3660 Analyzer for Oxygen or Ozone
Operator's Manual

Model 3660.xxx Indicating Instrument

Model 311xx.xx Oxygen Sensor or 313xx.xx Ozone Sensor

O-rings

29006.0 (set of 2)

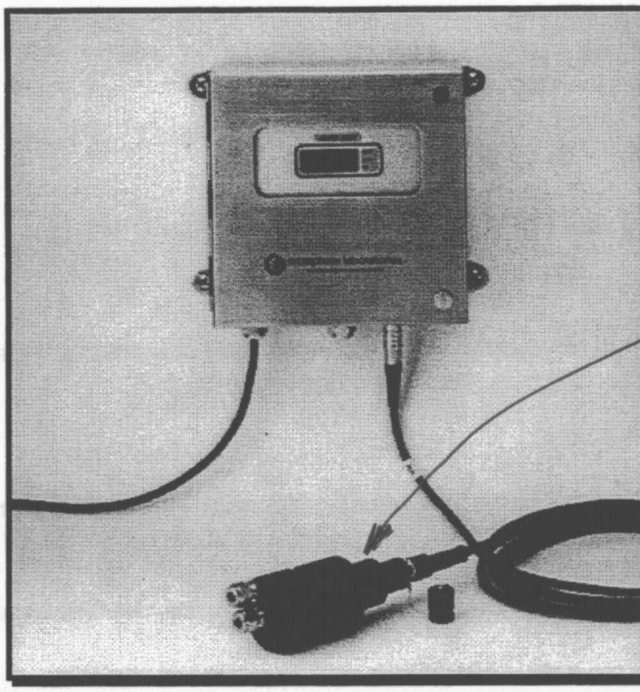
$10.00

Dirk Bender

x17

Kevin Boyle

973-839-7544



Model/Serial #.

ORBISPHERE LABORATORIES
70 Kinderkamack Rd.
Emerson, NJ 07630

201-265-4900

TO OBTAIN NEW SENSOR ON "MAINTENANCE PLAN":

Phone 201-265-4900
x19 Emilios
x20 Jim

They send new sensor UPS Red

Put old sensor in enclosed Fed-Ex mailer back to them.

Must have model/serial # from side of probe.

Kevin Day

Orbisphere Laboratories, 20 rue du Puits-Godet, CH-2000 Neuchâtel, Switzerland.
☎ (+41) 32 721 41 95, (+41) 32 725 34 33, E-mail: salesinfo@orbisphere.ch

CE conformity

The **3660** instrument is manufactured conforming to the requirements of the electromagnetic compatibility directive:

89 / 336 / CEE

and the low voltage directive:

73 / 23 / CEE.

The **3660** instrument complies with all the requirements of the electromagnetic compatibility standards:

EN 50081 - 1 (Jan. 1992) and **EN 50082 - 1** (Jan. 1992)

As a result, the instrument can be used in residential and commercial sites, and for light industry. It is designed for indoor as well as outdoor use.

The **3660** instrument satisfies the conditions of the safety standard:

EN 61010 - 1 (1993)

The **3660** instrument is developed, manufactured, and inspected by Orbisphere Laboratories, which is certified in accordance with the quality standard:

ISO 9001 / EN 29001

The tests for safety and for electromagnetic compatibility were performed by the CEM test laboratory (EMC Fribourg SA, zone industrielle de Montenaz, CH-1728 Rossens) which is acknowledged by the Swiss Federal Office of Metrology.

Supplementary safety recommendations

For safe operation of the instrument, it is imperative that these service instructions be read and that the safety recommendations mentioned herein be scrupulously respected.

Opening the instrument exposes non-insulated electrical components with hazardous voltages. Therefore the instrument should not be opened. If repairs or adjustments are necessary, the instrument should be returned to an authorized Orbisphere service center.

If these danger warnings are not heeded, serious material or bodily injury could occur.

Table of contents

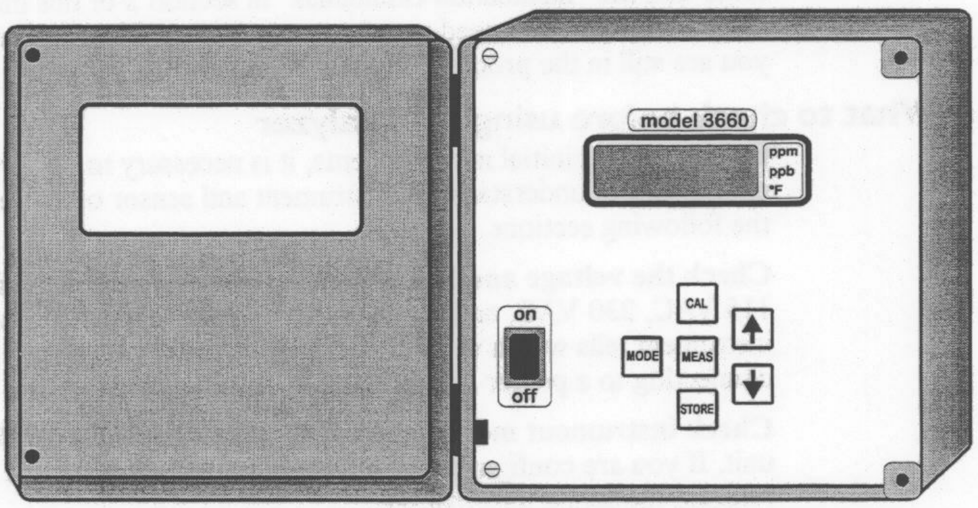
1. Operating Instructions

1.1 What you have received

The model 3660 Analyzer is a process analyzer for making either dissolved or gaseous oxygen or dissolved ozone concentration measurements, depending on your application (see table of Instrument Configurations in section 3.1, System Specifications). The analyzer incorporates:

- An *Indicating Instrument* (model 3660.xxx), with keypad and display, and
- An oxygen *Sensor* (model 311xx.xx), made of stainless steel or plastic, or an ozone *Sensor* (model 313xx.xx), made of titanium.

The front of the instrument has a three-digit liquid crystal display (LCD). To the LCD's right, is a list of measurement units configured at the factory for your application. The front door is opened by loosening two flat-head screws.

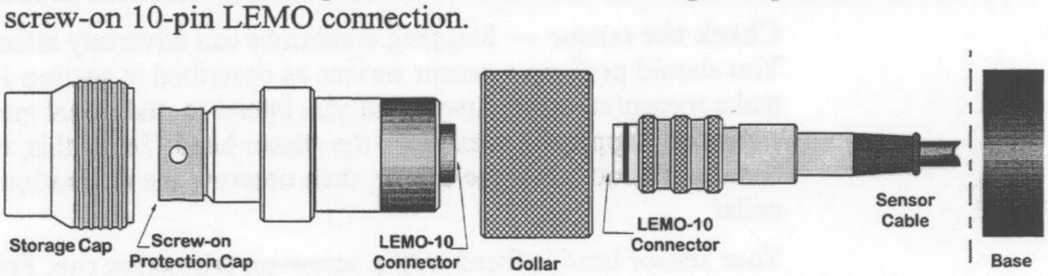


3660 instrument

The instrument front panel keyboard includes the following buttons:

- "MODE" changes the operating mode of the instrument.
- "CAL" calibrates the instrument against a reference sample and allows choice of calibration method. (This button can be locked out via the WIN3660 program.)
- "MEAS" places the instrument in "measurement" mode.
- "STORE" places a measurement value into memory.
- "↑" or "↓" toggle between gas and temperature measurement displays while in "measurement" mode. In "storage" or "memory recall" mode these buttons are used to increase or decrease the storage label number.

The oxygen or ozone sensor has a threaded collar and storage cap on top. A plastic screw-on base at its rear provides a stand for servicing, and protects the sensor's screw-on 10-pin LEMO connection.



Sensor components — exploded view

Also included with your shipment are:

- A sensor cable, with a mating screw-on connector and a snap-in LEMO-10 plug for connecting to the instrument.
- The *WIN3660* program, which runs on a personal computer (PC) under Windows®, on a 3½-inch disk;
- A communications cable for your PC connection; and
- A recharge kit appropriate to your sensor, in a blue plastic case, containing materials to maintain the sensor, such as membranes, electrolyte, a membrane mounting tool, polishing powder, and a polishing cloth.

You should check to see that any needed mounting hardware has been included. This varies with each application, but in general a flow chamber or sensor socket is usually needed to bring the sensor in contact with the liquid or gaseous sample. Note that the "Installation Guidelines" in section 2 of this manual include all the instructions you will need to set up your system. Please refer to this section now if you are still in the process of configuring your installation.

1.2 What to check before using the analyzer

Before making initial measurements, it is necessary to perform the following checks and to understand the instrument and sensor operation that are described in the following sections.

Check the voltage and line power — The indicating instrument is available in 115 VAC, 230 VAC, and 10-30 VDC versions. The sticker on the rear of the instrument tells which voltage you have. Make sure that it is correct *before* connecting to a power supply.

