #2, the time responses of analog outputs #1 and #2, and the status (whether ON or OFF) of the eight internal DIP switches on DIA board 48-3. If DIP switch #8 is ON, additional functions, which follow the status of the DIP switches, are displayed. These are the front panel thumbwheel settings for ZERO and SPAN (disagreement with the actual thumbwheel settings would indicate either a faulty switch or poor connection), and the number of the program used in the instrument, which should agree with program number given at the beginning of this manual.

c. Test H.A. - The <u>fourth</u> actuation of this pushbutton will display the ratio of the intensities of the light source through the sample (CO) side and reference (N2) side of the correlation wheel. This function enables the user to check the status of the wheel without the need to remove it from the instrument. Normally the S/R ratio should lie between the values of 1.14 and 1.18. If the ratio falls outside of this range, this would indicate the possibility of a dirty correlation wheel, or leakage of gas within the wheel, which could cause increased zero drift and/or decreased sensitivity.

B. TROUBLESHOOTING CHART

Use of the following chart in conjunction with the procedures outlined in Chapters V and VIII should be used to help isolate and/or correct any problems or failures encountered while operating the Model 48.

TROUBLESHOOTING CHART

MALFUNCTION	POSSIBLE CAUSE	CHECK	REMEDY
Does not startup.	No power.	Check all voltages.	Replace or repair faulty power supply.
	Digital electronics defective.	Replace one board at a time with a spare board to isolate defective board.	Send defective board to factory for repair.
Hangs up (Displays Hello continuously or does not update every ten seconds).	No reset pulse.	That chopper motor is on.	Check that the motor is receiving power. If not, correct, otherwise replace motor and/or chopper motor capacitor.
		Source for light output.	Check source with ohm meter for continuity. If open, replace source. If okay, check for voltage across source. If not present, repair or replace bias power supply. If voltage okay, replace detector.

TROUBLESHOOTING CHART
(Continued)

MALFUNCTION	POSSIBLE CAUSE	CHECK	REMEDY
		Optical switch with oscilloscope for 30 Hz output.	If 30 Hz not present, check continuity to optical switch. If faulty, repair. If okay, replace optical switch.
		Signal input conditioning board.	Replace signal input conditioning board with known good board, or check board with oscilloscope, comparing to figures on schematic, and repair board.
	Digital electronics defective.	Replace one board at a time with a spare board to isolate defective board.	Send defective board to factory for repair.
Pressure tranducer does not hold calibration or is noisy.	Pressure transducer defective		Replace pressure or density tranducer.

TROUBLESHOOTING CHART
(Continued)

MALFUNCTION	POSSIBLE CAUSE	CHECK	REMEDY
	Digital electronics defective.	Replace one board at a time with a spare board to isolate defective board.	Send defective board to factory for repair.
Run output noisy.	Recorder noise.	Analog output.	Replace or repair recorder.
	Sample CO concentration varying.	Run Model 48 on a span CO source - if quiet, no malfunction.	
	Foreign material in optical bench.		Clean bench.
	Leaky solenoid	Leak Check.	Replace solenoid.
	Digital electronics defective.	Replace one board at a time with a spare board to isolate defective board.	Send defective board to factory for repair.

TROUBLESHOOTING CHART
(Continued)

MALFUNCTION	POSSIBLE CAUSE	CHECK	REMEDY
Analyzer does not calibrate properly.	Leak.	Leak Check.	Find and repair leak.
	Pressure or temperature transducer out of calibration.	Pressure and temperature transducer calibration.	Recalibrate transducer.
	Dirty system.		Clean cells and flow components.
	Leaky correlation wheel.		Replace with known good wheel.
	Digital electronics defective.	Replace one board at a time with a spare board to isolate defective board.	Send defective board to factory for repair.
Analog test ramp improper.	Faulty recorder.		Replace.

