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Windows Oxymax
Hardware Manual

0233-002M

Columbus Instruments

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Table of Contents

1.0 Specifications

Power Consumption

Oxymax system:	100 Watts
Controller/computer:	200 Watts

Physical Dimensions

Sample Pump & Sensors:	13" x 11.5" x 22"	(33 x 29 x *56* cm)
Expansion Interface:	13" x 11.5" x 7.5"	(33 x 29 x 19 cm)
Controller:	17" x 17" x 7"	(43 x 43 x 18 cm)

Weight

System Sample Pump & Sensors: 44 lbs. (20 Kg)
Expansion Interface: 12 lbs. (5.5 Kg)
Controller: 40 lbs. (18 Kg)

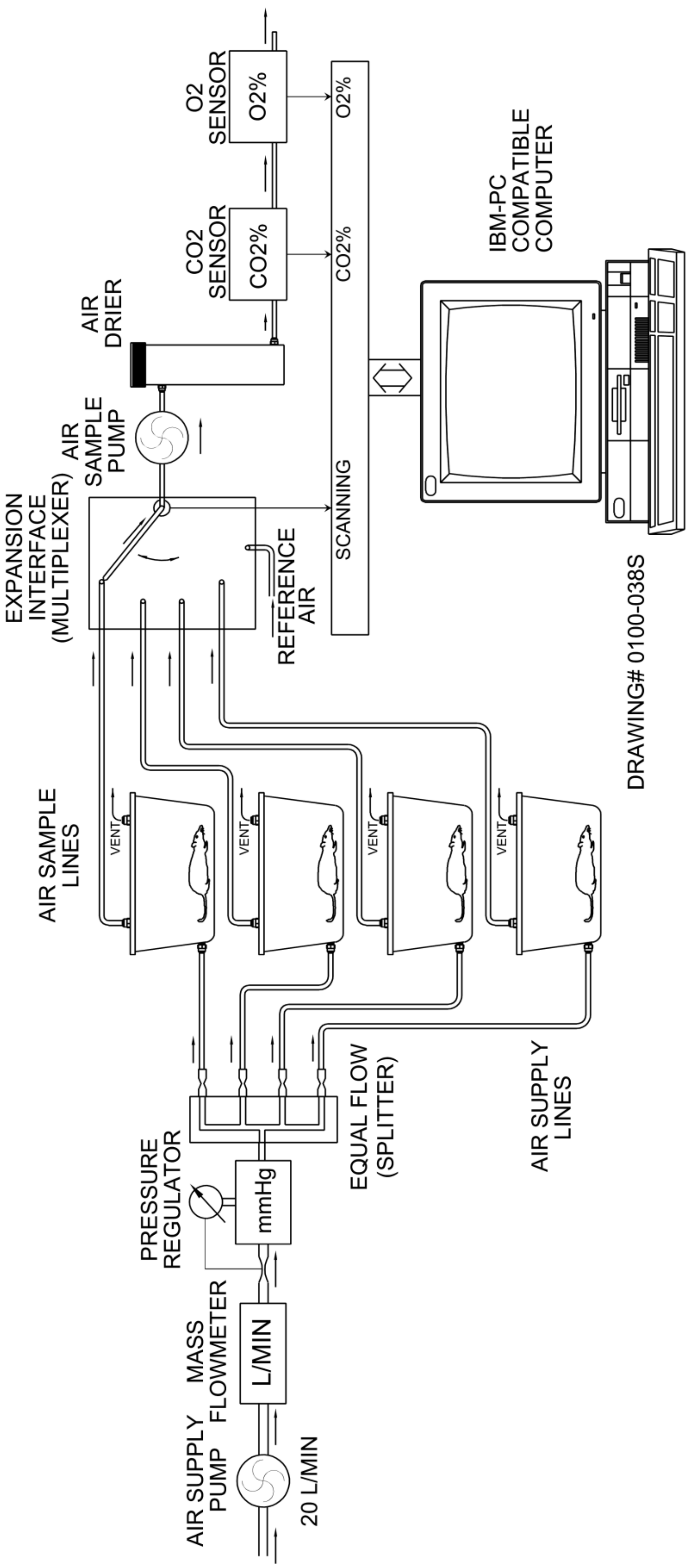
Gas Sensor Ranges (Standard)

C02: 0% - 0.9%*
02: 19.3% - 21.5%*

Optional: H2, H2S, S02, CH4 and CO sensors.

* Alternative ranges are available, contact Columbus Instruments.

Note: A maximum of three sensors can be used simultaneously.



AIR SUPPLY PUMP
20 L/MIN
MASS FLOWMETER
L/MIN
PRESSURE REGULATOR
mmHg
EQUAL FLOW (SPLITTER)
AIR SUPPLY LINES
AIR SAMPLE LINES
VENT
VENT
VENT
VENT
EXPANSION INTERFACE (MULTIPLEXER)
REFERENCE AIR
SCANNING
AIR SAMPLE PUMP
AIR DRIER
CO2 SENSOR
CO2%
CO2%
O2 SENSOR
O2%
O2%
IBM-PC COMPATIBLE COMPUTER
DRAWING# 0100-038S

Figure 0

2.0 Introduction

The Oxymax is an open circuit calorimeter. The integrated instrumentation is designed to monitor oxygen consumption and carbon dioxide production for a variety of studies involving laboratory animals. This system represents a fully automated approach utilizing personal computer as a dedicated controller. With the addition of optional Expansion Interfaces, the system can be expanded up to twenty (20) chambers.

2.1 System Overview

The Oxymax performs measurements on an open system, meaning that air is pumped through the test chamber(s) and the gas sensors and then expelled into the atmosphere. The percent 02 and C02 gas levels of the test chamber environment are measured periodically and the changes in the levels are used to compute the 02 consumption (V02), C02 production (VCO2) respiratory exchange ratio (RER), and heat. Results may be presented in ml or liters per hour or minute and normalized to subject mass or volume. The Oxymax employs three methods of reference air measurement and has options for chamber damping compensation as well as body mass index correction. The control, measurement, display, and storage of data is performed by a personal computer loaded with the Oxymax software. Refer to Drawing # 0100-038S.

A great deal of flexibility was designed into Oxymax to allow a wide variety of applications. There is support for different gas sensors including methane. Chamber size, ventilation type, and ventilation rate requirements are addressed for each system. Various methods are available for varying the system response time. In addition, the form and content of the data displays can be changed.

Oxymax supports eight user-defined inputs per chamber. Each input can be defined as a Columbus Instruments Iso-Thermex channel (temperature), a precision scale, a Columbus Instruments volumetric drinking monitor channel, or a Columbus Instruments Event Counter channel. These measurements could represent respiration rate, heart rate, chamber temperature,body temperature, subject activity, drinking volume, wheel activity, lick detections, food dispenses, or any other measurable parameter provided there is a compatible interface. Each input can be customized via a user-defined equation. Equation variables can be other user defined inputs and previous results.

2.2 The Gas Sensor

The Oxymax gas sensors measure the gas concentrations from a sample drawn from the selected chamber. A settling time is required before measurement to purge the lines to ensure an accurate sample.

The Oxymax carbon dioxide and methane sensors are single-beam, infrared devices, while the other line of gas sensors work on an Electro-chemical principle. The C02 sensor has a working range of 0-.9% and the oxygen sensors range is from 19.3 –21.5%. Optional expanded ranges are available for both 02 and CO2. H2, CH4, CO, H2S and S02 sensors are also available. Please contact Columbus Instruments for details.

2.3 Controller Requirements

The Oxymax is intended for use with Pentium class computers running Window 95SE, Windows 98, Windows ME, Windows 2000, Window NT, or Windows XP operating systems. These machines must have at least 128 Mbytes of available memory, a hard drive, one CD drive, and a VGA display. In addition, the computer must have a free RS232 communication port available.

3.0 Installation

If a computer is not included with the system, refer to the computer manuals for instructions on installing and configuring the components.

3.1 AC Power Filtering and Battery Backup

It is highly recommended to use an AC power filter/surge suppresser with the system to protect all instrumentation. The Oxymax system warranty does not cover damage due to power surges. It is also a good idea to connect the system (including the computer) to an un-interruptible power supply. This will prevent the interruption of experiments and loss of data during brief power outages, and brownouts. Make sure that the un-interruptible power supply delivers a minimum of 500 watts of electrical power.

3.2 Drier Assembly

The System Sample Pump requires two clips for mounting the reference air-drying column. Figure 1 illustrates assembly of the drier mounting clips and tubing connections. The drying columns are filled at the factory. When changing the desiccant care must be taken when reassembling the drier to ensure an airtight seal is maintained. When reassembling the drier the rubber 0-ring seal located on the ends of the column must be clean as well as the shoulder of the threaded glass piece. Overfilling can also prevent an airtight seal. **Do not over tighten the threaded end-caps, as the glass will break**. Replace the desiccant when 2/3 of the column becomes consumed. The *Oxymax Sample Pump Diagnostic* can be used to leak check the reference air drier.

Reference Air Drier Leak Check Procedure:

1. Select the *Sample Pump* entry from the *Tools* menu.
2. Ensure *Ref Air/Cal* valve open and *N2* and *Test In* valve closed.
3. Turn *Sample Pump* ON.
4. Observe sample pump flow meter indicates flow and adjust for .5 LPM.
5. Disconnect drier input tubing at the sample pump and block the tubing.
6. Observe the sample pump flow meter ball drop to the bottom after a few seconds. If the ball doesn’t drop at all or doesn’t go *completely* to the bottom, there is a drier leak.

To leak check animal cage driers;
Animal Cage Drier Leak Check Procedure:

1. Select the *Sample Pump* entry from the *Tools* menu.
2. Ensure *Test In* valve open and *N2* and *Ref Air/Cal* valve closed.
3. Turn *Sample Pump* ON.
4. Using the *Expansion Interface Channel Select* buttons, select the chamber to be tested.
5. Observe sample pump flow meter indicates flow and adjust for .5 LPM.
6. Disconnect drier input tubing at the animal cage and block the tubing.
7. Observe the sample pump flow meter ball drop to the bottom after a few seconds. If the ball doesn’t drop at all or doesn’t go *completely* to the bottom, there is a drier leak

Drier Assembly

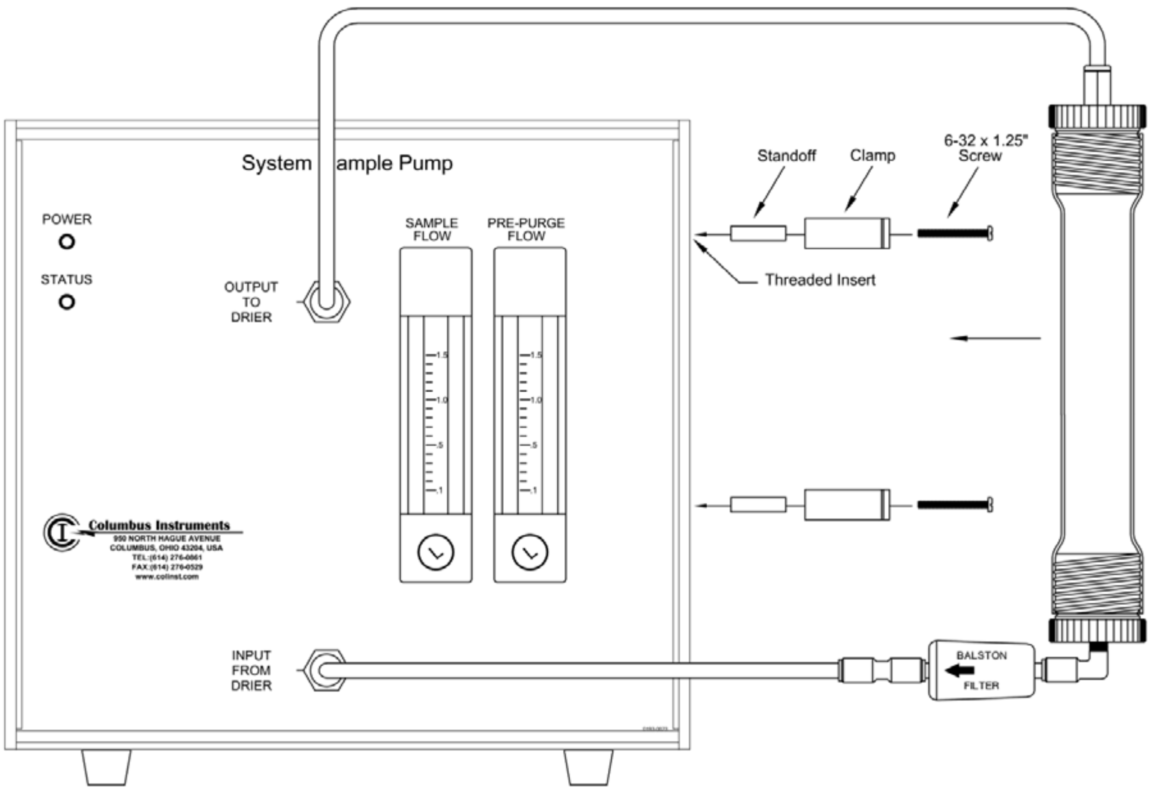


Figure 1

3.3 Component Placement

Refer to Figure 2 when placing the components, connecting the dryers and tubing to assure proper installation. It is recommended that the components be positioned to allow easy access to the rear of the system, since this is where most of the connections will be made. The arrangement of the components from left to right should be the computer, the three cabinets of the Oxymax system in a single stack, the Expansion Interface(s) (if present) and the animal chamber(s).