Check instrument mounting — The instrument is provided as a wall-mounted unit. If you are configuring your installation, check section 2.1 of this manual for relevant mounting information.

Check instrument connections — The instrument must be connected to the sensor and can be connected to the PC operating the WIN3660 application program. The instrument includes a LEMO-10 connector for the sensor and a LEMO-10 connector for serial RS-232 (or RS-422) to a PC. Connections for an analog recorder output and alarm contact outputs are also provided by the instrument. Complete wiring identification is given in section 2.1.1.

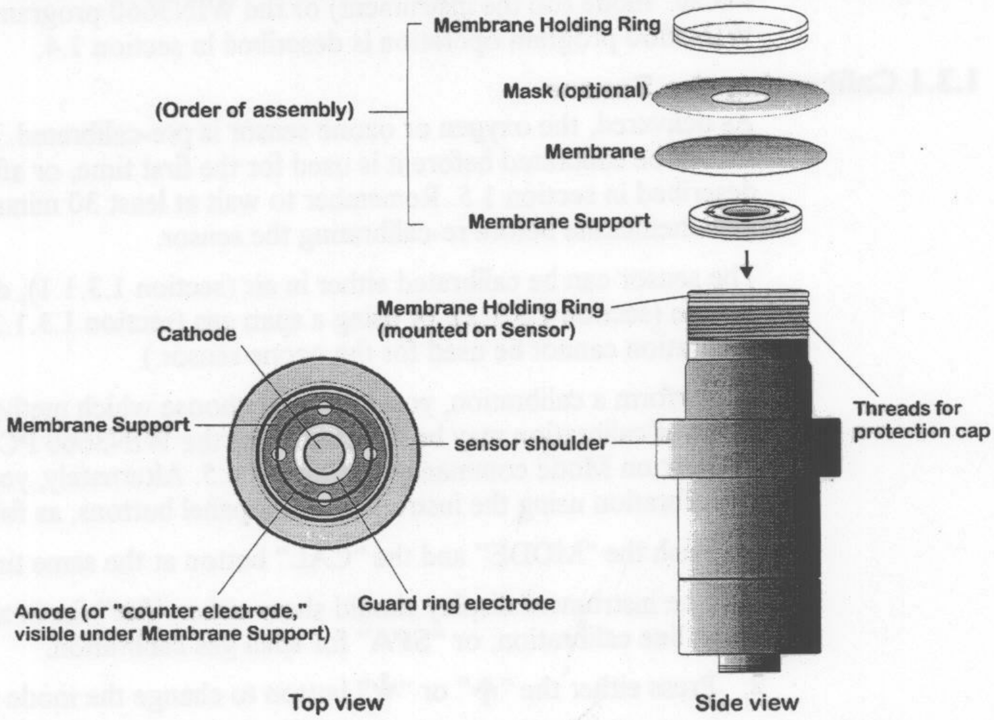
Check the serial connector before attempting to connect to your PC's serial port. On the PC side, note that you will need a 9-pin serial connector; your computer may only have a 25-pin connector available, which will necessitate a 25-to-9-pin adapter. Note: Make sure your adapter is designed for this purpose and thus has all nine pins accessible. Some 25-to-9 pin adapters are supplied for specific use, such as a mouse, and these may have only certain pins available.

Check instrument clock setting — If you will be using the analyzer to store measurements for downloading to a PC, you should verify the date and time settings of the instrument's internal clock, as described in section 1.4.7.6.

Check the sensor — Shipping conditions can adversely affect Orbisphere sensors. You should perform a sensor service as described in section 1.5 before trying to make measurements. However, if you intend to make trial measurements with the sensor as shipped, first examine the sensor head. To do this, remove the plastic base at the bottom of the sensor, then unscrew the calibration cap by loosening its collar.

Your sensor head is fitted with a screw-on protection cap. For a view of the sensor head, you will need to remove the cap, using the wrench supplied in your recharge kit. Do this carefully, making sure not to disturb the membrane that covers the sensor head, held in place by a membrane holding ring.

You should be able now to view the gold cathode, or "working electrode", in the center; a guard ring electrode surrounds the cathode, separated by a fine groove.



Sensor components, including exploded view of membrane assembly order

The anode, or "counter electrode", is underneath the membrane support. You will get a better look at all these components during your first sensor service. Before making a measurement, check the sensor head to see that:

- the membrane holding ring is firmly in place,
- the membrane surface is smooth and wrinkle-free,
- the electrolyte beneath the membrane is free of bubbles,
- the electrodes appear clear, clean and bright.

Check sensor placement — The sensor can be placed in a flow chamber for on-line sampling, that is, samples drawn off-line by 6mm or ¼-inch tubing, or in a sensor socket or ProAcc insertion/extraction valve for measurements made in-line, directly in a sampling pipe. Check to see that the recommendations made for this application in the Installation Guidelines are followed before proceeding with measurements.

1.3 Instrument Operation

Once you have completed the preceding checklist, the 3660 instrument can be operated independently, making measurements as an oxygen or an ozone analyzer. You may store these measurement values for later analysis via the "Memory Recall" mode (on the instrument) or the WIN3660 program (on your PC). The WIN3660 program operation is described in section 1.4.

1.3.1 Calibrating the Sensor

As delivered, the oxygen or ozone sensor is pre-calibrated. However, the sensor should be calibrated before it is used for the first time, or after a sensor service, described in section 1.5. Remember to wait at least 30 minutes after mounting a new membrane before re-calibrating the sensor.

The sensor can be calibrated either in air (section 1.3.1.1), directly in line in a liquid sample (section 1.3.1.2), or using a span gas (section 1.3.1.3). (Note: Span gas calibration cannot be used for the ozone sensor.)

To perform a calibration, you must first choose which method you wish to use. The mode of calibration may be selected using the WIN3660 PC program, via the Calibration Mode command, section 1.4.6.5. Alternately, you can select the mode of calibration using the instrument front panel buttons, as follows.

1. Push the "MODE" and the "CAL" button at the same time.

   The instrument display should show either "**Air**" for in air calibration, "**Li**" for in line calibration, or "**SPA**" for span gas calibration.
2. Press either the "↑" or "↓" button to change the mode to your choice.
3. Press "STORE" button to set the selected mode. The instrument displays "**Sto**" for a few seconds, then returns to measurement mode.

Your calibration mode is stored internally and is valid until the next modification.

Calibration Range Checking

When calibration is performed "In air" or "In a span gas", as detailed in the sections below, the sensor current is compared to an ideal current (stored in EPROM for each membrane).

- *If the current is not within 60% to 140% of the ideal current*, the instrument displays "**Er0**". This is only a caution message, and indicates that a sensor service should be performed (section 1.5). The sensor will calibrate correctly.

  (Note: If you have just changed the sensor membrane, this message may also be displayed, indicating a slight difference in the membrane permeability — particularly for the model 29552A membrane.)
- *If the current is not within 25% to 175% of the ideal current*, the instrument displays "**Er1**" and the system will not calibrate. It is likely that the sensor is dirty or out of order. Try a sensor service first; if this error still occurs, call your Orbisphere representative.

  (See also "Program Troubleshooting", section 1.4.7, if you suspect any problems with the instrument.)

Note: This calibration range checking can be enabled or disabled using the WIN3660 program (see Calibration Range Checking, section 1.4.6.6). It is recommended to leave this checking feature *enabled*. In special measurement situations it may be necessary to disable range checking — however, *contact an Orbisphere representative before disabling this feature*.

If you want to verify the accuracy of this calibration, place the analyzer back in measurement mode, and compare your displayed concentration in air against the appropriate value of the table at the end of this manual, in Appendix 1.

1.3.1.1 Calibration In Air

The sensor can be accurately calibrated in air. To perform this type of calibration, the instrument must be set for calibration "In air", as described in section 1.3.1.

1. In order to calibrate the sensor in air, you will need to extract the sensor from its mounting or flow chamber. The screw-on protection cap should be in place on the sensor head.

   Note: For applications using the model 29106 protection cap (such as carbonated beverage samples), if the Dacron mesh inside the sensor's protection cap is wet, please dry it before proceeding further.

2. Calibration is best done using the storage cap that protected the sensor during shipment. Put several drops of tap water in the cap, shake out the excess, then attach the cap to the sensor by means of its collar. It is best to leave the cap slightly loose, to avoid compressing the air in the cap.
3. Switch on the instrument.
4. Press the "CAL" button (remember, this button may have been locked out to prevent an accidental reset — see section 1.4.6.11 for details).
5. A brief clearing ("- - -") message appears.
6. Press "CAL" again within a 3 second period.
7. The percentage of the measured current to the ideal current is displayed.
   - *If the calibration current is not within 60% to 140% of the ideal current*, the instrument alternately displays "**Er0**" and the percentage. The sensor can be calibrated; however, a sensor service should be performed.
8. When the reading is stable, press "CAL" again.
   - *If the calibration current is within 25% to 175% of the ideal current*, the instrument displays "**CAL**" and returns to the measurement mode. The sensor is calibrated.
   - *If the calibration current is not within this range*, the instrument displays "**Er1**" and returns to measurement mode. The system will not calibrate.
9. Place the sensor back into the flow chamber or sensor socket, using its collar to secure it into place (see section 2.2).