TROUBLESHOOTING CHART
(Continued)

MALFUNCTION	POSSIBLE CAUSE	CHECK	REMEDY
Analog test ramp improper.	D/A calibration off.	D/A calibration with DVM known to be in calibration.	Recalibrate D/A.
	Digital electronics defective.	Replace one board at a time with a spare board to isolate defective board.	Send defective board to factory for repair.

CHAPTER VIII CORRECTIVE MAINTENANCE

The following chapter describes step-by-step procedures to be used to replace the subassembly modules in the Model 48. Fault location is accomplished in the preceding chapters of Periodic Maintenance and Troubleshooting. This chapter assumes that a subassembly has been identified as defective and needs to be replaced.

A. SOURCE REPLACEMENT

(Figures V-1 and VIII-1, 2)
Equipment required:
I.R. New Source (Part No. 7361)
Screw Driver

1. Disconnect power and remove cover.
2. Disconnect source cable from source cover.
3. Remove two screws holding source cover to motor plate, remove source cover.
4. Loosen both clamp screws from brass stand-off, remove source.
5. Install new source by following the above procedure in reverse.

B. CORRELATION WHEEL REPLACEMENT

(Figures V-1 and VIII-1, 2)
Equipment required:
New Correlation Filter Wheel (Part No. 7358)
Allen Wrench - 5/32" and 5/64"

1. Disconnect power and remove cover.
2. Remove chopper assembly by removing the three Allen head screws holding motor mount to the optical bench.
3. Loosen set screw holding correlation wheel to motor shaft. Note that there is an access hole in the bottom of the motor plate.
4. Carefully pry correlation wheel off of motor shaft.
5. Install new correlation wheel by following the above procedure in reverse. Make sure that the set screw seats on the flat of the motor shaft.
6. Calibrate the instrument.