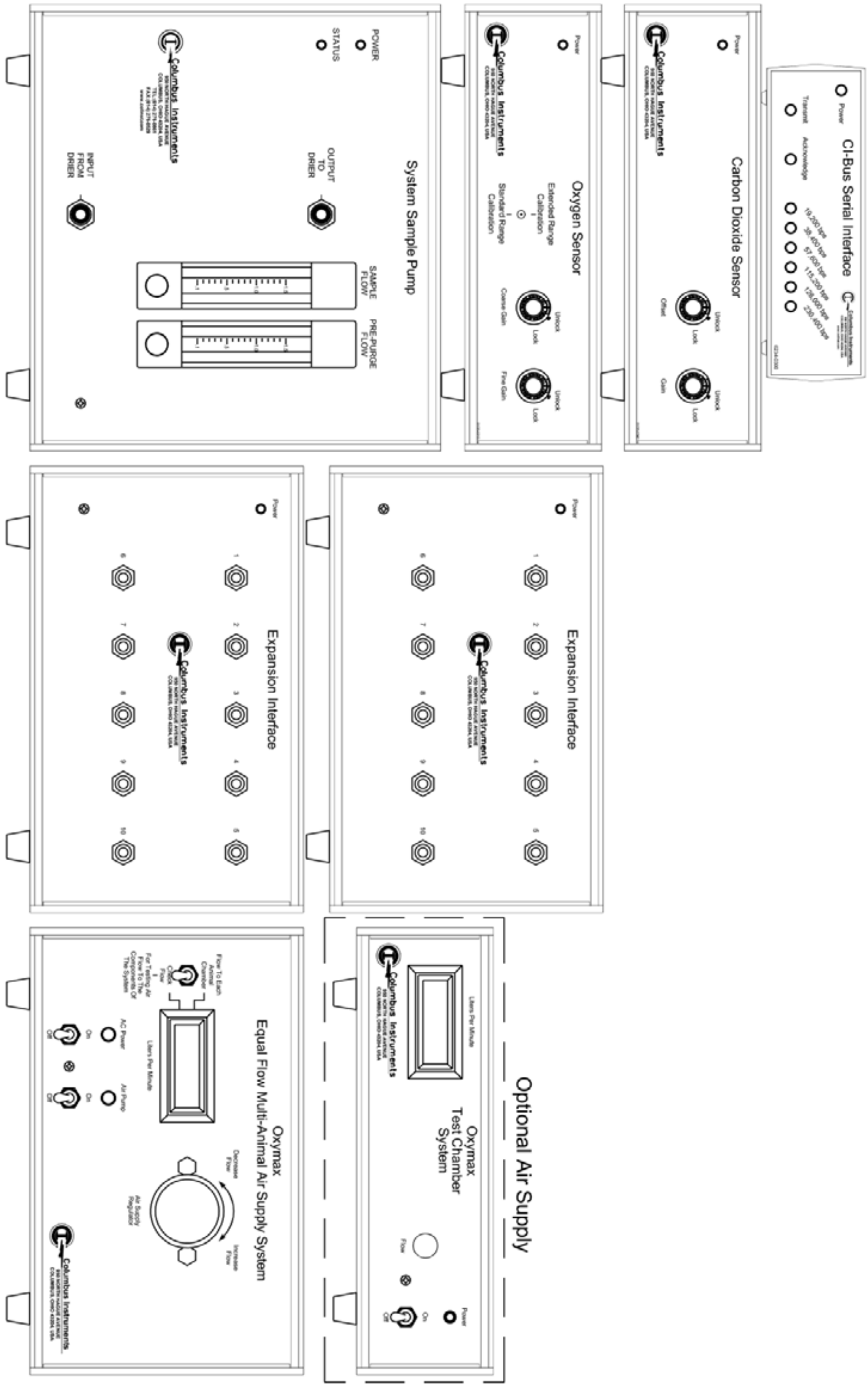

System Sample Pump
Oxygen Sensor
Carbon Dioxide Sensor
CI-Bus Serial Interface
Expansion Interface
Expansion Interface
Oxymax
Equal Flow Multi-Animal Air Supply System
Optional Air Supply
Oxymax
Test Chamber
System

Figure 2

3.4 Tubing Connections

Two types of tubing connection are used on the system. The connections on the back of the sensors, dryers, and System Sample pump employ a metal nut and 2 piece plastic ferrule. The other type of connection is a "quick connect" type fitting and is used on the expansion unit.

To make a connection using the nut and ferrule, slide the nut onto the end of the tubing and then slide on the two-part ferrule. Allow 0.25 cm of tubing to stick out beyond the end of the ferrule. Screw the nut on to the port finger-tight then tighten it another 1/4 turn using a wrench. Be careful not to over-tighten these connections. Excessive tightening may result in a pinched tube or damage to the fittings.

To make tubing connections using the "quick connect" type fittings, simply press the tubing into the fitting. Tubing should slide approximately *1.75* cm inside the connection and resist dislodging by pulling. To disconnect these fittings, hold the collar around the tubing firmly against the fitting while pulling the tubing. If excessive leakage occurs with these fittings, most likely the end of the tubing is worn. Cutting a 1 cm piece off the end of the tubing should restore the seal. Be sure to use a sharp knife when cutting the tubing for these fittings to ensure a good seal. Refer to Figure 3 when making the System Sample Pump, Sensor and Expansion Interface tubing connections.

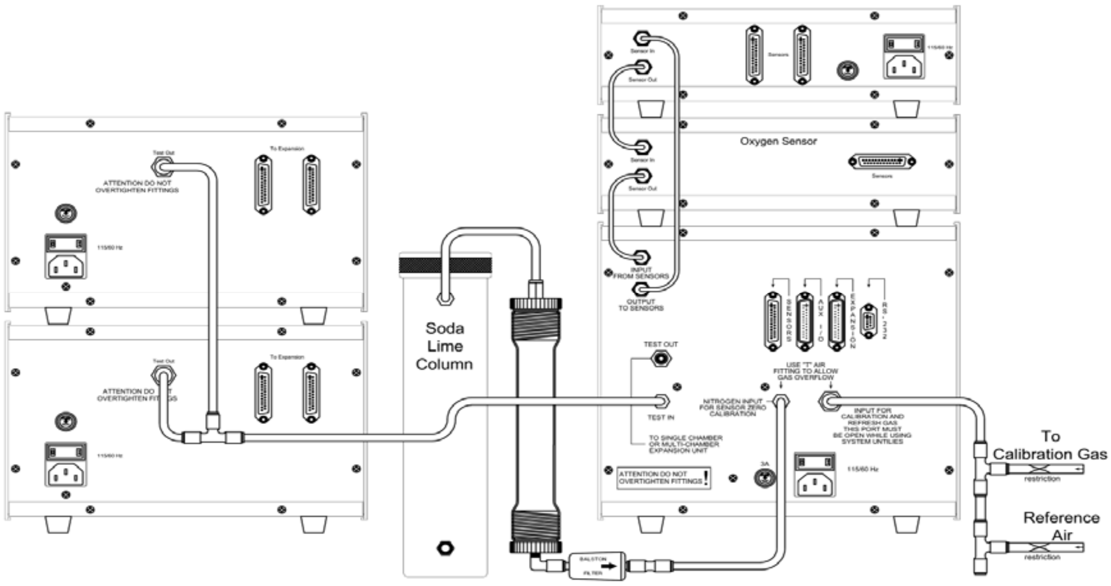


Figure 3

3.5 Cable Connections

Figure 4 Depicts the proper cable configuration.

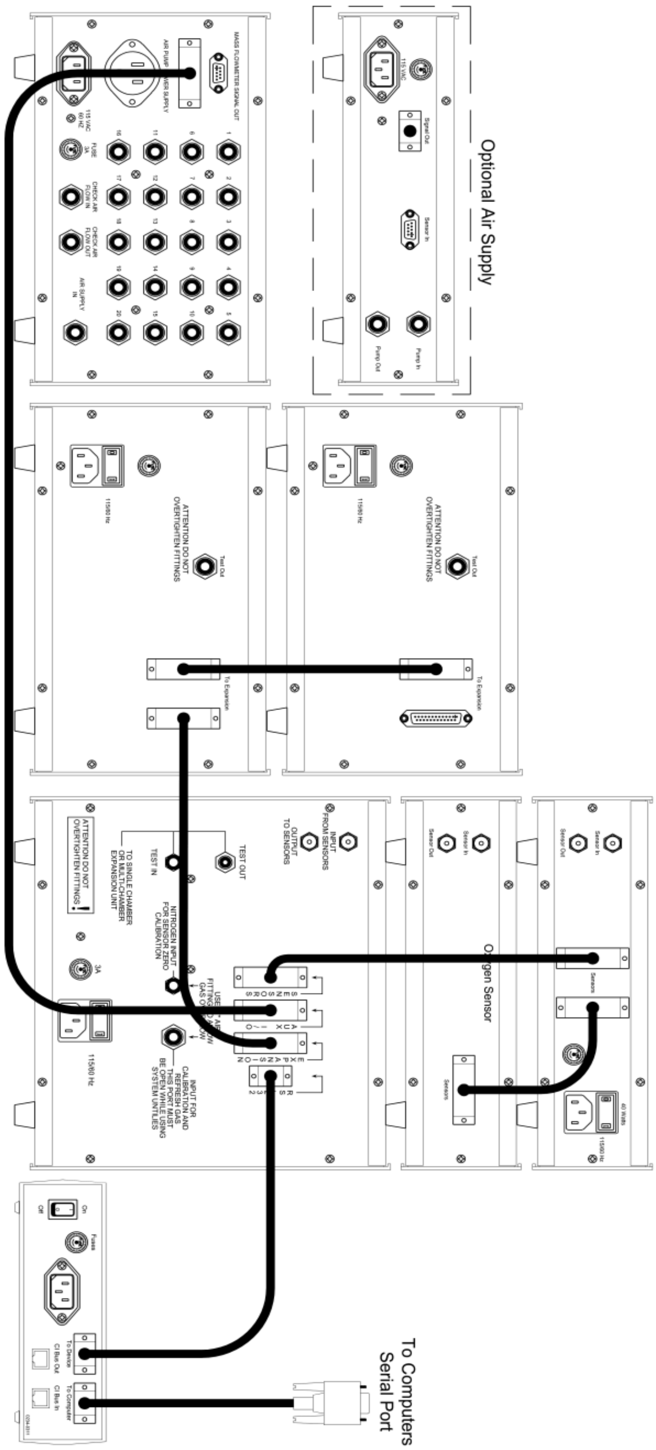


Figure 4

3.6 Equal Flow System

The Equal Flow System controls, monitors, and equally distributes the fresh air going to each chamber. The Equal Flow system can provide measured flow to 16 chambers. This is an economic advantage as well as a solution for systems, which require equal flows to all chambers.

3.61 Equal Flow System Installation

The cable and tubing connections for Oxymax with the Equal Flow System are shown in Figure 5. The “Signal Out” connector on the Equal Flow System cabinet is attached to the “Auxiliary I/O” connector on the rear of the System Sample Pump, through a 25-pin shielded cable. The Air pump connects to the “air supply in” fitting on the Equal Flow Cabinet. The filter must connect to the pump before any other connectors. In addition, the power cord for the Air Pump can be connected to the “Air Pump Power Supply” outlet on the rear of the Equal Flow System cabinet This connection allows operation of the Air Pump power from the front of the Equal Flow System cabinet The air going to the chambers is supplied at the tubing fittings on the rear of the cabinet. A flow restrictor (orifice) must be in each of the tubes going to the chambers. Make sure the arrow stamped on the orifice points towards the chamber away from the Equal Flow System cabinet. The restrictor (orifice) should be placed as close as possible to the chamber.