Your sensor should be ready to begin making measurements.

When you start the calibration procedure with the "CAL" button (step 6 above), the instrument holds the last measured gas concentration value for the analog and alarm outputs. (The LCD display and RS-232 outputs continue to display the actual readings during the calibration steps.) After the new calibration is stored (step 8 above), the instrument still holds the analog and alarm outputs, and flashes a "**hld**" message alternately with the measurement display. When the sensor is returned to the sample, press the "MEAS" button to resume normal output of measurements to the analog and alarm ports.

1.3.1.1.1 Calibration In Air: Avoiding false alarms with the "Hold" feature

As noted above, the instrument will "hold" analog and alarm outputs at the last measured value during calibration. If you wish to perform an "In air" calibration as a normal part of in-line oxygen measurements, *without setting off any alarms* (that is, without having the analog and alarm outputs reflect the equivalent dissolved oxygen level in air, usually about 5–10 ppm), it will be necessary to engage this "hold" feature before withdrawing the sensor from the sample.

To do this, simply press the "CAL" button twice, as shown in steps 4–6 of section 1.3.1.1, *while the sensor is still in the sample.* You may see a very low (or very high) percentage of expected current on the LCD, but this will change once the sensor is removed from the sample and placed in air.

The same considerations apply here as were described in section 1.3.1.1 for removing the sensor, drying out the Dacron mesh (if used), using the storage cap for a humidified sample and watching the percentage stabilize.

Once the percentage is stable—and it may take a few minutes for this to occur—press "CAL" a third time to calibrate the sensor.

You will see a "**hld**" message on the LCD, alternating with measurement values, as you place the sensor back in its sample. As above, press the "MEAS" button once you are satisfied that the measured value is sufficiently within your limits to avoid unnecessarily setting an alarm.

1.3.1.2 Calibration In Line

An "In line" calibration routine is used when calibrating the sensor directly in the sampling device, against a sample with a known dissolved oxygen or ozone concentration.

Performing an in-line sensor calibration can be convenient, since you can leave the sensor in its mounting, introduce the reference sample to the sensor, and adjust the expected values via the instrument keyboard.

To perform this type of calibration, the instrument must be set for calibration "In line", as described in section 1.3.1 above.

1. Switch on the instrument.
2. Expose the sensor to a liquid sample with a known gas concentration, and wait for the displayed measurement to settle.
3. Press the "CAL" button (remember, this button may have been locked out to prevent an accidental reset — see section 1.4.6.11 for details).
4. A brief clearing ("- - -") message appears.
5. Press "CAL" again within a 3 second period.
6. A measurement should be displayed, showing the gas concentration of the calibration sample.
7. Assuming you know the gas content to be a certain value, you can adjust the displayed value with the "↑" or "↓" button.
8. When the reading is adjusted to the known concentration, press "CAL" again. The instrument displays "**CAL**" and returns to the measurement mode. The sensor is calibrated.

When you start the calibration procedure with the "CAL" button (step 5 above), the instrument holds the last measured gas concentration value for the analog and alarm outputs. (The LCD display and RS-232 outputs continue to display the sensor readings during the calibration steps.) After the new calibration is stored (step 8 above), the instrument still holds the analog and alarm outputs, and flashes a "**hld**" message alternately with the measurement display. When the sensor is returned to the sample, press the "MEAS" button to resume normal output of measurements to the analog and alarm ports.

1.3.1.3 Calibration In a Span Gas

The span gas calibration procedure may be used when calibrating an oxygen sensor. When calibrating in a span gas, it is recommended to use the model 32001 flow chamber to introduce the span gas to the sensor (see section 2.2.1 for flow chamber calibration connections).

To perform this type of calibration, the instrument must be set for calibration "In a Span Gas", as described in section 1.3.1 above. The Windows WIN3660 program also must be used in this procedure.

1. If you are using a sensor socket or ProAcc for sampling, first extract the sensor from its socket or mounting, then insert the sensor into the model 32001 flow chamber. Connect a span gas sample of a known oxygen content to the flow chamber's central sample entry port and purge the system.
2. Switch on the instrument
3. Expose the sensor to a span gas sample with a known oxygen concentration.
4. Enter the percentage of oxygen in the span gas using the WIN3660 program "Span Gas" menu (see section 1.4.6.7).
5. Press the "CAL" button (remember, this button may have been locked out to prevent an accidental reset — see section 1.4.6.11 for details).
6. A brief clearing ("- - -") message appears.
7. Press "CAL" again within a 3 second period.
8. The percentage of the measured current to the ideal current is displayed.
   - *If the calibration current is not within 60% to 140% of the ideal current*, the instrument alternately displays "**Er0**" and the percentage. The sensor can be calibrated; however, a sensor service should be performed.
9. When the reading is stable, press "CAL" again.
   - *If the calibration current is within 25% to 175% of the ideal current*, the instrument displays "**CAL**" and returns to the measurement mode. The sensor is calibrated.
   - *If the calibration current is not within this range*, the instrument displays "**Er1**" and returns to measurement mode. The system will not calibrate.
10. Place the sensor back into the flow chamber or mounting, using its collar to secure it into place (see section 2.2).

Your sensor should be ready to begin making measurements.

When you start the calibration procedure with the "CAL" button (step 7 above), the instrument holds the last measured gas concentration value for the analog and alarm outputs. (The LCD display and RS-232 outputs continue to display the sensor readings during the calibration steps.) After the new calibration is stored (step 9 above), the instrument still holds the analog and alarm outputs, and flashes a "**hld**" message alternately with the measurement display. When the sensor is returned to the sample, press the "MEAS" button to resume normal output of measurements to the analog and the "MEAS" button to resume normal output of measurements to the analog and alarm ports.

1.3.2 Making Measurements

Once the system is calibrated, you should be able to begin making gas concentration measurements (oxygen or ozone, depending on your application).

Upon switching on the instrument, the displayed gas concentration value will typically start from a maximum and rapidly decrease to the actual concentration levels. It is normal for the right-most digits to vary in reaction to slight variations in gas content. However, if drastic changes occur, correct readings will lag as the sensor adjusts to the new concentration — the sensor response time depends on the membrane used in your application (see section 3, "Technical Information"). The measured gas concentration ranges are also membrane dependent. The different measured ranges for each membrane are given in section 3.

The instrument LCD includes a right-side marker to distinguish between gas concentration measurements and temperature. This marker also indicates which concentration units for instruments configured for multiple gas concentration units (such as ppb/ppm, see Selecting Measurement Units, section 1.4.6.3, see also Display Autoranging, section 1.3.2.2).

To switch from displaying gas concentration measurement to temperature measurement (and back again), press either the "↑" or "↓" button.

Note: If the sensor is not connected to the instrument, an "**out**" message is shown in place of the measurement display on the LCD.

1.3.2.1 Thermal Cut-off

The 3660 instrument includes a thermal cut-off feature. If the sample temperature could exceed the compensated temperature range of the sensor, the electrical signal to the sensor can be automatically cut off to extend the sensor's life. The default temperature cut-off is factory set at 65° C. This feature can be enabled or disabled, and is adjustable via the WIN3660 program, section 1.4.6.8.

If thermal cut-off is enabled, when the temperature of the sample exceeds this value, the sensor output will show only a trace level of gas concentration. When this occurs, the serial port and analog (recorder) output will report a trace level of the gas, and, depending on the Alarm Limits Low setting (see section 1.4.6.12), an alarm may be signaled from the alarm output port. If the instrument is set for "Events" mode of automatic storage (see section 1.4.6.9), a measurement sample is also stored at this time.

After a thermal cut-off action, the instrument restores the current supply to the sensor when the sample temperature falls 2.5°C/°F *below* the specified cut-off temperature.

1.3.2.2 Display Autoranging

Several gas concentration ranges can be displayed by the instrument. The different ranges are listed for each instrument model in section 3.1, System Specifications. The instrument autoranges the display based on the measured gas concentration — when the measurement drops below the minimum value of the higher range, the concentration is displayed in the lower range.

In addition, several 3660 models provide two different units of measurement, such as ppm/ppb for dissolved O_2 (models 3660.100/101) or dissolved O_3 (models 3660.300/301), or %/ppm for gaseous O_2 (models 3660.106/107). For these "composite" units, both units are available for display — when the measurement drops below the minimum value of the higher units, the concentration is displayed in the lower units. For example, in model 3660X.100, concentrations below 1.00 ppm are displayed in ppb (1 ppm = 1000 ppb), in model 3660.106, concentrations below 0.10 % are displayed in ppm (0.1 % = 1000 ppm).