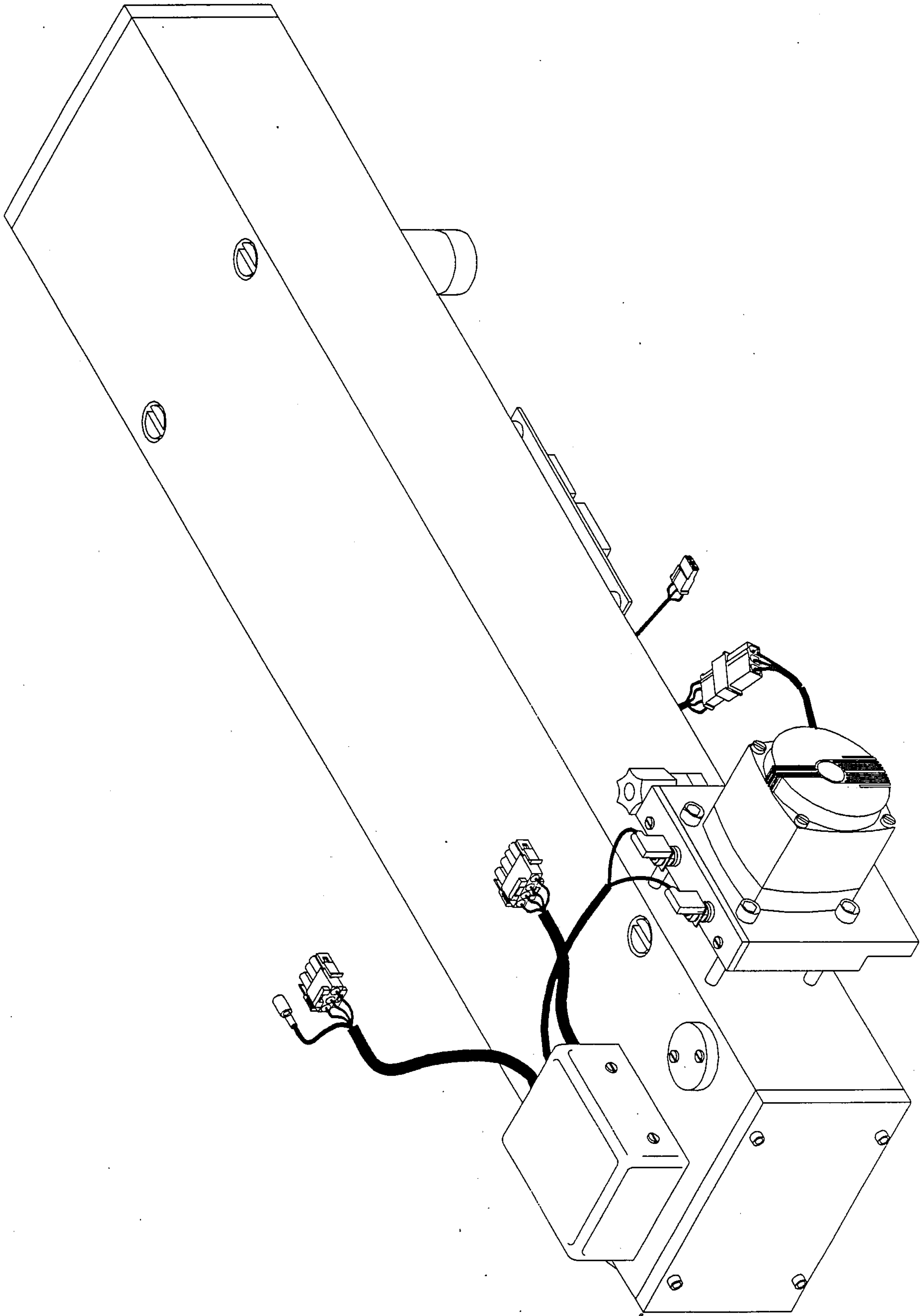

Figure VIII-1

Optical Bench

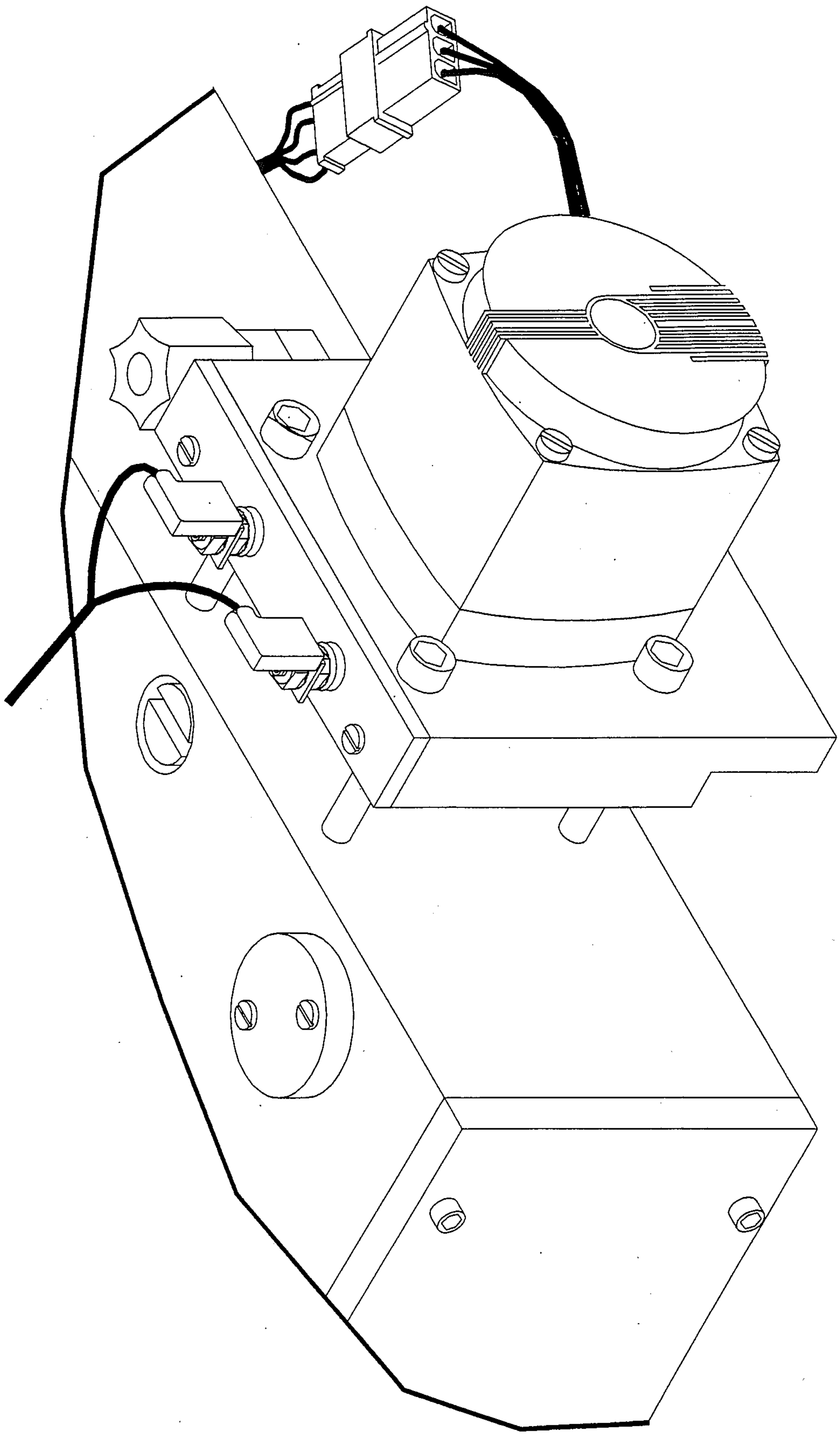

Figure VIII-2

Close-Up View of Chopper Assembly

C. CHOPPER MOTOR REPLACEMENT

(Figures V-1 and VIII-1, 2)
Equipment required:
New Chopper Motor (Part No. 4763, 110V
Part No. 7356, 220V)
Allen Wrench - 5/32" and 5/64"
Screw Driver

1. Follow direction for correlation wheel replacement, up to and including Step 4.
2. Remove the chopper motor from the motor plate by removing the two screws that hold it to the motor plate.
3. Install new chopper motor by following the above directions in reverse.
4. Calibrate the instrument.

D. OPTICAL BENCH REPLACEMENT

(Figures I-3 and VIII-1)
Equipment required:
Screw Driver

1. Disconnect power and remove cover.
2. Disconnect all connections between the optical bench and the electronics.