NOTE: ALL RESTRICTORS MUST BE CONNECTED TO THE EQUAL FLOW AT ALL TIMES

Equal Flow System Orifices

Orifice Diameter (in.)	Flow/Channel (LPM)	Color	CI Part Number
0.005	0.05 to 0.19	Dark green	5038-0524
0.006	0.07 to 0.24	Red	5038-0523
0.007	0.11 to 0.36	Light green	5038-0522
0.010	0.19 to 0.64	Ivory	5038-0521
0.012	0.29 to 0.90	Black	5038-0520
0.016	0.50 to 1.50	Gray	5038-0519
0.020	1.00 to 2.50	Blue	5038-0518
0.025	1.75 to 4.00	Brown	5038-0517
0.030	2.50 to 5.00	White	5038-0516
0.040	4.00 to 6.25	Rust	5038-0535

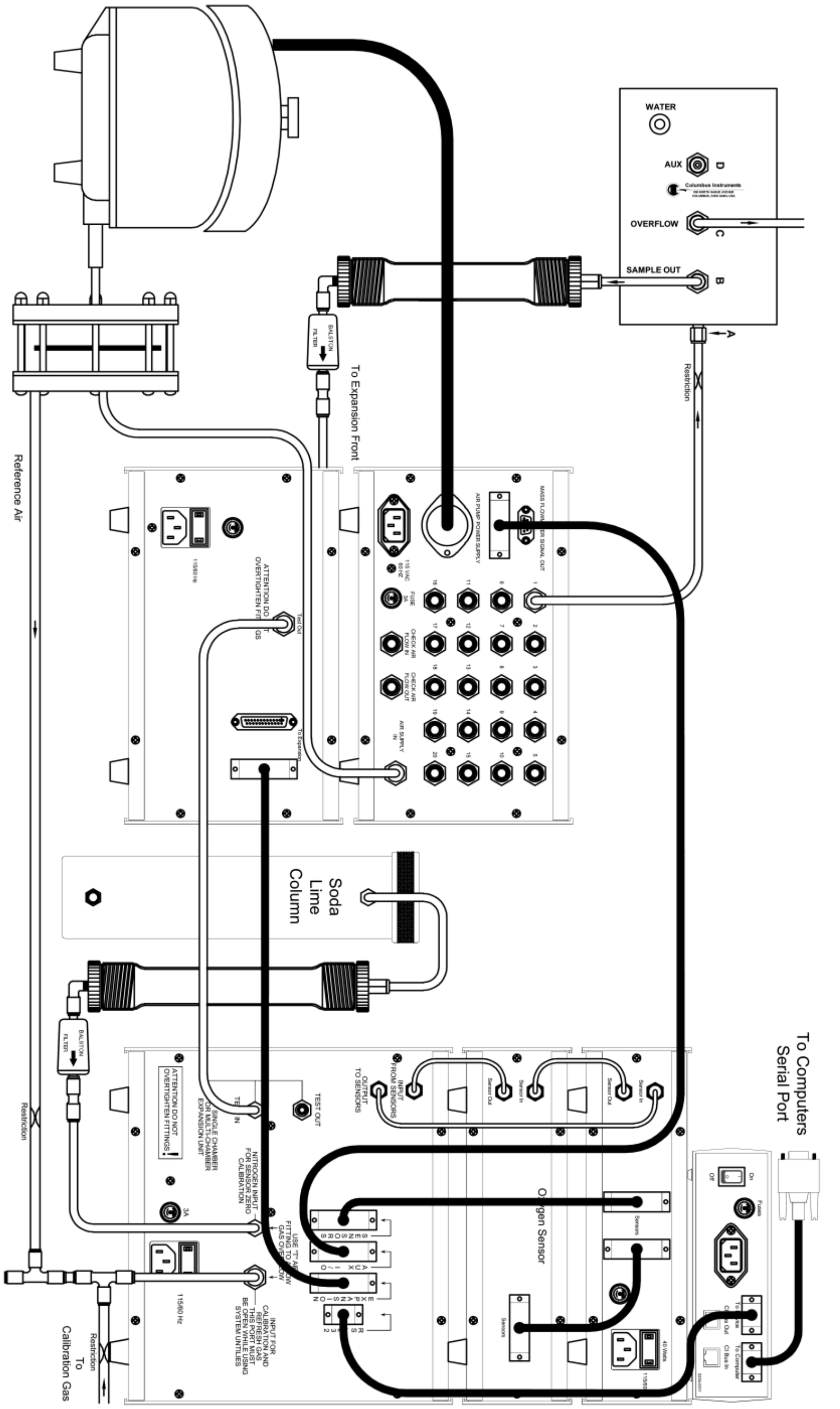

WATER
AUX
OVERFLOW
SAMPLE OUT
To Expansion Front
Reference Air
Restriction
Soda Lime Column
Oxygen Sensor
To Computers Serial Port
To Calibration Gas

Figure 5

3.7 Hardware Controls

3.71 System Sample Pump Figures 6 &7

The System Sample Pump has a sample flow meter on the right side of the front panel. The flow meter shows the flow rate of the sample stream of air through the sensors. The flow should be set to 0.50 1/min**, when the paramagnetic O2 sensor is used the flow must be 0.50 l/min to prevent damage to the sensor**.

System Sample Pump Front Panel Controls

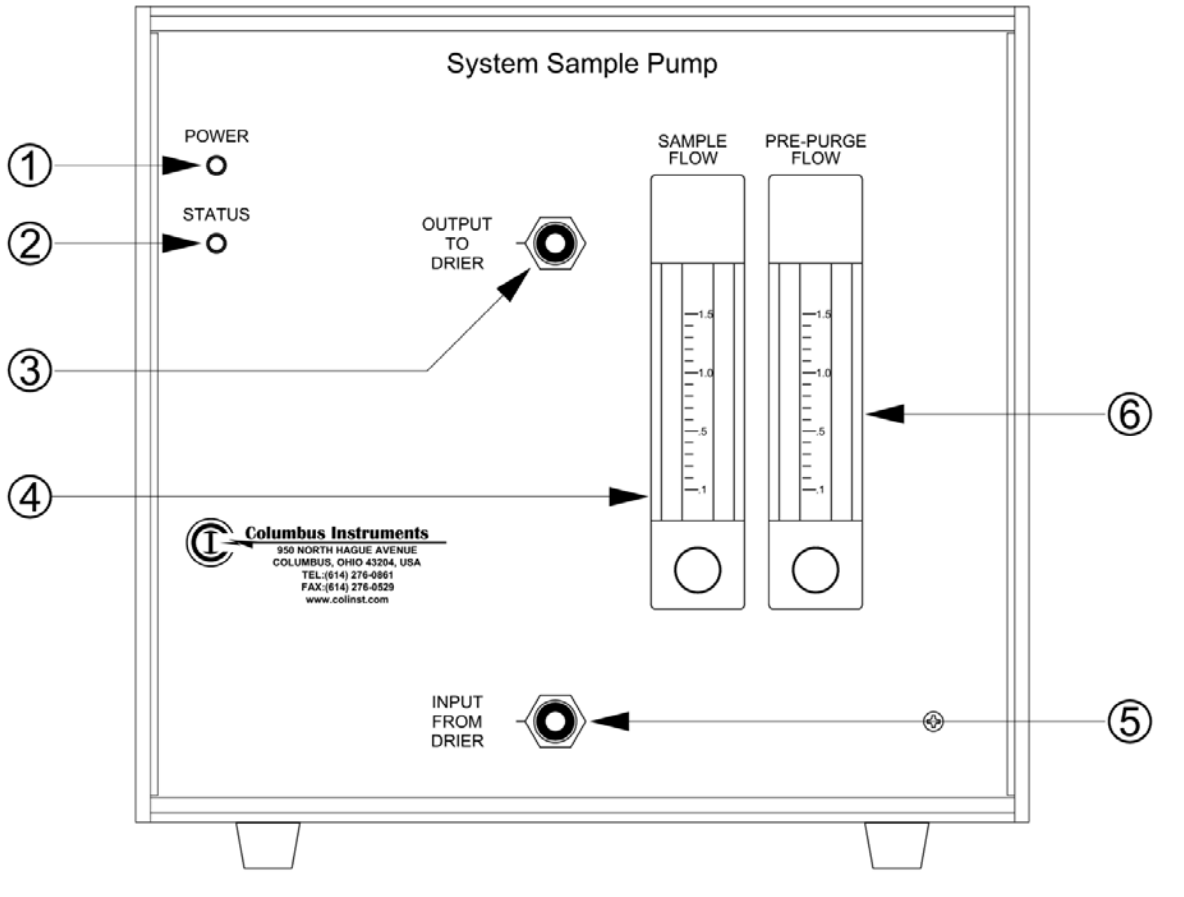


Figure 6

1. **<u>POWER LED</u>**. This indicates power is on

2. **<u>STATUS LED</u>**. This indicates the status of the system sample pump. During normal operation this led should blink. When the led does not blink an error has occurred and the system should be reset.

3. **<u>DRIER FITTING</u>**. This connects to the top fitting on drier.

4. **<u>SAMPLE FLOWMETER</u>**. This indicates the flow of sample gas through

the sensors. The flow should be adjusted to 0.50 L/min.

5. **DRIER FITTING**. This connects to the bottom fitting on drier.

System Sample Pump Back Panel Controls

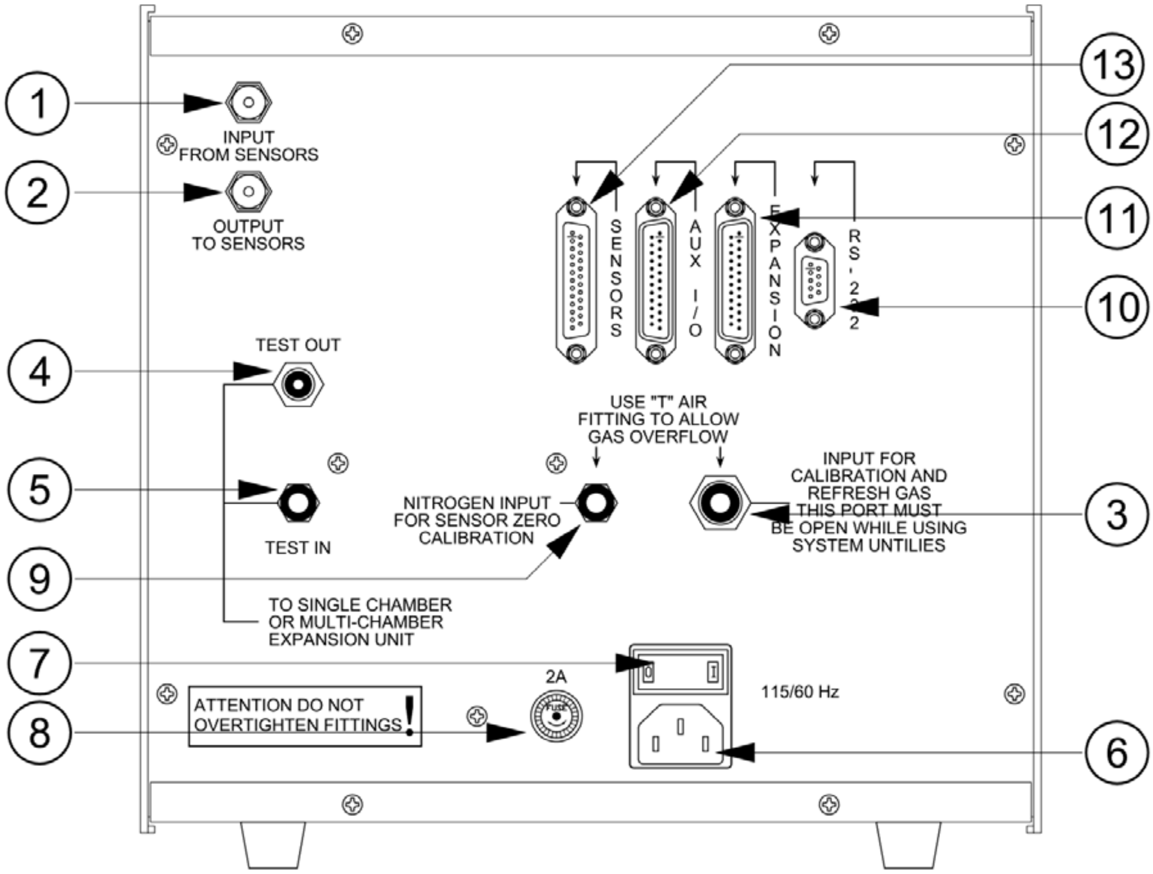


Figure 7

1. **SENSOR IN FITTING**. This connects to the "Sensor Out" connector on the 02 sensor.

2. **SENSOR OUT FITTING**. This connects to the "Sensor In" connector on the C02 sensor.

3. **REFRESH/CALIBRATION FITTING**. This is where the mixture gas used for calibration of the sensors is connected. Reference Air is also drawn through this fitting.

4. **TEST OUT FITTING**. The sample exhausts through this connector.

5. **TEST IN FITTING**. This connects to the sample chamber, for single channel systems. For multiple channel systems, this connects to the "Test Out" connector on the Expansion Interface.

6. **AC POWER CONNECTOR**. Connects to the specified voltage.

7. **POWER SWITCH** Turns power to the System Sample Pump on and off.

8. **FUSE**. Use 2.0A fuse for replacement.

9. **NITROGEN FITTING**. This is where the system draws in Nitrogen or C02 free air for calibration of the gas sensors (for "zeroing" C02 & CH4 sensors). A soda lime canister that scrubs CO2 from room air is normally supplied for this purpose.

10. **RS-232 CONNECTOR**. This connects to the serial communication connector located on the computer.

11. **EXPANSION CONNECTOR**. This connects to the Expansion Interface(s) with the 25-pin male to male cable.

12. **AUX I/O CONNECTOR**. The connector is used for connecting the flow signals(s) to the system sample pump.

13. **SENSORS CONNECTOR**. This connects to the gas sensor(s) with the 25-pin male to female cable.

3.72 Gas Sensors

The Oxymax can be configured to monitor up to three different gas sensors. Each sensor is preset at the factory to operate with one another. Please contact Columbus Instruments for details.

3.73 CO2 Sensors Figures 8 & 9

The standard C02 sensor has an operating range of 0 – 1.0 percent. If a higher C02 concentration is to be measured an optional 0 – 10 or 0 – 100 percent sensor is available. The standard CH4 sensor operates from 0 – 5 percent. Both sensors require a two-point calibration procedure. The first step is to offset the sensor, which is done with a source of CO2 free gas. This can be nitrogen or room air drawn through a soda lime canister. The second step is to span the sensor. This is accomplished with a set-point gas. A more detailed explanation is found in the software manual.