1.3.2.3 Analog Output Signal

An analog output signal representing the measured gas concentration is available, as either 0–20 mA or 4–20 mA. Wiring connections are described in section 2.1.1. This output can be scaled between any two custom concentration limits if desired; see section 1.4.6.13. If the lower of these limits is represented by L0, and the upper one by L1, the relation between the analog output signal I (current, mA), and the displayed concentration C is as follows:

0–20 mA	C = L0 + (L1 - L0) * I/20
4–20 mA	C = L0 + (L1 - L0) * (I - 4)/16

The analog output saturates at 20 mA whenever the displayed concentration is equal to or exceeds the upper limit L1. Similarly, it remains blocked at 0 mA or 4 mA if the concentration is equal to or less than the lower limit L0. The output also shows these extreme values under other conditions as summarized in the following table:

Analog output	Explanation
0 mA or 4 mA	Thermal cutoff, below analog output low level, or sensor disconnected
0 (or 4) mA < signal < 20 mA	Normal operating condition
20 mA	Overrange or above analog output high level

1.3.2.4 Alarm Relay Output

There are two separate alarm relay connections on the instrument's output card, NO and NC, for each alarm limit relay, High and Low (see section 2.1.1). The High and Low limits can be set to any two gas concentration limits; see section 1.4.6.13. When the measured gas concentration exceeds the high limit or falls below the low limit, an alarm is signaled from the alarm relay connections. The following table lists the possible alarm conditions signaled by the instrument.

Alarm Relay Conditions

Condition	LOW NC to COM *	HIGH NC to COM *	LOW NO to COM *	HIGH NO to COM *
Instrument power switch off	closed	closed	open	open
No alarm: Low Limit < measured gas < High Limit	open	open	closed	closed
Low alarm: measured gas < Low Limit	closed	open	open	closed
High alarm: measured gas > High Limit	open	closed	closed	open
Low test: "Low Alarm" test (see section 1.4.7.4)	closed	open	open	closed
High test: "High Alarm" test (see section 1.4.7.4)	open	closed	closed	open
Sensor not connected	closed	open	open	closed

* "LOW NC, HIGH NC, LOW NO, HIGH NO, and COM" identify the alarm relay connections at the instrument's output card (see section 2.1.1).

After a High or Low alarm condition is signaled, the instrument clears the High alarm when the gas concentration drops to 1% below the high limit, or clears the Low alarm when the concentration rises to 1% above the low limit.

1.3.3 Storing Measurements

The instrument will store up to 500 gas concentration measurement values, labeled as sample numbers 0 through 499, with the date and time of the measurement. You have the choice of acquiring this information manually or automatically, as described in the sections below. *Do not switch off the instrument while it is in the process of storing data*, or data values will be lost.

Before storing measurements, you should verify the date and time settings of the instrument's internal clock, as described in section 1.4.7.6.

1.3.3.1 Manual Data Acquisition

For the first measurement you wish to store, press "STORE" once to bring up a sample number display. The default sample number is "000." You can increase or lower this number by pressing the "↑" or "↓" button within five seconds.

[Should you, at this point, *decide **not** to store* this particular measurement, just wait five seconds. The "store" sample number disappears, and the display returns to measurement mode. You may also exit this routine by pressing "MEAS."]

Press "STORE" a second time, within five seconds of the first, and you will see the following sequence of displays on the LCD:

1. A brief clearing ("**- - -**") message,
2. A measurement display, for about three seconds,
3. A ("**- - -**") message as these values are being stored.

If you stored the first value as sample "001," the next value to be stored will be automatically advanced and labeled as sample "002." Of course, this sample number can be increased or lowered if desired, but should you label the next measurement "001," *your first measurement would be over-written by the second.* You may over-write any stored value this way.

Repeat the above procedures to store forthcoming measurements.

1.3.3.2 Automatic Data Acquisition

Gas concentration measurements can be stored automatically by the instrument, in sample numbers 0 through 499. Automatic storage can be set for "Timer" mode where the timing between storage samples (sampling interval) is at pre-specified intervals (from 30 seconds to 1 hour), or "Events" mode where samples are stored at the occurrence of specific events (such as Alarm and Thermal cut-off). Use the WIN3660 program to select Timer or Event mode and to set the sampling interval for Timer mode (sections 1.4.6.9 and 1.4.6.10).

To enter automatic data acquisition mode, hold down the "MODE" button while pressing the "STORE" button. You will see the letters "**Sto**" on the LCD for about two seconds. Then you will see the storage steps similar to those described above in section 1.3.3.1. That is, first a clearing message, a sample number (starting at sampling point "000"), followed by gas concentration measurement, a second clearing message, and a return to the normal measurement display.

If you have not cleared previously stored values, this data acquisition capability will automatically overwrite the prior values as they are stored.

If enough measurements are stored to fill the 500 samples, the instrument will start recycling through the memory storage. For each new measurement past this point, the oldest value (in time) is erased from memory and the new value is stored in memory. Thus, after the maximum of 500 samples is stored, memory will contain a continuously updated set of the 500 latest measurements.

To end automatic data acquisition mode, hold down the "MODE" button while pressing the "STORE" button. You will see the letters "**End**" on the LCD.

1.3.4 Using "Memory Recall"

You can use the instrument to view the stored measurements. To activate this "Memory Recall" mode, hold down the "MODE" button while pressing the "↑" button. You will see the letters "**rcl**" on the LCD for about two seconds.

You can now scroll through the locations of all the stored values using the "↑" or "↓" buttons. To see the gas concentration measurement at a particular storage location, push the "STORE" button. Pressing "STORE" a second time returns you to the next numbered location, to view another stored value.

To return to the measurement mode, hold down the "MODE" button while pressing the "↑" button. You will see the letters "**End**" on the LCD.

1.3.5 Shutting Down the System

During a short shut-down period (such as weekends) the sensor can be left in its flow chamber or sensor socket.

If this inactive period is likely to last a long time, you should remove the sensor from its flow chamber or sensor socket.

If you expect not to use your sensor for more than a few months, the sensor should be serviced as instructed in section 1.5 and then stored "dry," without electrolyte, with the calibration cap in place for protection.

1.3.6 Instrument Troubleshooting — Program Identification

In order to identify the software in your instrument, do the following:

1. Switch off the instrument;
2. Hold down the "MEAS" button and switch on the instrument. An identifying software version number will appear in the LCD for about two seconds.

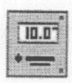
This information may be useful should you need to call an Orbisphere technician for service.

1.4 WIN3660 Program Operation

The WIN3660 program is an integral part of the 3660 analyzer. Running under Microsoft Windows®, this program provides:

- On-line monitoring of instrument measurements;
- Downloading stored measurement values from the instrument;
- Reviewing and setting instrument configuration parameters; and
- Troubleshooting to assure that the system is in good working order.

When properly installed under Windows, a Program Group labeled "Orbisphere" is available with two entries: the WIN3660 program and WIN3660 Help.



WIN3660

WIN3660 Help

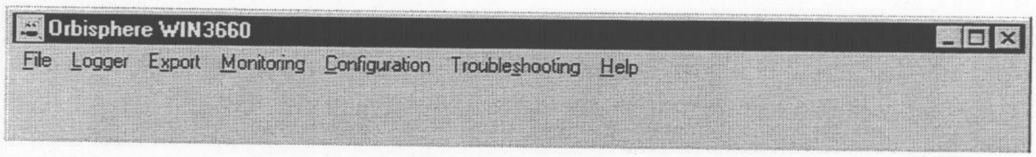
Select the WIN3660 icon to start the WIN3660 program; use the WIN3660 Help icon for program help.

In the event this application is not installed yet or is not working properly, refer to the WIN3660 Program Installation guidelines, section 2.3.

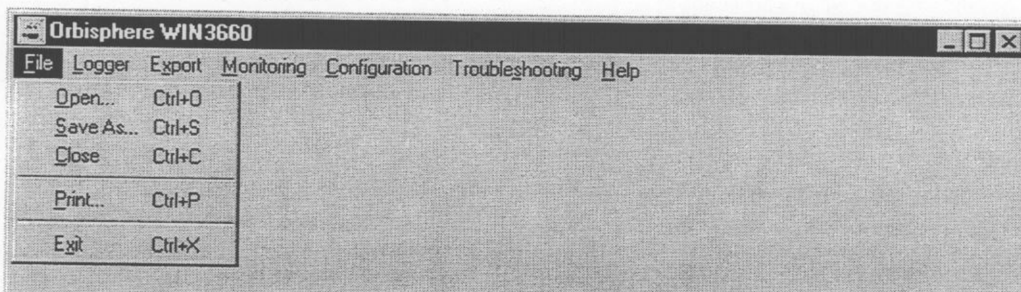
1.4.1 Main Menu Basics

Windows programs typically operate using a mouse or other pointing device such as a trackball. We assume that such a device is available for use. However, in this manual all menu commands are identified in bold, with one letter in the command underlined; you may use this underlined letter with the "Alt" key, if desired, to activate the command.