3. Remove the four screws holding the optical bench to the shock mounts and carefully remove the optical bench.
4. Replace the optical bench by following the above directions in reverse.

E. OPTICAL SWITCH REPLACEMENT

(Figures I-3, V-1, and VIII-1)
Equipment required:
New Optical Switch (Part No. 7360)
Screw Driver

1. Remove optical bench following the directions of D above.
2. Remove screw holding optical switch to optical switch mount block, and remove optical switch.
3. Install new optical switch by following the above directions in reverse.

F. BENCH HEATER AND BENCH HEATER POWER SUPPLY REPLACEMENT

(Figures I-3, V-1 and VIII-1)
Equipment required:
Bench Heater (Part No. 5924 110V) (Part No. 5925 220V)
Bench Heater Power Supply (Part No. 7362)
Heat Conductive Compound
Screw Driver

1. Remove optical bench following the directions of D above.
2. Remove screws holding heater and heater power supply to the optical bench bottom, and remove heater and power supply.
3. Install new heater and heater power supply by following the above directions in reverse.

G. PREAMPLIFIER - DETECTOR ASSEMBLY REPLACEMENT

(Figures V-1 and VIII-1)
Equipment required:
Preamplifier - Detector Assembly (Part No. 7363)
Screw Driver

1. Disconnect power and remove cover.
2. Disconnect cables between the preamplifier and source, bias power supply and input signal conditioning board.
3 Remove four screws holding preamplifier cover to preamplifier assembly and remove cover.
4 Remove the screws holding preamplifier-detector assembly to optical bench. Note access holes through the preamplifier printed circuit board. Carefully remove preamplifier-detector assembly from optical bench.
5 Install new preamplifier-detector assembly by following the above directions in reverse.