C02 Sensor Front Panel Controls

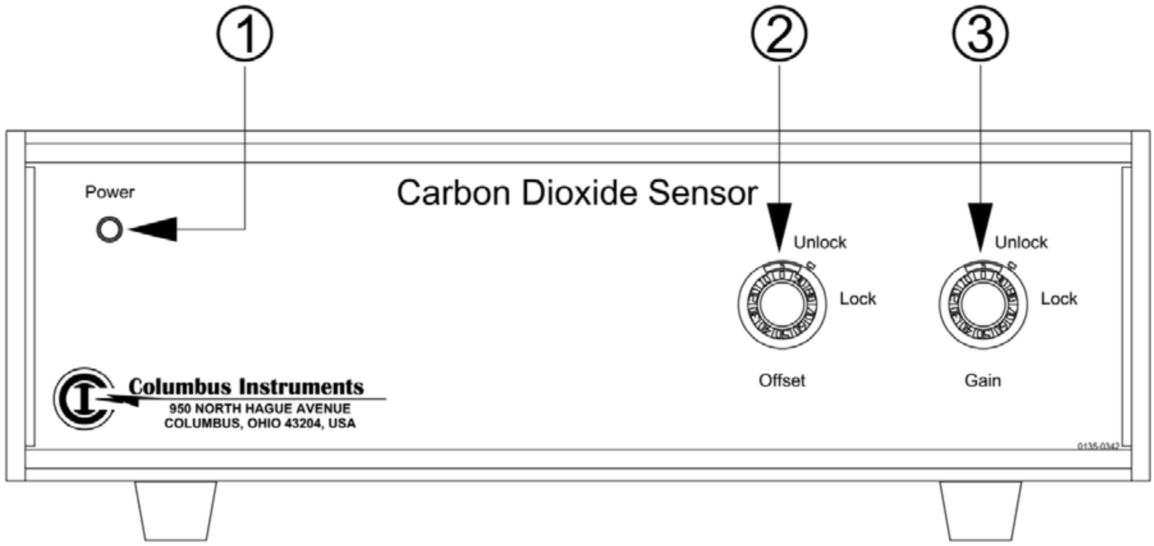


Figure 8

1. **POWER LED.** Indicates power is on.

2. **OFFSET DAIL**. Used to adjust the offset or zero point of the sensor during the calibration procedure.

3. **GAIN DAIL**. Used to adjust the gain or span of the sensor during the calibration procedure.

C02 Sensor Rear Panel Controls

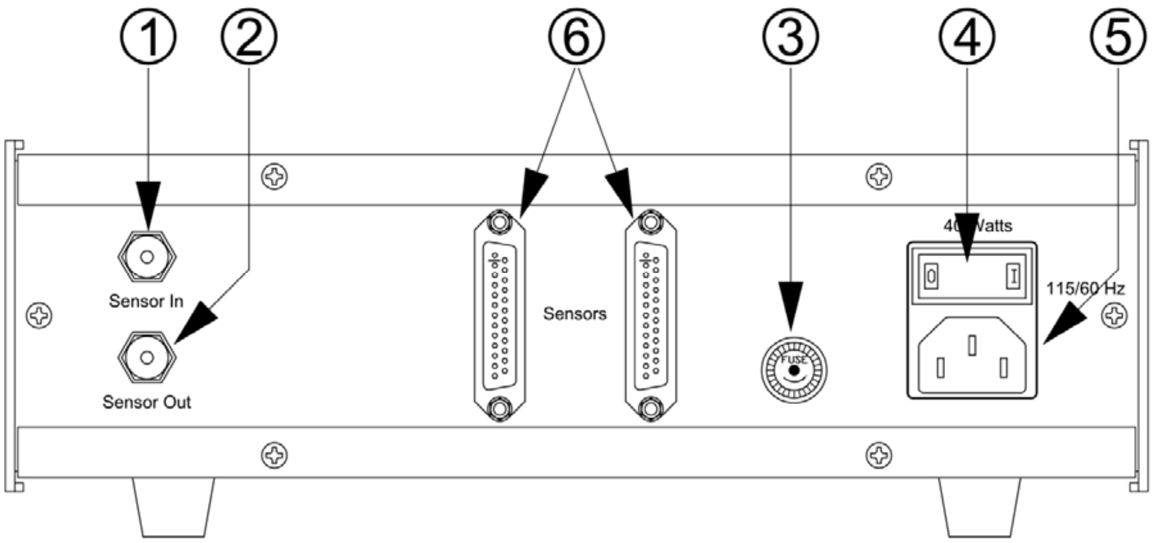


Figure 9

1. **SENSOR IN FITTING**. Connects to the Sensor Out connector on the System Sample Pump.

2. **SENSOR OUT FITTING.** Connects to the Sensor In connector on the next installed sensor (if

equipped) or to the Sensor In connector of the System Sample Pump.

3. **FUSE HOLDER.** Replace only with a 3.0 amp fuse.

4. **POWER SWITCH**. Turns sensor on and off.

5. **AC POWER CONNECTOR.** Connects to the specified voltage.

6. **SENSORS CONNECTOR.** Connects the sensor to the other sensors and to the System Sample Pump via the 25-conductor shielded cable.

3.74 Electrochemical Oxygen Sensor Figures 10 & 11

The standard electrochemical oxygen sensor has controls for adjusting the gain of the sensor. There will be a switch on the front panel of oxygen sensors equipped with the dual range option to select the range of operation. **Whenever the range of operation is changed, the sensor must be recalibrated and the software reconfigured for the correct range of operation**. The following is a list of controls and connectors corresponding to the O2 Sensor.

02 Sensor Front Panel Controls

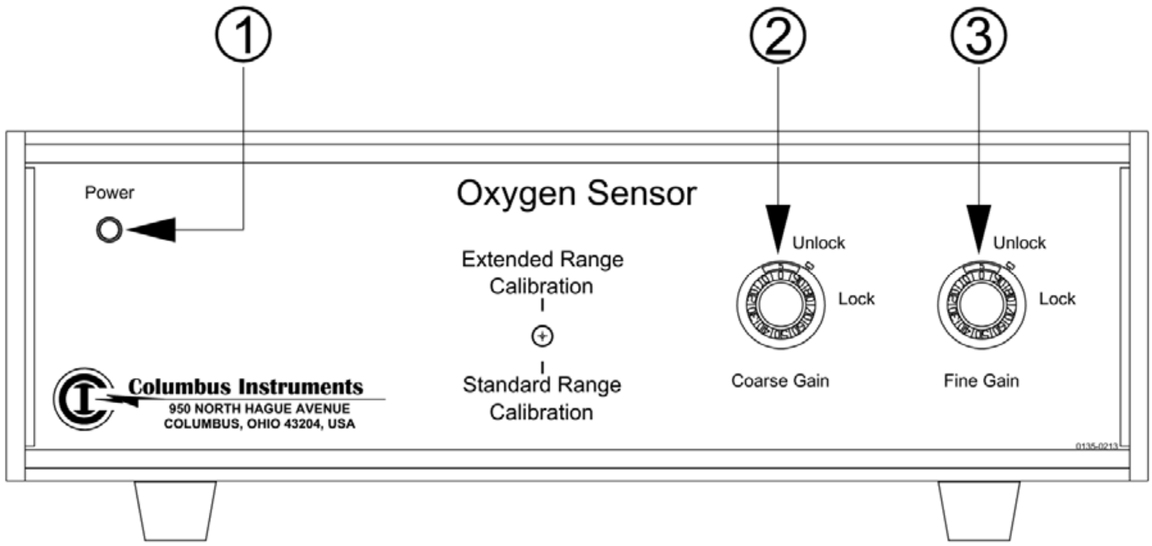


Figure 10

1. **POWER LED.** Indicates power is on. **NOTE**: The O2 sensor receives power from the CO2 sensor via the 25-conductor cable.

2. **COARSE GAIN DIAL.** Used to adjust the gain set point of the 02 sensor during the calibration procedure.

3. **FINE GAIN DIAL.** Used to fine-tune the gain or span of the 02 sensor during the calibration procedure.

02 Sensor Rear Panel Controls

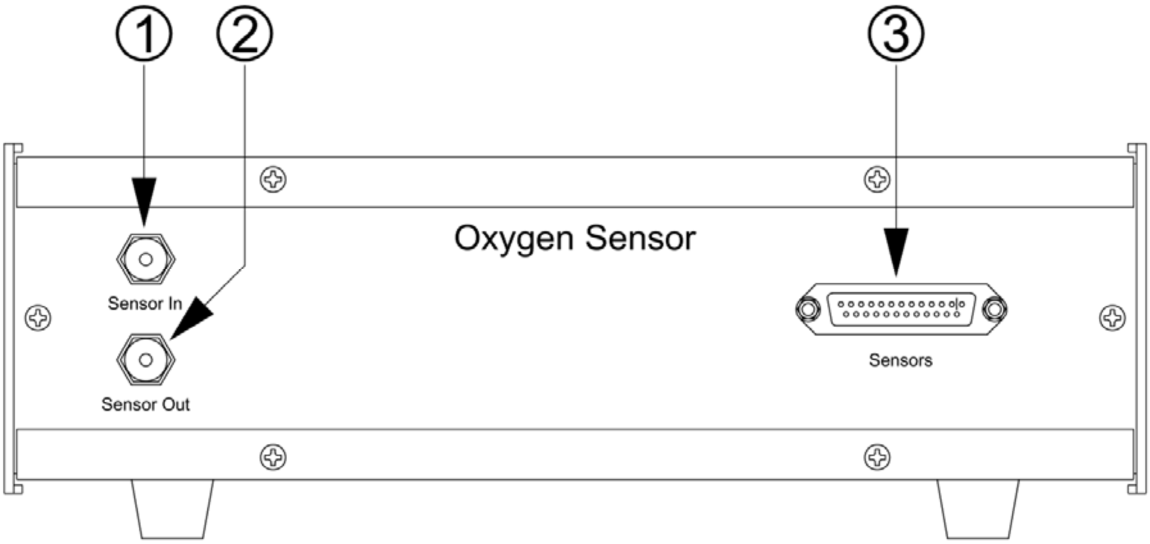


Figure 11

1. **<u>SENSOR IN FITTING</u>.** Connects to the “Sensor Out” connector on the CO2 sensor, or to the “Sensor Out” connector on the System Sample Pump for O2 only systems.

2. **<u>SENSOR OUT FITTING</u>.** Connects to the “Sensor In” connector on the System Sample Pump.

3. **<u>SENSOR SIGNAL.</u>**

3.75 Paramagnetic Oxygen Sensor Figures 12 & 13

The Oxymax system can be equipped with an optional paramagnetic oxygen sensor. The paramagnetic oxygen sensor offers programmable ranges of operation by the controls on the rear panel.

Paramagnetic 02 Sensor Front Panel Controls

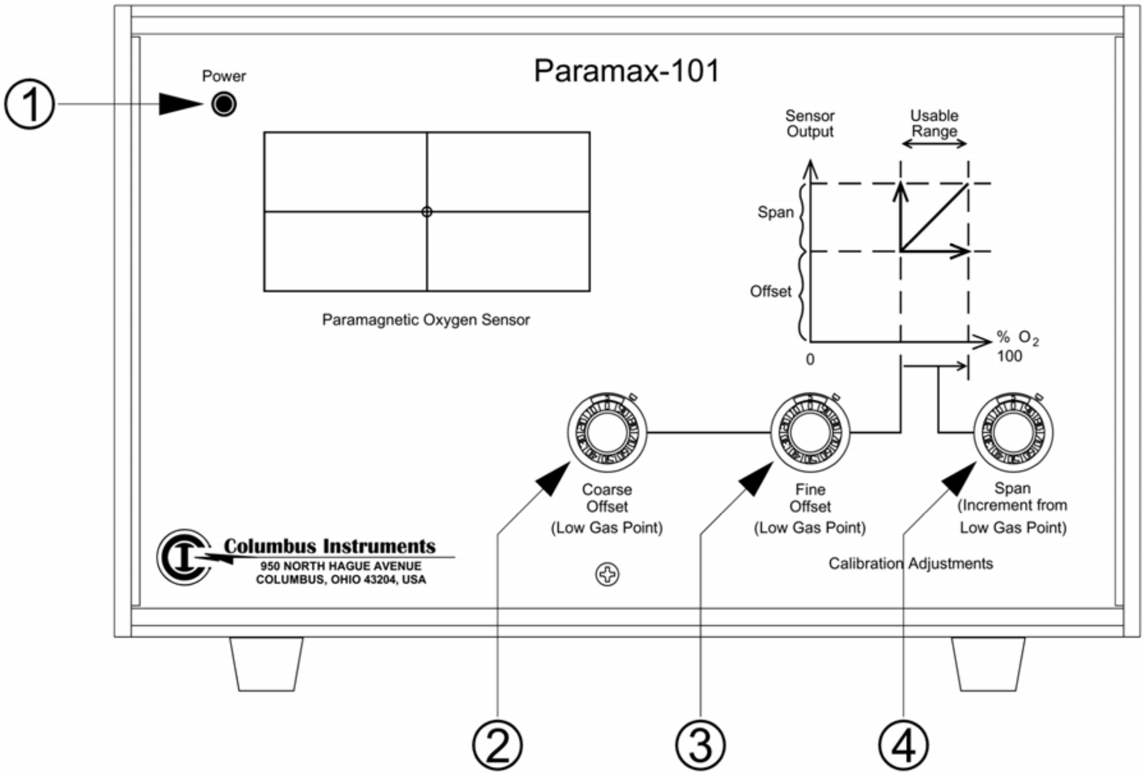


Figure 12

1. **<u>POWER LED</u>.** Indicates power is on.