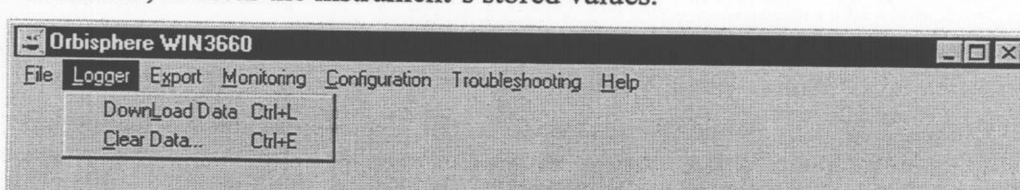
Select the WIN3660 program icon from the Orbisphere Program Group to bring up the main window and program menu, which automatically maximizes on opening and appears as follows:



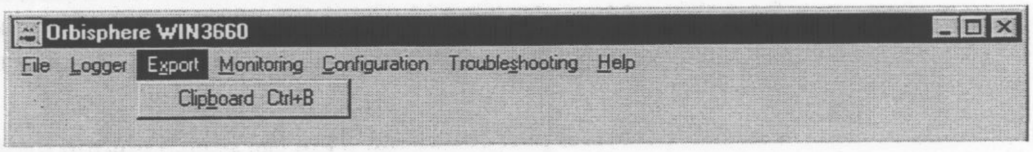
The File menu, shown below, serves typical Windows file management needs. WIN3660 data files can be opened, saved, closed, or printed, and you can exit from the WIN3660 program.



The Logger menu, below, permits you to download measurement values from the instrument, or clear the instrument's stored values.

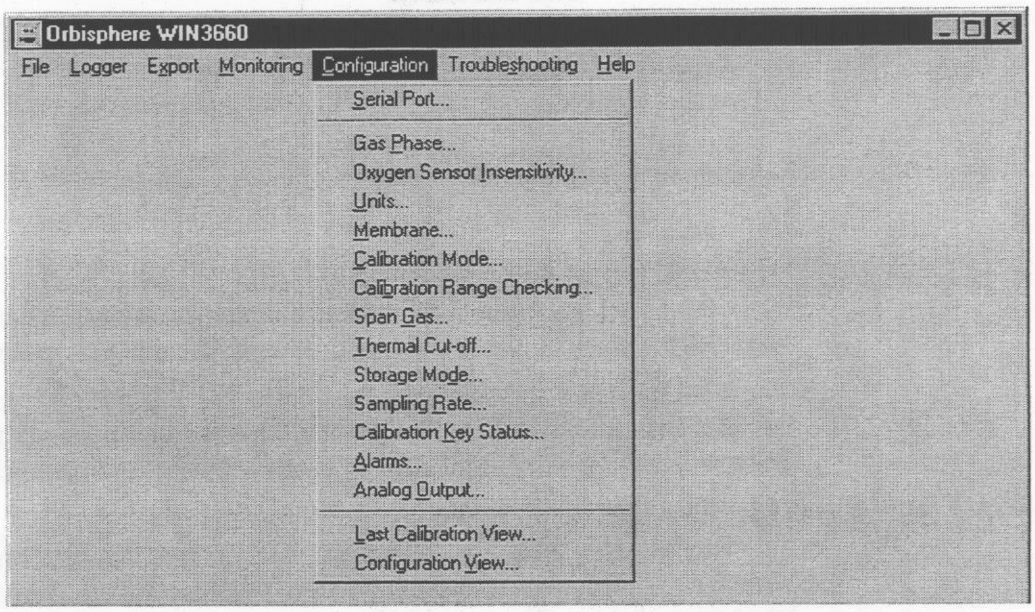


Export, below, places your information into the Windows Clipboard, so that it can be "pasted" directly into other Windows programs. This is especially useful when working with spreadsheet programs, but the information can be pasted into word processing programs as well.

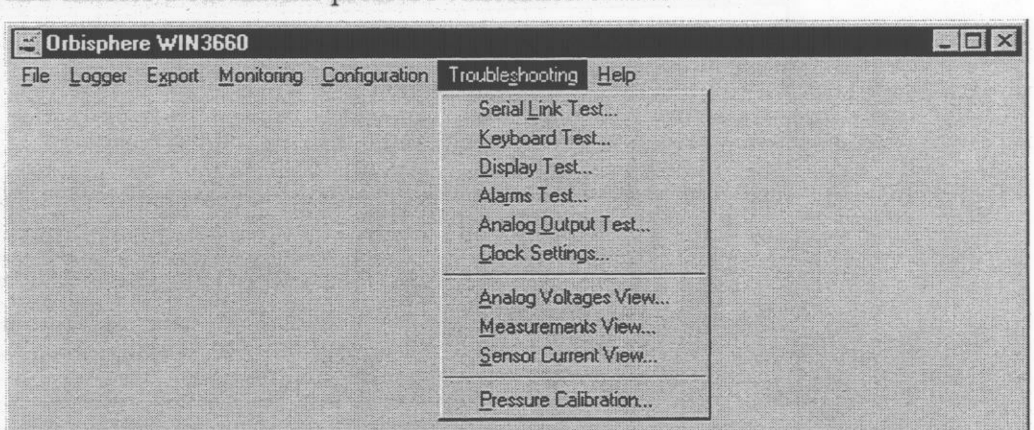


The Monitoring menu, illustrated in section 1.4.3, displays a running chart of real-time measurements from the instrument, similar to a chart recorder. These measurement data can be saved to the Windows Clipboard as well.

The Configuration menu, below, lets you review and change your instrument measurement and calibration configuration.



The Troubleshooting menu, below, includes a series of instrument operating tests, and enables a barometric pressure calibration routine.

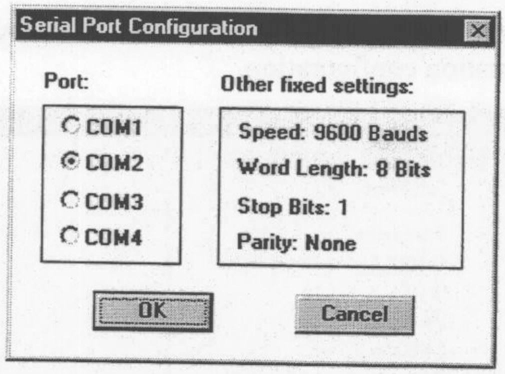


The Help menu accesses program help screens, and displays a screen that identifies the version number and copyright date of the WIN3660 program.

1.4.2 Instrument-PC Connection

A cable is supplied for instrument-to-PC connection, with a LEMO-10 plug on one end, and a 9-pin plug on the other (Model 32541 for RS-232, or Model 32542 for RS-422; see Installation Guidelines, section 2.1). Connect the LEMO-10 plug from this cable to the instrument, and the 9-pin plug to a serial port on your PC. (If your PC only has a 25-pin serial port connector, you will need a 25-to-9 pin adapter.)

Choose the Serial port command from the Configuration menu to select the PC communication port that is connected to the instrument. The instrument must be connected to the PC port and powered on to establish proper port communications. The following Serial port configuration dialog box is displayed.

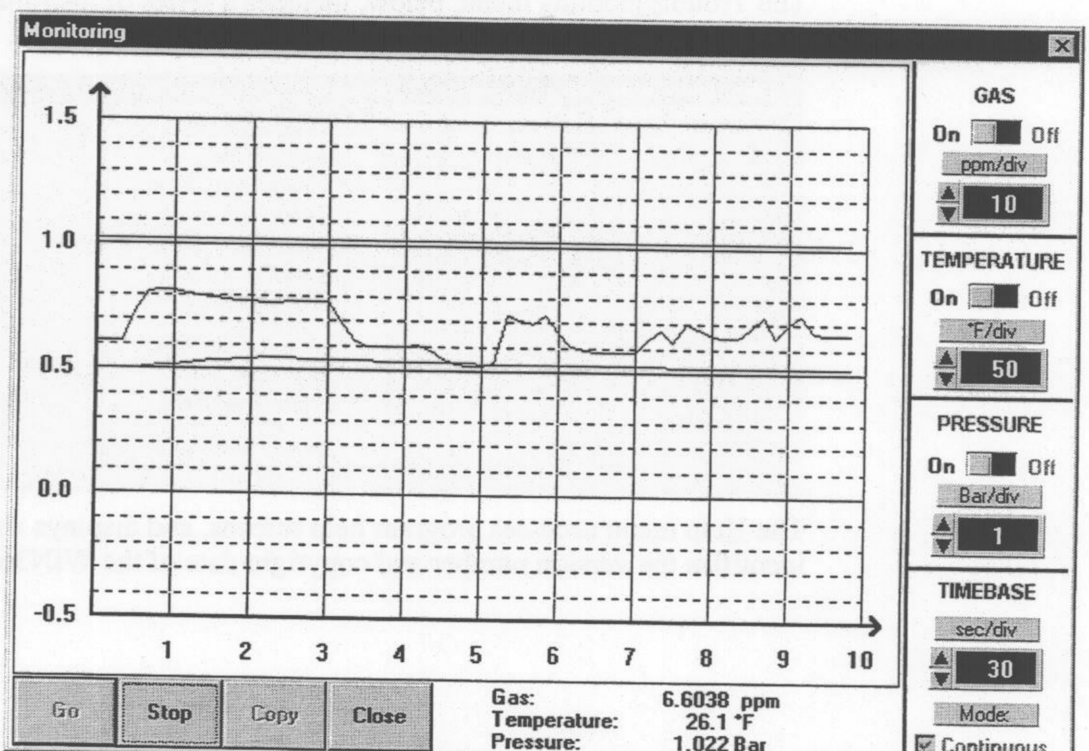


Click the COM port that is connected to the instrument. Note: In some manufacturers PC's, the COM1 port is used to connect a mouse. Try COM2 first.