****** NOTE ******

The screws used on this pump all have metric threads.

H. PUMP REBUILDING

(Figures I-3 and VIII-3)
Equipment required:
Screw Driver
Flapper Valve and Diaphragm (Part No. 8606 KNF) & (8907 ASF)

1. Disconnect power and remove cover.
2. Loosen fittings and remove both lines going to the pump.
3. Remove four screws from top plate, remove top plate,

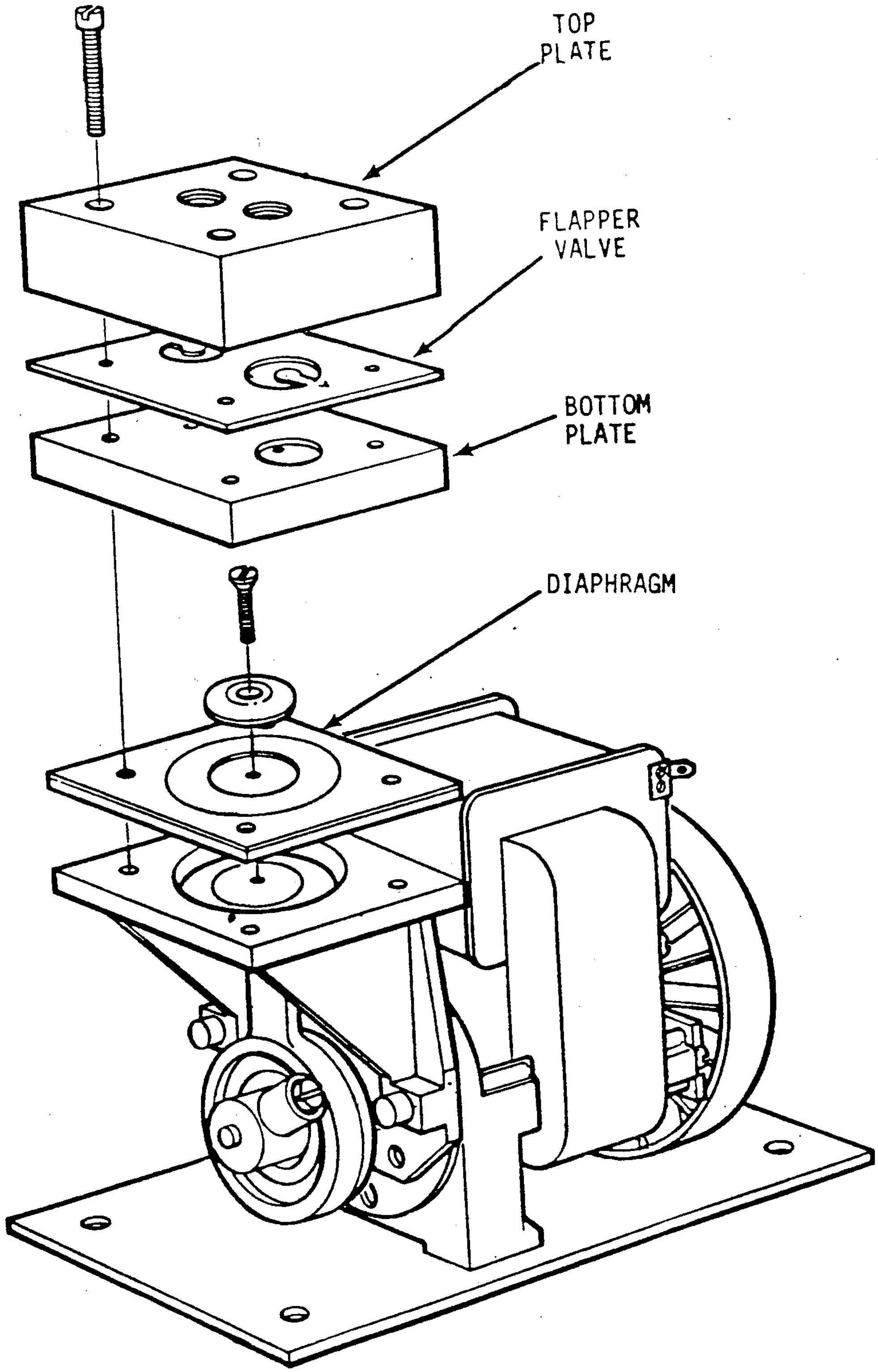

Figure VIII-3

Pump Assembly Diagram

flapper valve, and the bottom plate.
4. Remove screw holding diaphragm onto piston, remove diaphragm.
5. Assemble pump by following the above procedure in reverse, make sure the Teflon (white) side of the diaphragm is facing up and that the flapper valves cover the holes of the top and bottom plate.
6. Perform the leak test of Section V-F.

I. PUMP REPLACEMENT

(Figure I-3 and VIII-3)
Equipment required:
Pump (Part No. 8905 (110V) or 8906 (220V))
Nut Driver
Screw Driver

1. Disconnect power and remove cover.
2. Disconnect power line of pump from mother board.
3. Remove both lines from pump.
4. Remove four screws holding pump bracket to shock mounts.
5. Remove two screws holding pump to pump bracket.
6. Install new pump by following the above procedure in reverse.
7. Perform the leak test of Section V-F.

J. PRESSURE TRANSDUCER REPLACEMENT

(Figure I-3)
Equipment required:
Pressure Transducer (Part No. 8511)
Nut Driver

1. Disconnect power and remove cover.
2. Disconnect pressure transducer form mother board.
3. Remove four screws holding pressure transducer plate from floor plate. Remove four screws holding pressure transducer plate.
4. Install new pressure transducer following the above procedure in reverse.
5. Check calibration of pressure transducer.

K. MICROCOMPUTER ASSEMBLY REPLACEMENT

(Figure VIII-4)
Equipment required:
Nut Driver
Digital Electronics (Part No. 7364)

1. Disconnect power and remove cover.
2. Disconnect all plug-in connections form the micro-computer assembly.
3. Remove the two screws and two nuts holding the assembly onto the chassis.
4. Slide out the microcomputer assembly from the chassis.
5. Install the microcomputer assembly by following the above directions in reverse.