2. **<u>COARSE OFFSET DIAL</u>.** Used to adjust the offset set point of the 02 sensor during the calibration procedure.

3. **<u>FINE OFFSET DIAL</u>**. Used to fine-tune the offset set point of the 02 sensor during the calibration procedure.

4. **<u>SPAN DIAL</u>.** Used to adjust the span or gain of the 02 sensor during the calibration procedure.

Paramagnetic 02 Sensor Rear Panel Controls

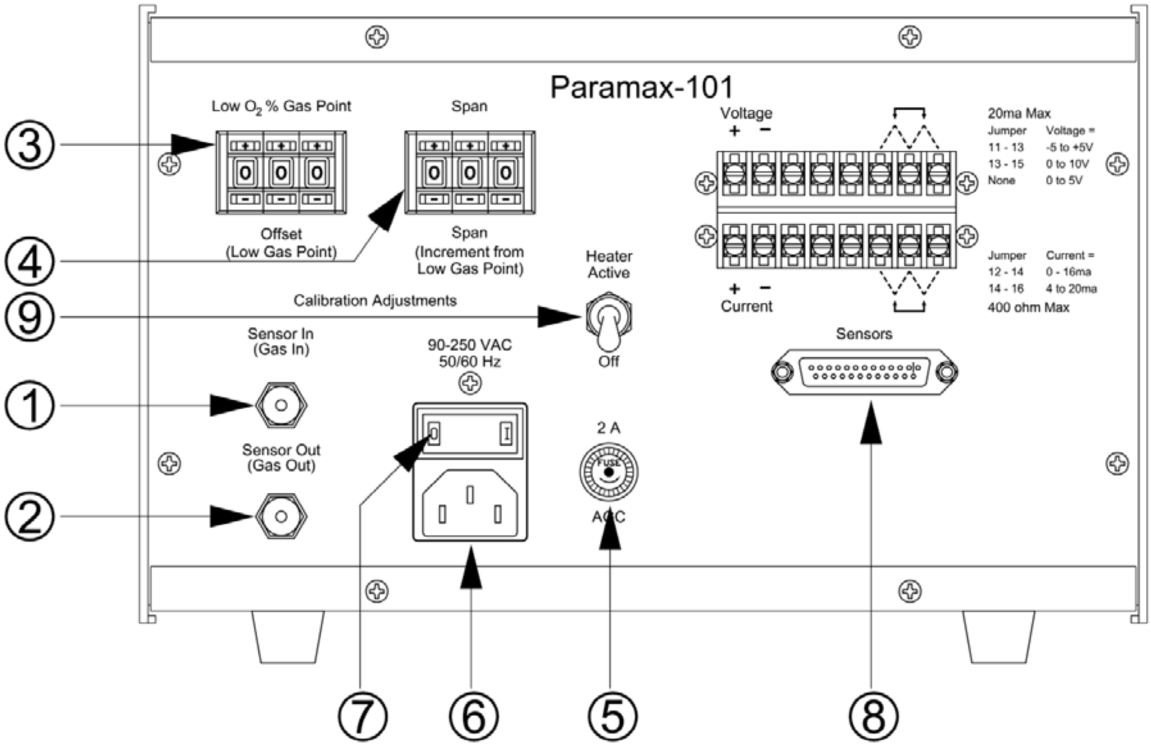


Figure 13

1. **<u>SENSOR IN FITTING.</u>** Connects to the "Sensor Out" connector on the CO2 sensor, or to the "Sensor Out" connector on the System Sample Pump for O2 only systems.

2. **<u>SENSOR OUT FITTING</u>**. Connects to the "Sensor In" connector on the System Sample Pump.

3. **<u>OFFSET PROGRAMMING SWITCH</u>.** Selects the offset or lowest concentration of oxygen to be measured. It is set as ##.# % O2

4. **<u>SPAN PROGRAMMING SWITCH</u>**. Selects the gain or the difference in oxygen above the offset that is the highest concentration of oxygen to be measured. It is set as % O2.

5. **<u>FUSE HOLDER</u>**. Replace with 2.0 amp fuse only.

6. **<u>POWER CONNECTOR</u>**. Connects to the specified voltage.

7. **<u>POWER SWITCH</u>**. Switch used to turn the power on to the unit.

8. **<u>SENSOR CONNECTOR</u>**. Connects the sensor to the other sensors and to the System Sample Pump via the 25-pin conductor ribbon cable.

9. **<u>HEATER ACTIVE</u>.** This switch is used to turn on/off the heater, which heats the gases before it enters the sensor. This switch is normally turned on.

3.76 Expansion Interface Figures 14 & 15

System equipped with more than one channel will include one or more Expansion Interface (s). The expansion interface contains valves to select the gas stream from multiple chambers and direct it through the sensors. The following is a list of controls and connectors that corresponds with the following diagram.

Expansion Unit Front Panel Controls

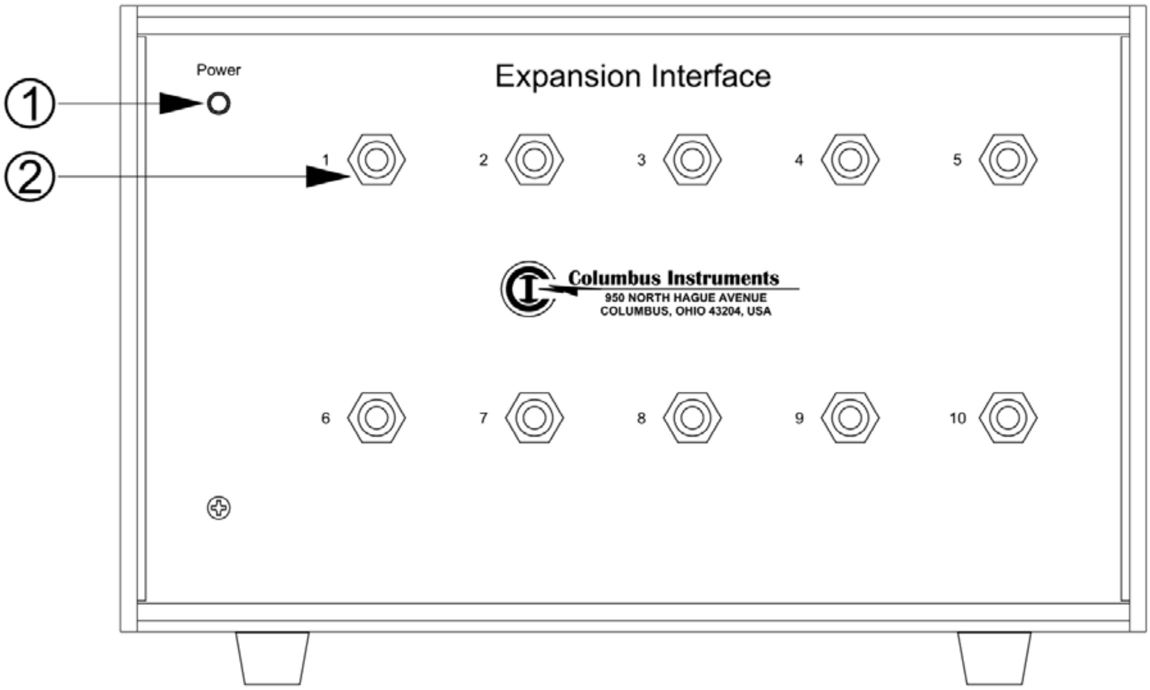


Figure 14

1. **POWER LED**. Indicates power is on.

2. **GAS SAMPLE IN FITTING.** This is where the gas from the sample chamber enters the system.

Expansion Unit Rear Panel Controls

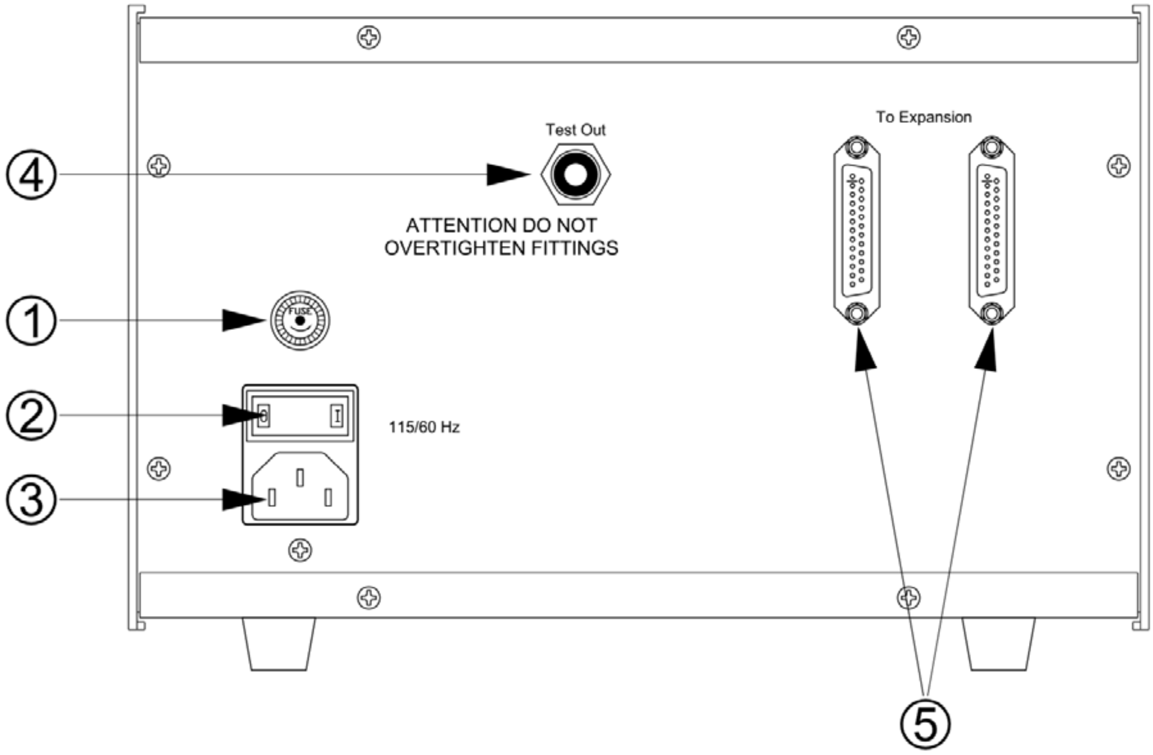


Figure 15

1. **FUSE HOLDER.** Replace with 3-amp fuse only.

2. **POWER SWITCH.** Turns power on and off.

3. **POWER CONNECTOR.** This connects to the specified voltage.

4. **TEST OUT FITTING.** This is connected to the "Test In" fitting on the Sample Pump.

5. **EXPANSION CONNECTORS.** This connects to any other expansion interfaces (if present), and to the "EXPANSION" connector on the System Sample Pump.

3.77 Equal Flow System Hardware Figures 16 &17

The Equal Flow System controls, measures, and equally distributes the fresh air going to each chamber. A mass flow meter is employed by the Equal Flow System to measure the airflow. Mass flow measurements eliminate the need to compensate for temperature or pressure conditions. The meters used are designed to provide flow measurements normalized to a Standard Temperature & Pressure of 0° C and 760 mmHg. Electronics contained within the controller housing provide a metering device that allows for the regulation of flow to be accurately maintained at a user selected set point. The following is a list of controls and connectors corresponding to the following drawings.