Click OK to select and initialize the desired port. If the port you have selected in this dialog box is available, the WIN3660 program returns to the main menu. Otherwise, an "RS232 ERROR" message advises you to select another port.

1.4.3 Real-time Monitoring

You may wish to view the instrument measurements in real-time via the WIN3660 program. To use, choose the Monitoring command from the Monitoring menu to bring up a chart as illustrated below:



The Monitoring chart shows the gas concentration (in blue), temperature (in red), and pressure (in green) as the sample is being measured by the instrument. The chart is updated directly from instrument measurements, at a rate determined by the time scale set in the TIMEBASE box at the lower right corner of the chart.

Click the TIMEBASE up/down pointers to change the time scale of the divisions of the chart. Each division mark along the baseline (1, 2, ...10) can be made to represent from 30 seconds to 2½ hours, providing from 5 minutes to 25 hours of continuously displayed samples. The chart updating rate is determined by the time scale selected, as shown in the following table.

TIMEBASE	Updating rate*	Maximum samples (10 divisions)
30 seconds/division	5 seconds/sample	60
1 minute/division	5 seconds/sample	120
10 minutes/division	5 seconds/sample	1200
30 minutes/division	9 seconds/sample	2000
1 hour/division	18 seconds/sample	2000
2:30 hours/division	45 seconds/sample	2000

* This chart "updating rate" is independent from the rate set via the Sampling Rate command, section 1.4.6.10.

Click on the Continuous box, in the lower right corner, to enable or disable continuous charting. When this box is checked, the chart "scrolls" continuously after reaching the "10" division, and the oldest samples are lost off the left of the chart. When Continuous is not checked, the chart stops displaying new results after reaching the "10" division, and all subsequent measurements are lost.

Click the up/down pointers for each measurement variable (GAS, TEMPERATURE, and PRESSURE) at the right of the chart to change the scaling of that value on the chart. The display of each measurement variable may be turned on or off by choosing the appropriate On or Off switch at the right of the chart. Thus, if your measurements do not chart properly, try using a higher or lower value scale or time base than the one displayed. Adjust these scale factors *before* starting the monitoring operation, below.

A running display of latest sample Gas, Temperature, and Pressure is also shown in the bottom-right corner of the chart.

Use the buttons at the bottom of the chart to control real-time monitoring. Choose Go to clear the chart and start the real-time monitoring display; choose Stop to stop real-time monitoring; choose Copy to copy the data on the chart as text information to the Windows Clipboard. This information can be pasted from the clipboard into any Windows application, such as a spreadsheet or word processor. See the table above for the maximum number of samples that can be copied for each chart time scale.

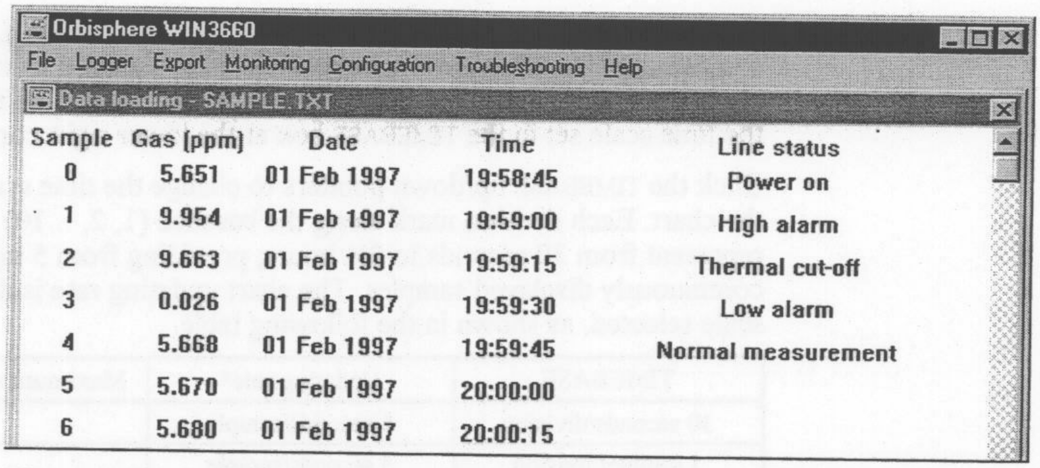
Choose Close to close the Monitoring window.

1.4.4 Accessing Stored Measurements

If you have made measurements and stored them in the instrument, you can download them into the WIN3660 program to display, save, and print the data.

1.4.4.1 Downloading Stored Values

To download the stored results from the instrument to the PC, choose the DownLoad Data command from the Logger menu. A message "DownLoading in Progress..." is displayed while the data is being transferred to the PC. The following is a typical display of the downloaded data.



Sample	Gas (ppm)	Date	Time	Line status
0	5.651	01 Feb 1997	19:58:45	Power on
1	9.954	01 Feb 1997	19:59:00	High alarm
2	9.663	01 Feb 1997	19:59:15	Thermal cut-off
3	0.026	01 Feb 1997	19:59:30	Low alarm
4	5.668	01 Feb 1997	19:59:45	Normal measurement
5	5.670	01 Feb 1997	20:00:00	
6	5.680	01 Feb 1997	20:00:15	

The download window presents a display of the stored measurements from the instrument. The window displays five columns of data: Sample (sequence number of the sample), Gas (concentration of the measured gas), Date (date of the measurement), Time (time of the measurement), and Line Status (the event for each sample stored in Event mode, see section 1.4.6.9).

1.4.4.3 Copying Values

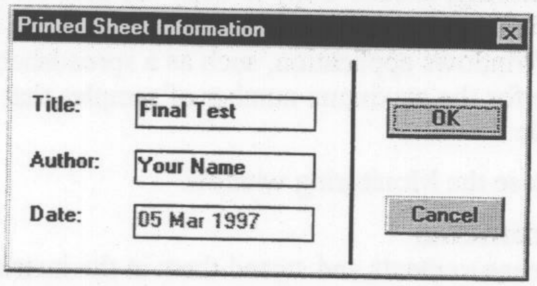
To copy this list of measurement results to the Windows Clipboard, so that this information can be "pasted" into a spreadsheet, word processor, or any other Windows program that accepts tabular text information, choose Export, Clipboard.

1.4.4.4 Saving Values

To save this list of measurements as a text (".txt") file, capable of being recalled by the WIN3660 program or imported as a text file into other Windows programs, choose File, Save as. A dialog box appears, with a space to fill in with an eight-letter name. (The program automatically attaches a ".txt" suffix to this file name.) If you have saved previous files, a "grayed-out" list of these names appears as well. Typical to Windows programs, "Directories" and "Drives" boxes can be used to locate other places to save (for example, on a floppy disk); you may also type the drive and directory directly into the dialog box when saving the file.

1.4.4.5 Printing Values

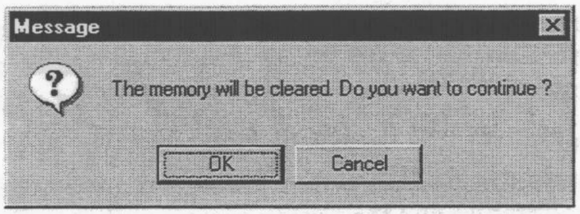
To place this list of measurements into a tabular format and send it to the Windows printer, choose the Print command from the File menu. The program asks you to enter optional "Title" and "Author" information as follows. Note that the "Date" is fixed by your operating system.



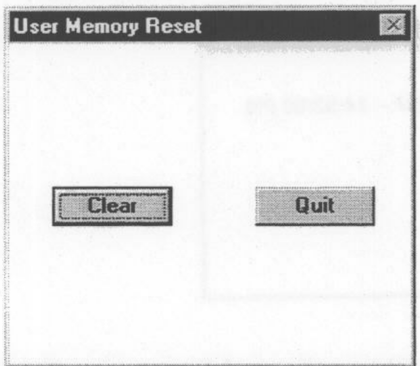
The resulting printout will include this information on each page.

1.4.4.6 Clearing Stored Values

To clear all the values stored in the instrument via the WIN3660 program, choose Logger, Clear data. Since this action will clear the storage memory of the instrument, a warning message appears first:



Choose OK to bring up the next dialog box to confirm the clear action:



Choose Clear to start the memory clear function in the instrument. A message is now displayed in this box stating "Reset in Progress … This takes about 35s." A message "Reset should be completed," appears at the bottom of this box when the reset is finished. Choose Quit to return to the WIN3660 menus.