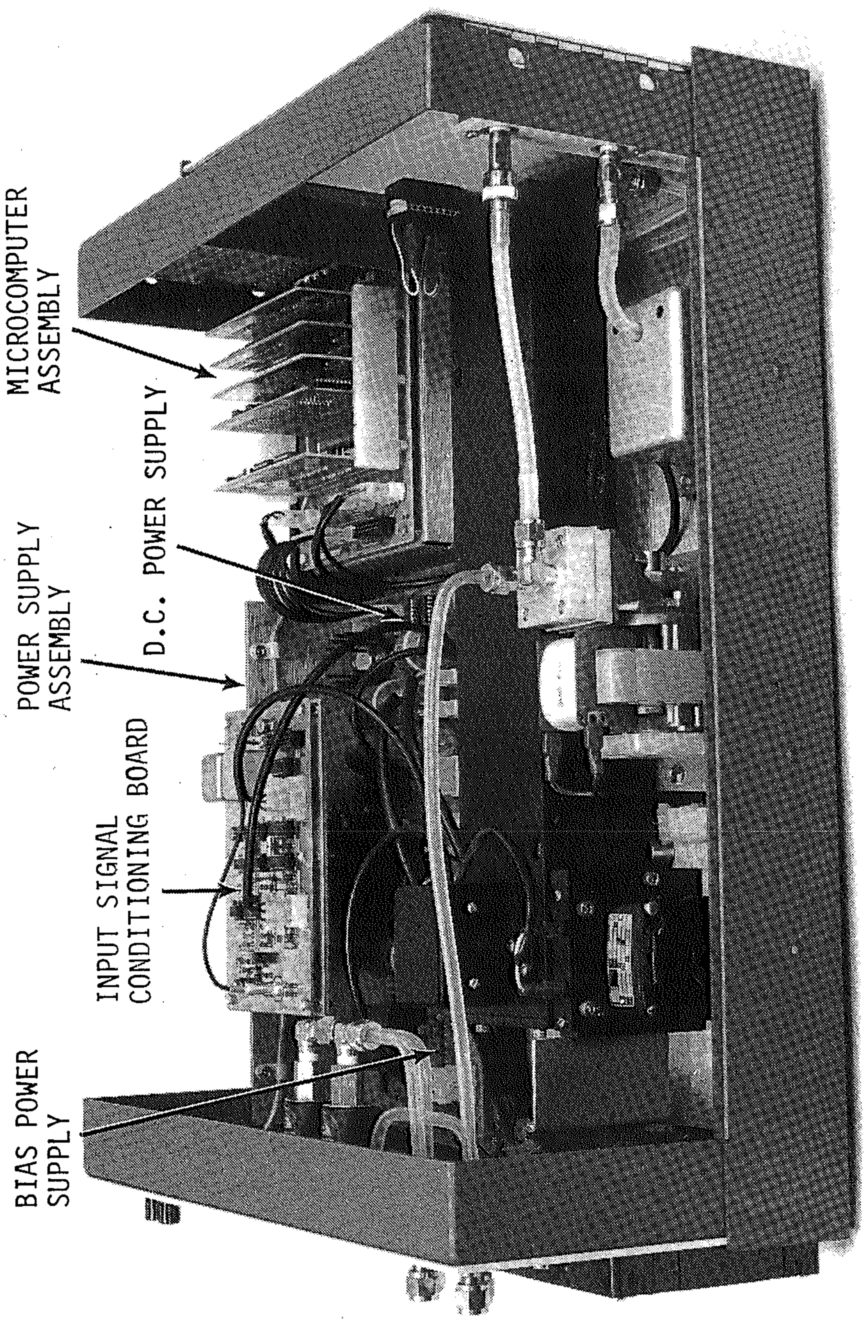

Figure VIII-4: Electronics and Power Supply Removal

L. INPUT SIGNAL CONDITIONING BOARD REPLACEMENT

(Figure VIII-4)
Equipment required:
Nut Driver
Input Signal Conditioning Board (Part No. 7365)

1. Disconnect power and remove cover.
2. Disconnect all plug-in connections from input signal conditioning board.
3. Remove all screws holding board to bracket, and remove the board.
4. Install new board by following the above directions in reverse.

M. D.C. AND BIAS POWER SUPPLY BOARDS REPLACEMENT

(Figure VIII-4)
Equipment required:
Nut Driver
Screw Driver
Replacement Board (Part No. 7366) for DC power supply board, Part No. 7367 for bias supply board)

1. Disconnect power and remove cover.
2. Disconnect all plug-in connections from input signal conditioning board.
3. Remove four screws holding input signal conditioning board bracket form main power supply bracket, and remove input signal conditioning board assembly.
4. Disconnect all plug-in connections from power supply board being replaced.
5. Remove screws holding board to chassis and remove board.
6. Install new board by following the above directions in reverse. Case should be exercised to insure that voltage regulators fit into the plug on the bottom of the board.

N. CAPILLARY REMOVAL

Equipment required:
Capillary (Part No 7336)
Wire to clean old capillary

1. Disconnect power and remove cover.
2. Remove knurled nut on capillary holder.
3. Remove capillary, clean with less than .015" diameter wire or replace.
4. Install capillary by following the above directions in reverse.

O. SOLENOID VALVE REPLACEMENT

(Figures I-3 and II-1)
Equipment required:
Solenoid Valve (Part No. 7368)
Screw Driver
Wrench - 9/16"

1. Disconnect power and remove cover.
2. Unplug solenoid from main power supply.
3. Remove Teflon lines form solenoid.
4. Remove both screws holding solenoid to rear panel.
5. Install solenoid by following the above directions in reverse.
6. Leak check.