Equal Flow Front Panel Controls

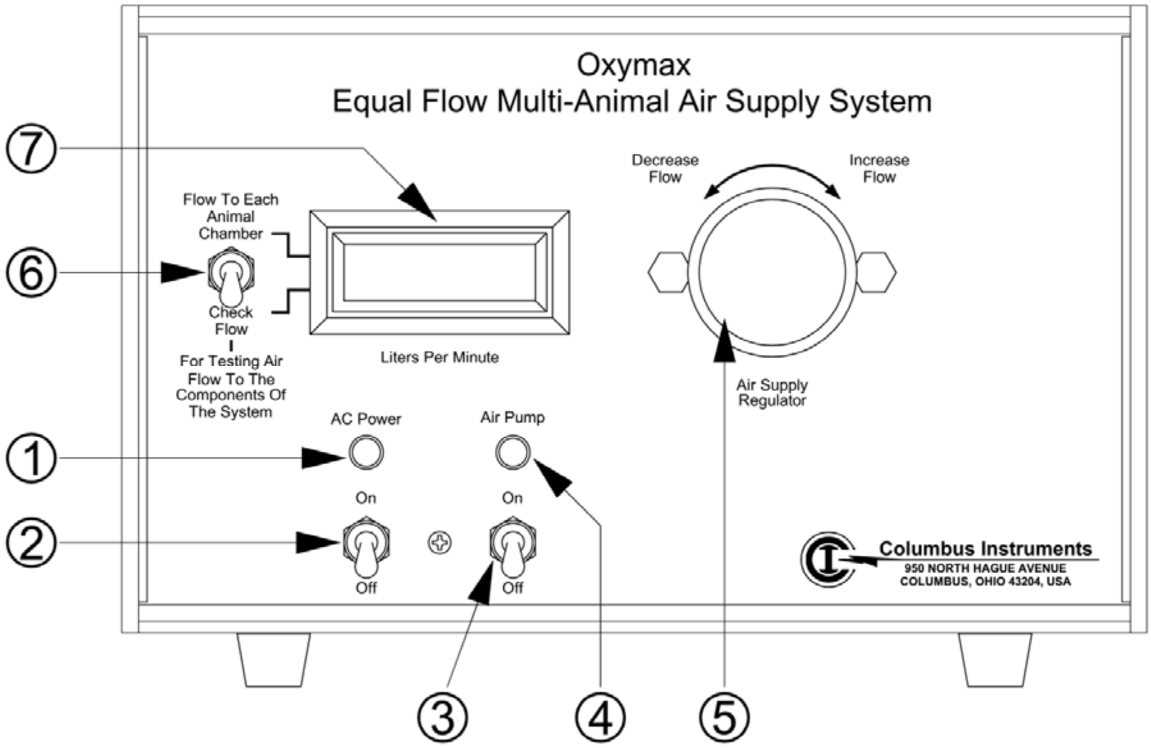


Figure 16

1. **POWER LAMP**. Indicates when power is on.

2. **POWER SWITCH.** Used to turn power to the equal flow system on and off.

3. **AIR PUMP POWER SWITCH.** Turns power to the fresh air pump on and off.

4. **AIR PUMP POWER LAMP.** Indicates when power to the fresh air pump is on.

5. **AIR SUPPLY REGULATOR.** Controls the flow of air to each chamber**. IF THE** KNOB BECOMES DIFFICULT TO TURN IT IS AT THE END OF IT'S ADJUSTMENT, DO NOT TIGHTEN ANY FURTHER OR DAMAGE WILL RESULT. Turning clockwise will increase the flow. Turning counterclockwise will decrease the flow.

6. **DISPLAY SELECTOR SWITCH.** Selects which flow is displayed. In the up position, the flow going to all of the chambers is displayed. In the down position, the flow through the "Check Air Flow In" fitting on the rear panel is displayed.

7. **FLOW DISPLAY.** Displays the flow to each chamber or to a single chamber (depending on the position of switch # 6). Flow is displayed as Liters per Minute.

Equal Flow Rear Panel Controls

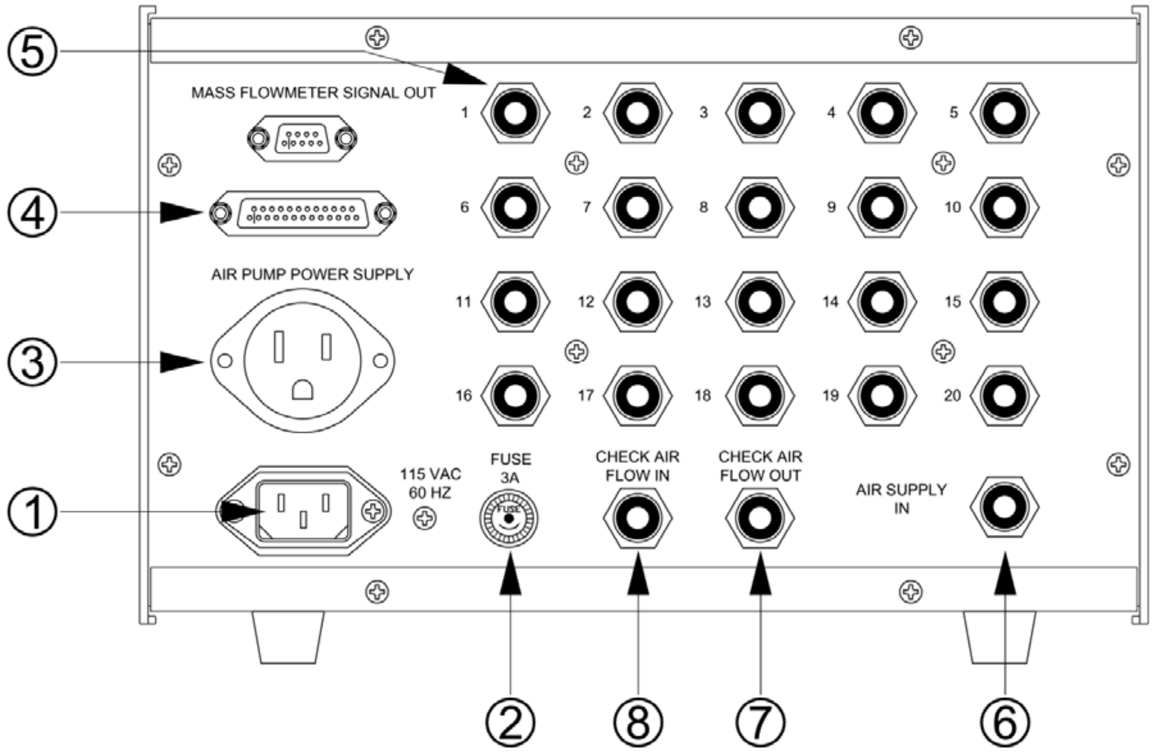


Figure 17

1. **<u>POWER CONNECTOR</u>**. This connects to the specified voltage.

2. **<u>FUSE HOLDER</u>.** Replace with 1 amp MDA fuse only (2 amp for 220 volt systems).

3. **<u>AIR PUMP POWER SUPPLY CONNECTOR</u>.** The fresh air pump plugs in here. This allows the power to the pump to be turned on and off with the "Air Pump Power Switch" on the front panel.

4. **<u>AIR MASS FLOWMETER SIGNAL OUT CONNECTOR</u>**. This connects to the connector labeled "Equal Flow" on the back of the System Sample Pump, and provides the flow signal.

5. **<u>CHAMBER AIR SUPPLY FITTING</u>**. Connects to the flow restrictor, and supplies air to each chamber. Be sure to place the restrictor as close as possible to the chamber with the arrow pointing towards the chamber.

6. **<u>AIR SUPPLY IN FITTING</u>.** The fresh air pump connects here. Be sure there are no kinks or sharp bends in the tubing.

7. **<u>CHECK AIR FLOW OUT FITTING</u>.** This is the exhaust of the diagnostic flow meter that is used to check the flow to an individual chamber. No connections are made to this fitting.

8. **<u>CHECK AIR FLOW IN FITTING</u>**. This connects to the air supply tube of an individual chamber to measure the flow to that chamber. Be sure the restrictor is in the tube when making this connection.

4.0 Operations

Before starting an experiment, the system should warm up for three (3) hours to allow the sensors to come to operating temperature. The system may be left on continuously so that the warm up period can be omitted. What follows is a description of different factors that affect the operation of the system

4.1 Air Flow-Rate Settings

The sample flow should be set to 0.5 L/min. The sample flow is adjusted using the metering valve on the "Sample Flow" flow meter on the front of the System Sample Pump.

4.2 Range of Sensors

Unless the system is equipped with sensors with non-standard ranges, the range of the oxygen sensor is 19.3% to 21.5%, and the range of the carbon dioxide sensor is 0% to 1.0%. If the oxygen level or the carbon dioxide level goes outside these measurable ranges during the experiment, the consumption and production readings will be incorrect.

To operate the system with gases other than ambient air (e.g. air with elevated CO2 content or depleted O2 Content) Columbus Instruments can supply the appropriate sensors and system modifications. Contact Columbus Instruments for prices and availability.
The following is a list of the additional sensors available:

Extended range CO2	0 - 10%, 0 - 100%
Extended range O2	0 - 21%, 10 - 21%, user picks
Paramagnetic O2	0-100% user programmable
CH4	0 - 5%
CO	0 - 5%, 0 - 0.2%
H2S	0 - 200 ppm
H2	0 - 2000 ppm

4.22 Calibration Connections Figure 18

It is recommended that the gas sensors be calibrated before the beginning of each experiment.

The filters connected to the Calibration/Refresh connector and the Nitrogen connector must be used to prevent contamination of the System Sample Pump.

NOTE: The source air pump must be OFF during calibration. Turn the pump off/on via the Air Pump Power Switch on the Equal Flow Controller. Turn the pump ON after calibration is complete.

Refer to the drawing for the tubing connections. If the system sample pump is equipped with an internal calibration manifold, calibration gas connections will be made to the "Calibration/Refresh Gas" and "Nitrogen" fittings on the rear of the system sample pump. A bottle of Primary Standard grade gas is used for sensor calibration. A soda lime column is connected for signal zero adjustments. Optionally, a nitrogen bottle can be used

Calibration Connection

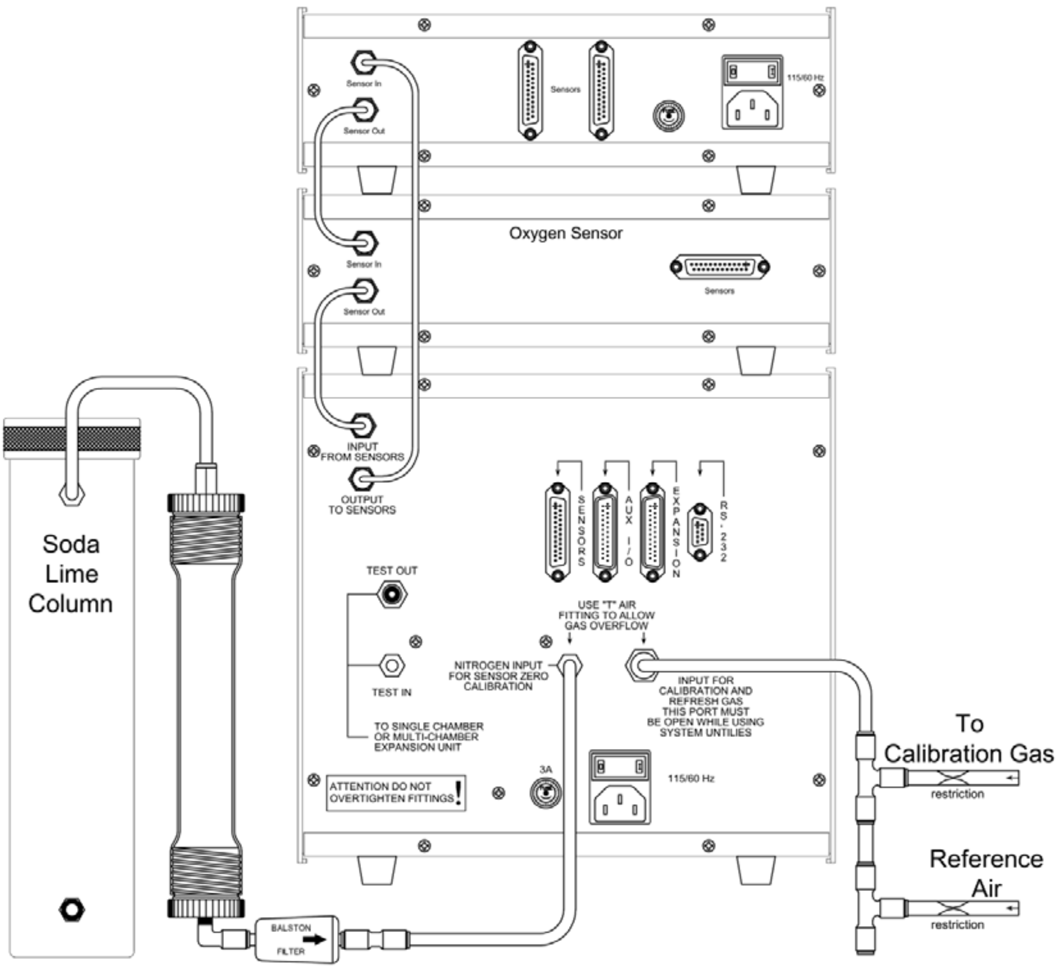


Figure 18

5.0 Maintenance

5.1 Replacement of the Oxygen Sensor

The Oxymax oxygen sensor is designed to supply about nine months of service. Replacement of the sensor is indicated when the desired calibration Set-point oxygen level can no longer be obtained (ie increasing the gain during calibration has no effect). The drawing on the following page shows the oxygen sensor housing assembly. The following steps outline the procedure for replacement:

1. Turn off and unplug the System Sample Pump and Carbon Dioxide Sensor from the AC power source.

2. Remove the tubes from the "Sensor In" and "Sensor Out" fittings on the rear of the Oxygen Sensor cabinet.

3. Unplug the cable from the Oxygen Sensor cabinet.

4. Place the Oxygen Sensor on a clean workspace and remove the two Philips screws that fasten the top panel. Remove the top panel.

5. Unplug the sensor (cell) cable from the printed circuit board.

6. Remove the thumb screws and top cap from the sensor housing.

7. Slide the old sensor (cell) assembly out of the housing.
   N**ote: make sure the "O-ring is not stuck to the sensor (cell).**

   Slide the new sensor (cell) assembly back into the housing.