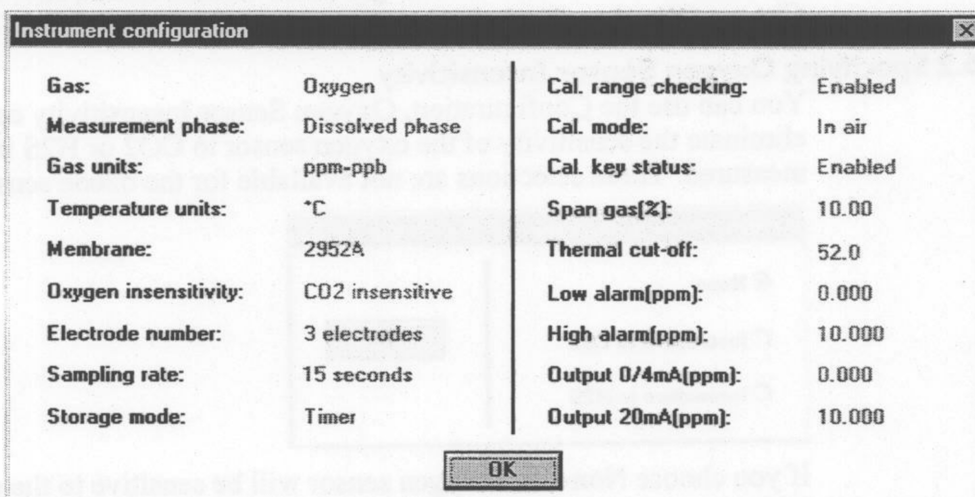
(Note that you can also accomplish the memory clear at the instrument, passively, by simply overwriting a set of stored values with new ones, see section 1.3.3.)

1.4.5 Reviewing Instrument Configuration

Two commands in the Configuration menu allow you to review the current configuration and calibration status of your 3660 instrument.

1.4.5.1 Instrument Configuration

Choose Configuration, Configuration View to verify if the analyzer has been set up as expected. You will see a window like the one illustrated below, listing the current instrument configuration.

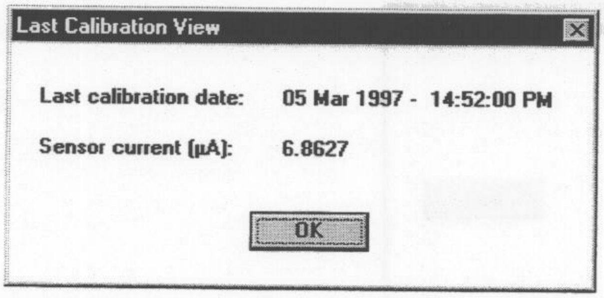


Many of these configuration items can be changed by the user, via the commands described in section 1.4.6. The type of gas being measured (Oxygen or Ozone) and the number of electrodes in the sensor (3 or 4 electrodes) cannot be changed via the WIN3660 program. Should you see any unexpected items listed on this display window, contact your Orbisphere representative.

Note: When you turn power on to your instrument, the factory-configured model number is displayed briefly. If you change the configuration of the instrument via the menus in section 1.4.6, the model number will not be displayed at power on.

1.4.5.2 Last Calibration Results

Use the Configuration, Last Calibration View command to display the date and time of the last calibration and the sensor current at that calibration. The values for this display are updated only after a successful calibration.

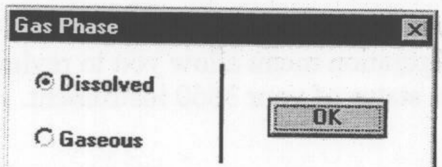


1.4.6 Configuring the Instrument

The 3660 analyzer can be readily configured for your application using the following commands in the Configuration menu. The instrument needs to be connected to your PC in order to change its configuration.

1.4.6.1 Liquid or Gaseous Sample Selection

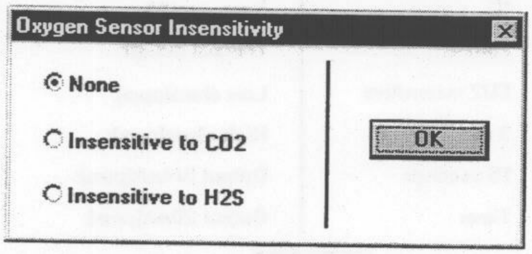
You can use the Configuration, Gas Phase command to establish the measurement phase (dissolved or gaseous) for the instrument. Ozone sensor measurements may only be made in dissolved phase.



Choose "Dissolved" to set the instrument for dissolved gas measurement in liquids. To set the instrument to gas phase measurement, choose "Gaseous". Choose OK when the desired measurement phase is selected.

1.4.6.2 Specifying Oxygen Sensor Insensitivity

You can use the Configuration, Oxygen Sensor Insensitivity command to eliminate the sensitivity of the oxygen sensor to CO2 or H2S in the sample being measured. These selections are not available for the ozone sensor.

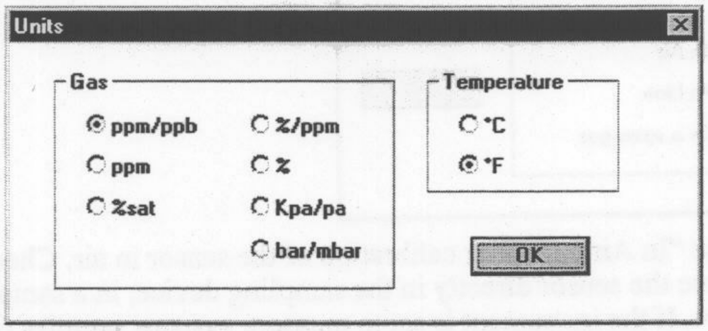


If you choose **None,** the oxygen sensor will be sensitive to the presence of CO2 or H2S in the sample. You may eliminate the sensitivity to either of these gases by selecting the appropriate entry, **Insensitive to CO2**, or **Insensitive to H2S**. Choose OK when the desired sensitivity is selected.

1.4.6.3 Setting Measurement Units

Choose Configuration, Units command to specify the measurement units for gas concentration and temperature. The selected units are used for the instrument LCD display and appear in all WIN3660 displays, printouts, and data copied or saved.

Ozone sensor gas concentration measurement units are limited to ppm/ppb or ppm.



The following choices are available:

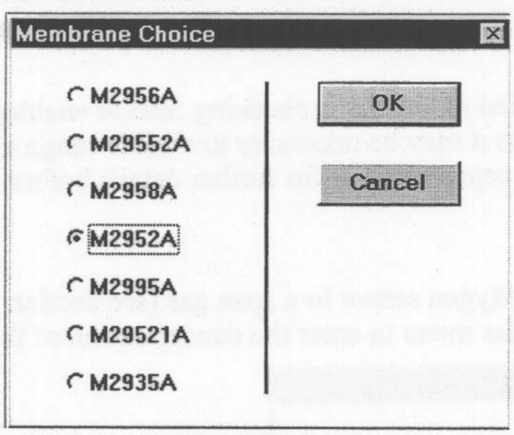
- Gas measurements in dissolved phase: ppm/ppb, ppm or %sat
- Gas measurements in gaseous phase: %/ppm, %, kpa/pa, or bar/mbar
- Temperature measurements: °C or °F.

If you choose "composite" units, such as ppm/ppb or %/ppm, the instrument display will automatically switch between the units (autoranging) when the measurement drops below the minimum value of the higher units (see section 1.3.2.2). Choose OK when the desired units for gas and temperature are selected.

1.4.6.4 Selecting Sensor Membrane

You may find it necessary to use a different type of membrane for different applications. Naturally, with any membrane change, you will need to recalibrate (see section 1.3.1); you should also consider the changes in required flow rates and response times, which are specified in section 2.

Choose the Configuration, Membrane command to review or change the membrane model selected for the oxygen or ozone sensor.

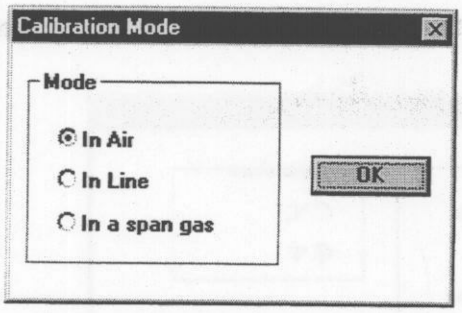


This menu gives a choice between several membranes. For an oxygen sensor, it is possible to select the following membranes: 2956A, 29552A, 2958A, 2952A, 2995A, 29521A,or 2935A. For an ozone sensor, you can select only two membranes: 2956A or 29552A — all other membranes are grayed out.

Choose OK when the desired membrane is selected. Choose Cancel to exit without changing the membrane model.