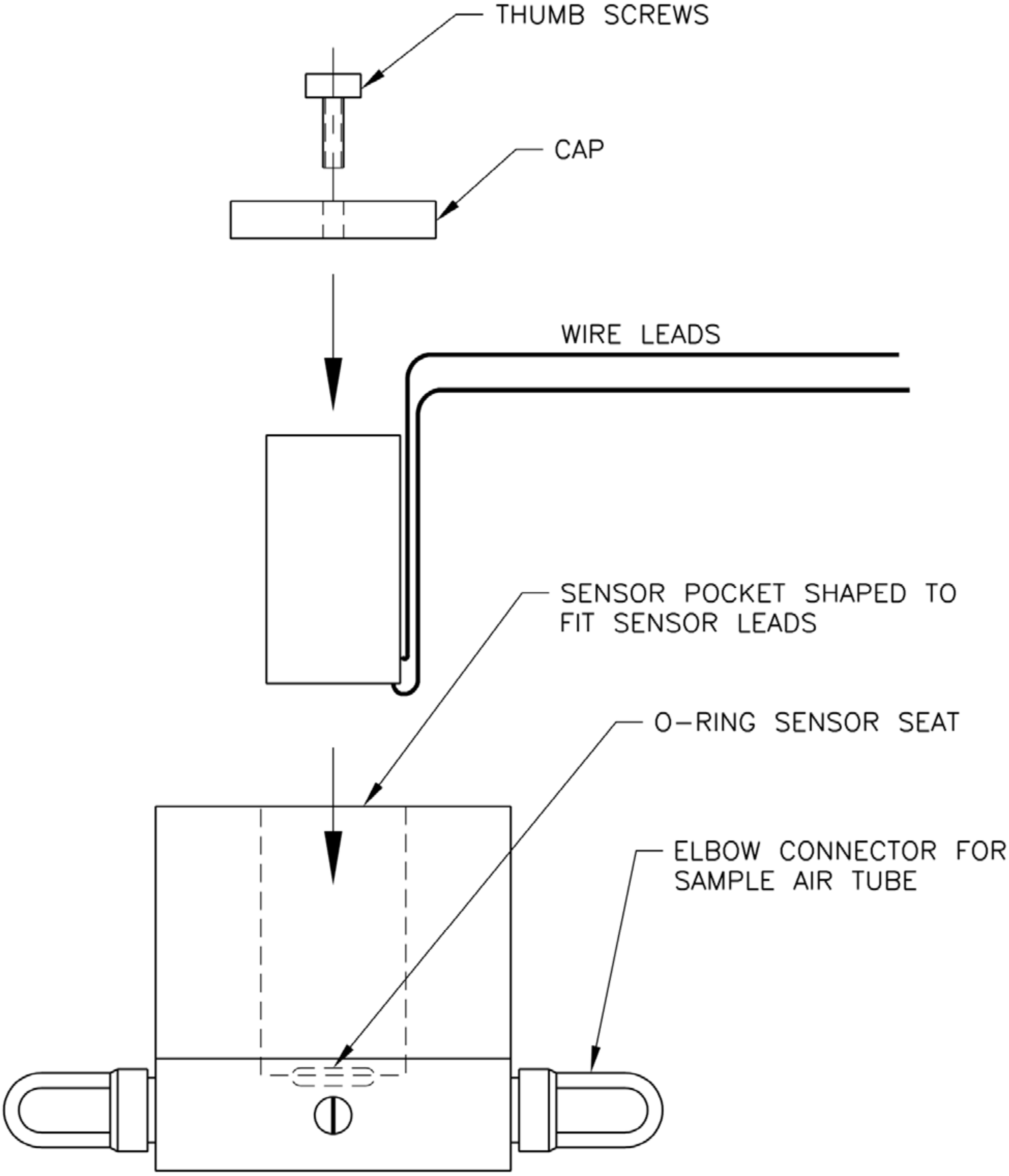
8. Replace the top cap and fasten with thumb screws.

9. Plug the sensor cable back into the printed circuit board.

10. Replace the top panel and secure it with the two Philips screws and lock washers.

11. Return the Oxygen Sensor cabinet to its location in the system and reconnect all the cables and tubes that were removed.

Oxygen Cell Replacement



6.0 Equation

Oxygen Consumption, Carbon Dioxide Production, and Methane Production

The following four equations are used to calculate oxygen consumption (VO_2), carbon dioxide production (VCO_2) and methane production (VCH_4). The oxygen consumption is calculated by taking the difference between the input oxygen flow and the output oxygen flow. Similarly, the carbon dioxide production is calculated by taking the difference between the output and input carbon dioxide flows. The methane production is calculated by taking the difference between the output and input methane flows. Note that the methane information is only applicable if a methane sensor is present. This equation requires the input ventilation rate (V_i) which is calculated using the Haldane transform. The nitrogen fractions needed in the Haldane transform are simply the balance of the input or output samples. The resultant consumption and production values have the units of liters per subject mass per minute (L/mass/min). Standard conversion factors are included in the calculation to result with the units selected in the Software Configuration.

$$VO_2 = V_i O_{2i} - V_o O_{2o}$$

V_i and V_o are the input and output ventilation rates (LPM)
O_{2i} and O_{2o} are oxygen fractions at the input and output

$$VCO_2 = V_o CO_{2o} - V_i CO_{2i}$$

V_i and V_o are the input and output ventilation rates (LPM)
CO_{2i} and CO_{2o} are carbon dioxide fractions at the input and output

$$VCH_4 = V_o CH_{4o} - V_i CH_{4i}$$

V_i and V_o are the input and output ventilation rates (LPM)
CH_{4i} and CH_{4o} are methane fractions at the input and output

$$V_o = V_i \times \frac{N_i}{N_o}$$

N_i and N_o are nitrogen fractions at the input and output

$$N_x = 1 - O_2 - CO_2 - CH_4$$

N_x is the nitrogen fraction of the sample
O_2 is the observed oxygen fraction of the sample
CO_2 is the observed carbon dioxide fraction of the sample
CH_4 is the observed methane fraction of the sample

Respiratory Exchange Ratio

The respiratory exchange ratio (RER) is simply the ratio between the carbon dioxide production and the oxygen consumption. This value is a ratio and thus does not have a unit.

$$RER = \frac{VCO_2}{VO_2}$$

Heat

Oxymax will calculate heat with one of two methods. Both methods calculate the heat before the application of any normalization and, thus, reflect the exact heat of the subject. The method termed Internal will derive a calorific value (CV) based on the observed respiratory exchange ratio. This calorific value is then used with the observed oxygen consumption (VO_2) to calculate heat. The equations are:

$$Heat = CV \times VO_2$$
$$CV = 3.815 + 1.232 \times RER$$

The other method, termed User Defined, allows the user to enter calorific values (CV_X) relating to the oxygen consumption (VO_2) the carbon dioxide production (VCO_2), and the methane production (VCH_4). Note that the methane term drops out if a methane sensor is not present. Each of the calorific values is entered in the form Kcal/Liter of the respective gas. The equation used is:

$$\text{Heat} = CV_1 \times VO_2 + CV_2 \times VCO_2 + CV_3 \times VCH_4$$

7.0 Experiment Procedure for V 2.42 – V2.52

Turn on power to the computer and to the Oxymax system. The system should be on for at least 1 hour before starting an experiment.

Run OxymaxWin software.

Click on **File** select **Open**; choose the **Default.exp** file **(?????Default.exp)** then click **open**.

On the Experiment Configuration Tab verify the following:

1. The Settle and Measure Times
2. The Reference Method

On the Data file name, click the Browse button, type in file name of the experiment and click the save button. Verify the files path; C:\Program Files\OxymaxWin V2.??\

On the click on the Chamber Configuration Tab verify the following:

1. Select the number of chambers by placing or removing the check mark from the square box. (Check Box = chamber enable)
2. Select the Radio Button (round) (Radio Button = chamber select) Type in Subject ID and the Subjects Mass (g) (the weight of the animal has to be entered). If labels are used fill in the label information.

Click on the Apply button then the Save button, type in file name (same name as the data file name) then click the save button. This saves the file as an experiment (.exp)

Click on the Calibration Button.

1. Adjust the Sample flow to 0.50 LPM.
2. Calibrate the CO2 Offset by clicking on the CO2 Offset button. Wait about 2 minutes then adjust only the Offset Dial to the reading of 0.000%.
3. Click on the CO2 Gain button. Turn on the Calibration Gas Tank and make sure there is over flow coming out of the "T" tee fitting. Wait about 2 minutes then adjust the Gain Dial to what ever your gas tank states it is. (0.500%)
4. Click on the O2 Gain button. Adjust the Oxygen sensors Coarse Gain dial to what ever your gas tank states it is. (20.50%)
5. Turn off the Calibration Gas Tank and disconnect the hose from the regulator.

Turn on the Air Supplies, Equal Flow and/or Test Chambers, adjust flow if needed.

Click on the Exit Button.

To start the experiment, click on the Run button.

8.0 Test Chamber Connections

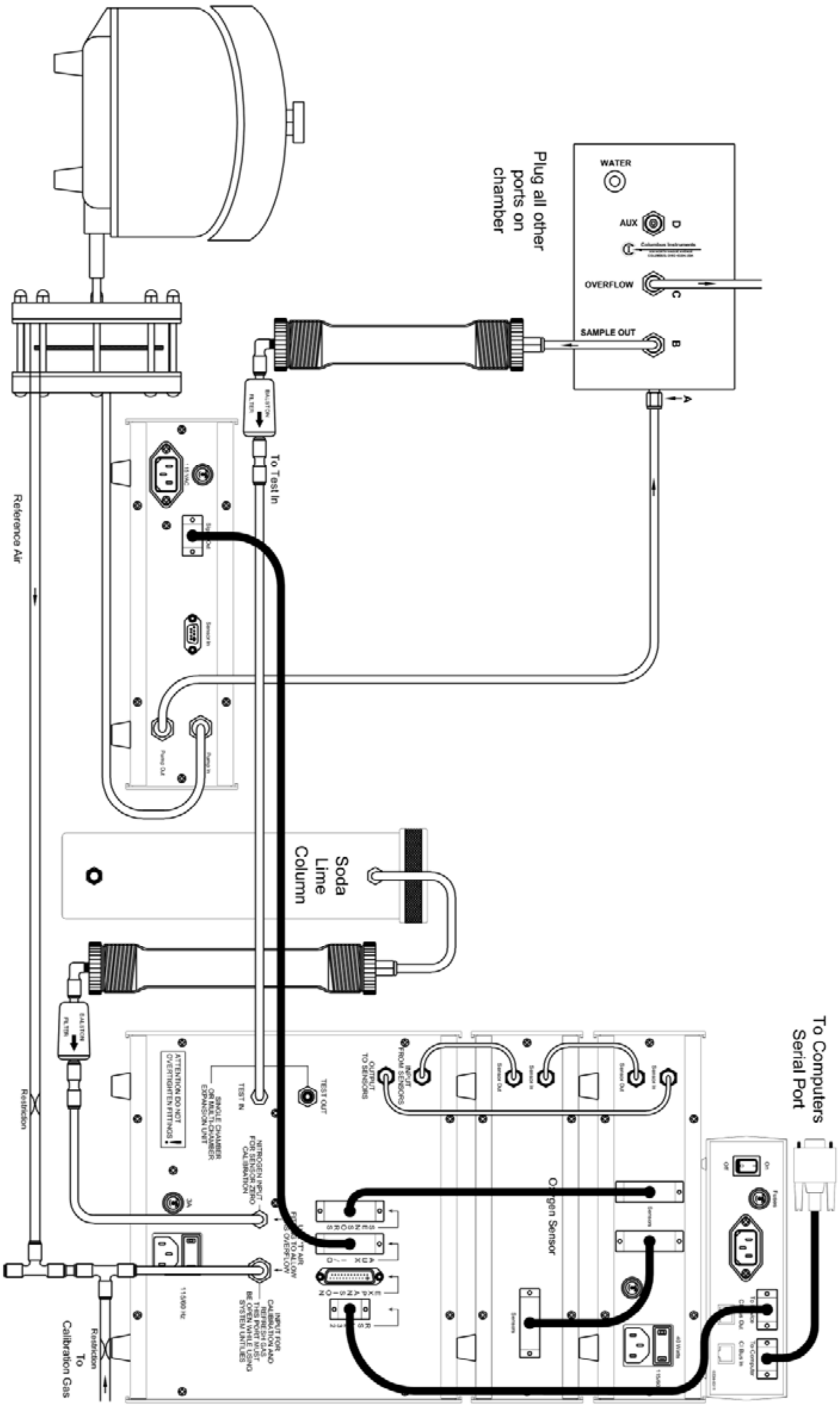


Figure 19

Single Test Chamber (ECO) Cable and Tubing Connections

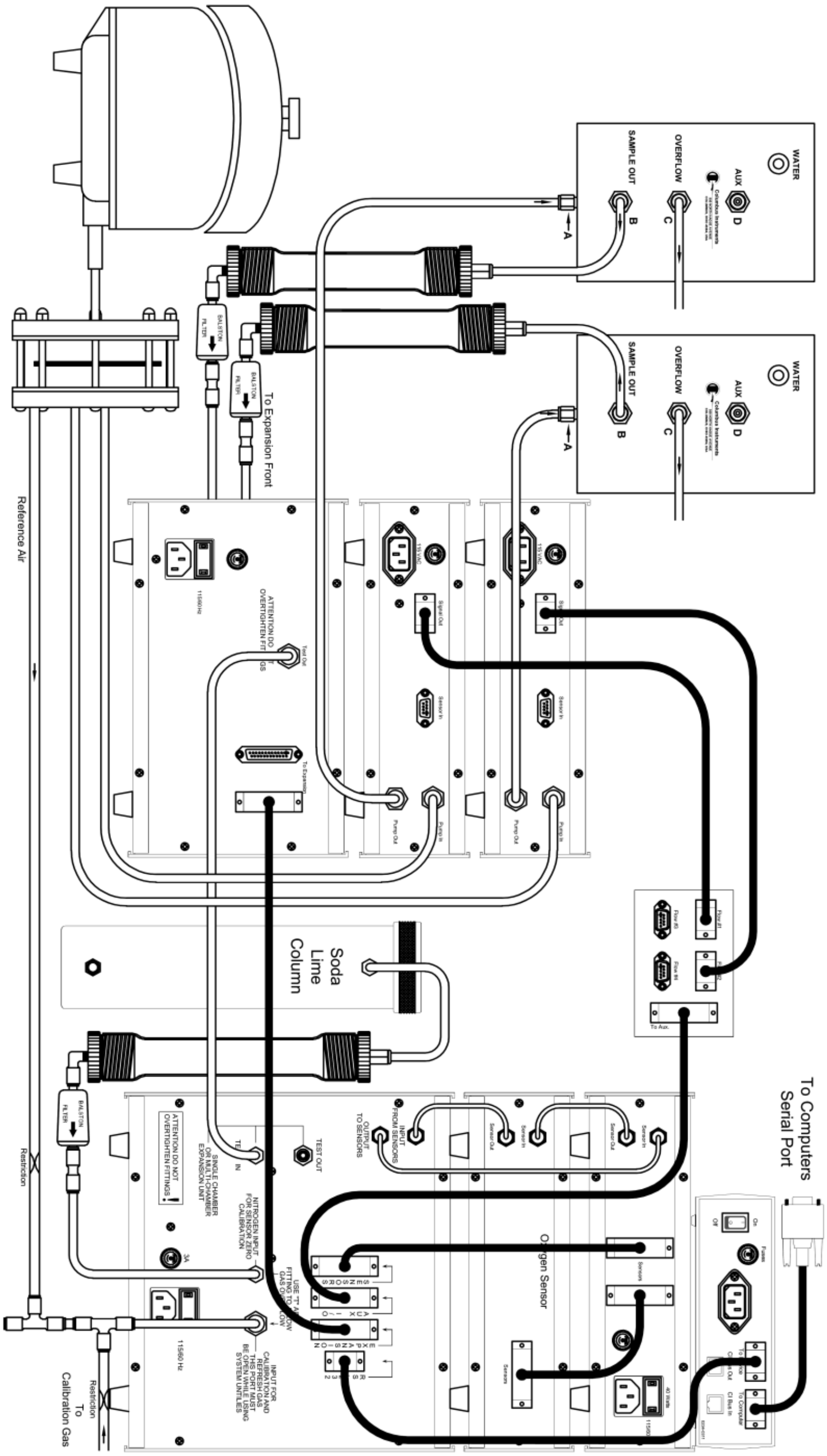


Figure 20

Multiple Test Chambers (4 units max) Cable and Tubing Connections

9.0 Oxymax Troubleshooting Techniques

System Description

Before embarking on troubleshooting, it will be of value to understand the overall function of Oxymax. Oxymax is an “open-circuit indirect calorimeter”. It infers heat production based on observations of oxygen consumption and carbon dioxide production. Knowledge of the foodstuff (fuel) being combusted and the rate of gas exchange required to support the combustion process allow the calculation of heat (Calories or Joules).

Gas exchange (presented as volume a [mL] or rate [mL/(time)]) is derived by monitoring both flow and the difference in gas concentrations appearing between inlet and outlet of a sealed chamber through which flows a known mass of air (L/Min). Knowledge of air mass and gas fractions (% by volume) provides the basic information required for the determination of volumes of both O2 and CO2 present at the inlet and outlet. Subtraction of the respective inlet and outlet volumes yield the volume of oxygen consumed (VO2) and the volume of carbon dioxide produced (VCO2). The relationship VCO2/VO2 provides an indication of the makeup of the foodstuff combusted. This “Respiratory Exchange Ratio” [RER] varies between 0.7 and 1.0 for the combustion of fats and carbohydrates respectively. Of course, dietary mixtures are reflected in RER with a normal diet providing an RER of approximately 0.85. Oxymax employs an equation that derives a calorific value based on observed RER. This value relates amount of heat produced per volume of oxygen consumed for the given mixture of fat and carbohydrate as assessed by RER (ie: Kcal/L). The calorific value varies in accordance with RER with an approximate 5% increase in heat produced as RER increases over the 0.7 to 1.0 nutritional range.

Gas differences (both O2 and CO2) appearing across the chamber (outlet to inlet) and mass air flow through the chamber are the basic elements measured by Oxymax. With respect to gas concentrations, Oxymax makes a differential measurement. It first assesses the composition of the air introduced to the chamber(s) and then scans the effluent from each chamber. The measured differential is a function of the metabolic rate of the animal and air flow through the chamber. Oxymax employs precision mass flow controllers to maintain a constant delivery of fresh air. This assures that the observed differential is a function of animal performance rather than an aggregate of animal performance and flow variation. When properly configured, the flow through the chamber is adjusted such that a resting animal yields an oxygen differential of -0.3% (input referenced). This difference in concentration provides suitable “signal” from which reliable calculations can proceed. Increases in animal metabolism will increase the signal.

Tips ….
Useful tips contributed by Columbus Instruments staff and Oxymax end-users

T1) Keep a log book of control knob settings, making recordings at each calibration.
Gross changes to control knob settings may indicate a system problem or calibration gas error.

T2) Calibrate before each experiment and check calibration at experiment conclusion.
Blunders during experiment execution could cause calibration knobs to be accidentally adjusted.

T3) Mark felts pads with side facing drying agent.
Inadvertently flipping a pad could cause accumulated debris to be liberated into sample path.

T4) Sample room air (approximately 20.93% O2) following calibration with new set-point gas.
Failure to observe 20.93% O2 may indicate problem with new set point gas.

When things go wrong ….

This section takes the form of a question and answer approach to troubleshooting Oxymax.

Q1) VO2 and VCO2 are too low when compared with published data.
Q2) VO2 and VCO2 are too high when compared with published data.
Q3) RER is too high.
Q4) RER is erratic, exhibiting large swings above and below nutritionally acceptable values.
Q5) Resting animals provide an oxygen differential less than –0.3%.
Q6) Experiment data slowly deviated from acceptable values over the course of the experiment.
Q7) All chambers look "OK" with the exception of chamber number __?__.
Q8) I'm unable to achieve the oxygen concentration indicated in my set point gas during calibration.

Q1) VO2 and VCO2 are too low when compared with published data.

A1a) There is a leak in the gas sampling portion of Oxymax. Gas sampling begins at some point in the effluent flow (the flow exiting the chamber). A slight vacuum exists in this sample line. Any leaks will allow the sample to be diluted with ambient air. This dilution will reduce the observed gas differential and result in readings that are low. **Solution:** Check all air fittings to assure an air-tight connection. If there is a dryer in the sample line, check the end cap(s) and "O"-rings to make sure that no leaks are present.

A1b) The sample drawn for analysis is in excess of the flow available from the chamber effluent. Drawing too much air will cause the sample to be diluted. This dilution will reduce the "observed" gas differential and result in readings that are low. **Solution:** Reduce the sample rate (via the valve at the base of the flow meter on the front of the System Sample Pump) to a level that is, at least, 20% below the rate of fresh air delivered to the chamber. This will assure that adequate overflow exists.

A1c) A leak has developed internal to the System Sample Pump. After years of operation, the mechanical pump within the System Sample Pump cabinet may begin to fail. This failure can allow ambient air to be internally mixed with the sample gas. The resulting diluted sample provides a diminished differential. Solution: Oxymax is equipped with a diagnostic section within the program. Proceed to Diagnostic|Sample Pump and enable any valve. Occlude the input to the valve with your figure and note the action of the ball in the sample flow meter on the front panel of the System Sample Pump. The ball should drop to the very bottom of the flow meter. If it does not, the pump has developed a leak and must be replaced.

Q2) VO2 and VCO2 are too high when compared with published data.

A2) There is a leak in the pathway delivering fresh air to the chamber. Leaks on the input side of the chamber will prevent the animal from receiving the full amount of fresh air. The resulting diminished flow will cause an excessive gas differential (both O2 and CO2) across the chamber. The erroneous, high, differentials will cause Oxymax to calculate high figures for VO2 and VCO2. **Solution:** Check all air fittings to assure an air-tight connection. Check connections between tubing and orifice for leaks as well as all connections between the Equal Flow cabinet and the "A" fittings on each chamber.

Q3) RER is too high.

A3a) There is a leak in the gas sampling side of the chamber between the dryer and the gas sensors. The leakage of moist (room) air into the sample gas causes the water vapor to displace the measured components (O2 and CO2). Additionally, presence of water vapor in the CO2 sensor and O2 sensor will cause them to read improperly**. Solution:** Check all air fittings to assure an air-tight connection. Check the end caps and “O”-rings on the dryer to make sure that no leaks are present. Confirm the drying agent is not expired. Replenish if necessary.

A3b) The oxygen sensor is out of calibration. Oxymax systems equipped with electrochemical cell based oxygen sensors have an upper limit of (approximately) 21.08%. Atmospheric air (dry) has an oxygen content (% by volume) of 20.93%. An error in calibration may cause Oxymax to misread ambient oxygen concentration. The resulting diminished differential oxygen reading (caused by Oxymax reaching the upper O2 limit when observing ambient air) causes an elevated RER. **Solution:** Examine the data for ambient O2 reading(s). Readings well in excess of 20.93% indicate a possible error in the composition of the calibration gas. Have the calibration gas re-certified.

A3c) Insufficient Settle Time. It takes a certain time for the gases from a previous measurement to be purged. In Oxymax jargon, this is referred to as “Settle Time”. It is the amount of time required for the gas sensors to settle to the new reading. Oxymax systems are plumbed with the oxygen sensor located downstream from the carbon dioxide sensor. It is possible that, with insufficient Settle Time, the sample gas could clear the carbon dioxide sensor and not yet fully purge the oxygen sensor. The result is a diminished differential reading as perceived by the oxygen sensor. Consequently, RER is calculated as too high. **Solution:** Increase Settle Time. During calibration of the carbon dioxide sensor, you are requested to connect a “zero” and “set-point” gas. You must then press a key to engage each gas’ valve and then adjust the appropriate knob (Offset or Gain). During this process you must wait until the display of CO2 settles before making control adjustments. The amount of time spent waiting is Settle Time and is the **minimum** amount of time required by Oxymax to purge the gas sample pathway. Measure this time and add 10%. The result is the shortest Settle Time entry allowed to assure proper operation of Oxymax.

Q4) RER is erratic, exhibiting large swings above and below nutritionally acceptable values.
A4) You are, most likely, employing a bad batch of Drierite as your desiccant. Some batches of Drierite will absorb and release CO2. The resulting distortion of the CO2 concentration measurements causes very abnormal RER indications. **Solution:** Replace all Drierite with Magnesium Perchlorate or Columbus Instruments Aquasorb. Neither compound has any affinity for CO2.

Q5) Resting animals provide an oxygen differential less than |–0.3%|.
A5) Flow and effluent oxygen concentration are inversely related. Too much fresh air and the effluent gas composition will approach the incoming gas composition. Thus diminishing the required gas differential. **Solution:** Reduce the flow of fresh air to the chamber.

Q6) Experiment data slowly deviated from acceptable values over the course of the experiment.
A6) Oxymax must make measurements of gas composition in a dry sample. The gradual consumption of drying agent over the course of an experiment may allow moist samples to pass through for analysis. **Solution:** Replenish drying agent.

Q7) All chambers look “OK” with the exception of chamber number __?__.
A7) Fortunately, you have a statistical frame of reference on which to base your observation. You may then revert to answers for Q1 through Q4 to isolate the problem. **Solution:** In a properly configured system, all chambers are identical. You may substitute or criss-cross pneumatic lines as required to assess if the problem lies upstream or downstream of the point of intervention. When making such substitutions or crossings, remember to make only one change and evaluate. Restore the system to the starting point before proceeding with a subsequent substitution or crossing. Don’t be shy about swapping subjects among chambers. Animals do differ and to rely on them as a “standard” is a poor idea.

Q8) I'm unable to achieve the oxygen concentration indicated in my set point gas during calibration.

A8) The most likely source is a dying or dead oxygen sensor cell. Oxymax systems equipped with an electrochemical cell based oxygen sensor will require periodic replacement of the cell. The cell contains, much like any battery, a finite amount of electrolyte that is consumed over time. New cells are warranted for a period of 6 months with many lasting 8-10 months. **Solution:** Replace the oxygen sensor cell.