1.4.6.5 Selecting Calibration Mode

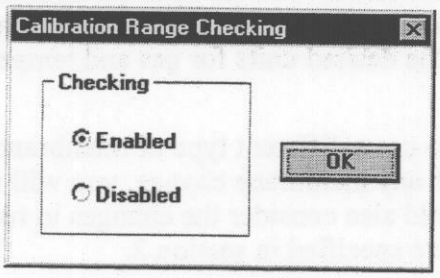
You can use the Configuration, Calibration Mode command to select whether the sensor is to be calibrated in air, directly in-line, or in a span gas. Span gas calibration cannot be selected for the ozone sensor.



Choose "In Air" to allow calibration of the sensor in air. Choose "In Line" to calibrate the sensor directly in the sampling device, in a sample of known gas content. If the instrument is set to measure gaseous samples (section 1.4.6.1), you may select "In a Span Gas". Click OK when the desired mode is selected.

1.4.6.6 Calibration Range Checking

When calibration is performed, the sensor current is compared to an ideal current to determine whether or not to complete the calibration, as detailed in section 1.3.1. You can use the Configuration, Calibration Range Checking command to enable or disable this calibration range checking for "In Air" and "In a Span Gas" calibration modes (see section 1.4.6.5.above).

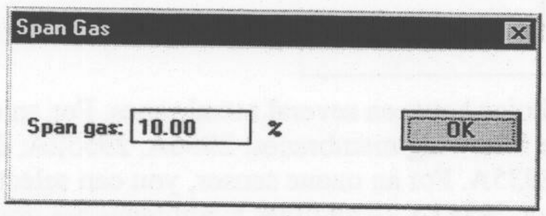


If range checking is **Enabled**, at calibration the measurement current should be between 25 and 175% of the ideal current calculated by the instrument. If range checking is **Disabled**, there is no limitation. Choose OK when the desired type of checking is selected.

Note: It is recommended to leave this checking feature enabled. In special measurement situations it may be necessary to disable range checking; however, contact an Orbisphere representative for further details before disabling this feature.

1.4.6.7 Entering Span Gas Value

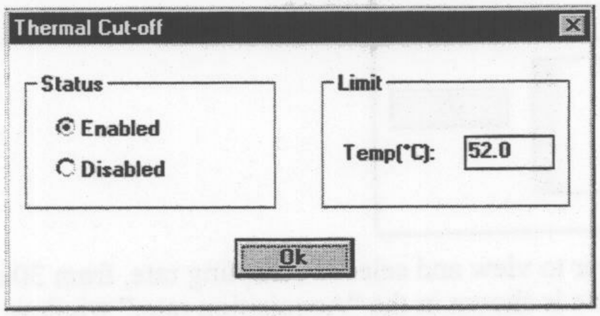
When calibrating the oxygen sensor in a span gas (see section 1.3.1.3), use the Configuration, Span Gas menu to enter the concentration of the span gas.



Enter the percentage of oxygen in the span gas (for example, 10.00%), then choose OK when the value is entered as desired.

1.4.6.8 Setting Thermal Cut-off

A user-adjustable thermal cut-off feature lets you set a temperature limit above which the analyzer will be switched off. This feature protects the sensor should the sample temperature go beyond the temperature compensated range of the sensor, and alerts the user via the display, analog, and digital outputs. (See Thermal Cut-off, section 1.3.2.1.) To set the sample temperature limit choose Configuration, Thermal cut-off, to bring up this dialog box.

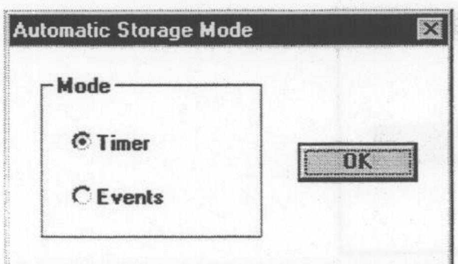


Use this box to enable or disable the thermal cut-off feature and to enter the temperature limit. If **Enabled,** when the sample temperature exceeds this limit, the instrument switches off the sensor. If **Disabled** is selected, there is no sensor current cut-off. Choose Ok when the status and temperature are set as desired.

After a thermal cut-off, the instrument restores the current supply to the sensor when the sample temperature falls 2.5°C/°F *below* the specified cut-off value.

1.4.6.9 Automatic Data Acquisition — setting storage mode

The instrument can operate as a standalone data recorder, automatically recording gas and temperature measurements and storing up to 500 of these values (see automatic data acquisition, section 1.3.3.2). Choose the Configuration, Automatic Storage Mode command to select the mode for this storage.



If **Timer** mode is selected, measurements are stored at intervals defined by the Sampling Rate command, section 1.4.6.10 below.

If **Events** mode is selected, one measurement is stored when an event occurs, for each of the following events:

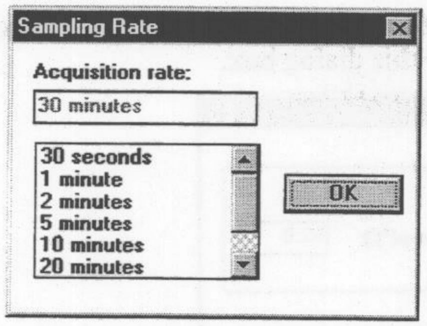
- Power On
- Sensor Out
- Thermal Cut-off
- Alarm High
- Alarm Low

The type of event is also recorded in the Line Status column of the data display for that event (see Download Data, section 1.4.4.1). When the event ends, such as sensor plugged back into the instrument or alarm condition ending, the event "Normal Measurement" occurs and a measurement is stored.

Choose OK when the desired mode is selected.

1.4.6.10 Automatic Data Acquisition — setting sampling interval

Choose the Configuration, Sampling Rate command to select the time interval (Acquisition rate) for the automatic storage capability. This rate is used when automatic storage mode is set to Timer, see section 1.4.6.9 above.

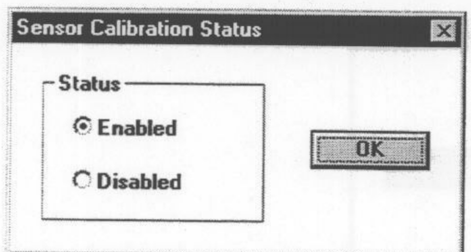


Use the slide bar to view and select a sampling rate, from 30 seconds to 1 hour. The selected rate is shown in the "Acquisition rate:" window. Click OK to save this rate. Once your choice is made, the instrument can be used independently of the WIN3660 program for automatic data acquisition, as described in section 1.3.3.2 above.

Note: The Acquisition rate set via this menu is independent from the Monitoring chart updating rate described in section 1.4.3. The Sampling rate menu applies only to automatic data acquisition mode, section 1.3.3.2, while the chart updating rate is used only for displaying real-time results via the WIN3660 program Monitoring chart.

1.4.6.11 Locking Out the "CAL" Button

You can use the Configuration, Calibration Key Status command to prevent an accidental sensor recalibration via the instrument front panel.

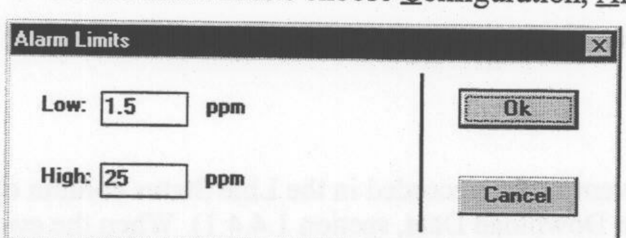


Choosing "Disable" will lock out the "CAL" button on the instrument front panel. To unlock this capability, choose "Enable". Click OK when the desired status is selected.

1.4.6.12 Setting Alarm Limits

You may find it necessary to reconfigure the gas concentration low and high limits for an alarm condition. See section 1.3.2.4 for description of the alarm conditions.

To set the alarm limits choose Configuration, Alarms, to bring up this dialog box.



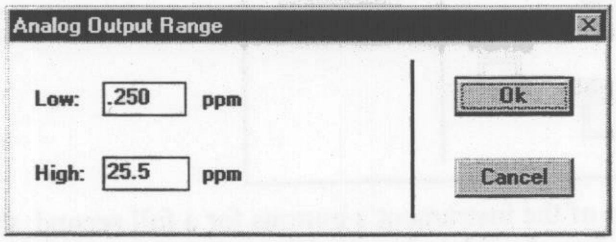
Enter the High and Low concentration limits for your application. Choose Ok to save the new limits, or Cancel to exit without saving the new values.

When the measured gas concentration exceeds the high limit or falls below the low limit, an alarm is signaled from the instrument alarm output connections. After a High or Low alarm condition is signaled, the instrument clears the High alarm when the gas concentration drops to 1% below the high limit, or clears the Low alarm when the concentration rises to 1% above the low limit.

1.4.6.13 Setting Analog Output Limits

Use this command to specify the range of the analog output from the instrument. See section 1.3.2.3 for description of the analog output signal.

To set the analog output limits choose Configuration, Analog output, to bring up this dialog box.



Enter a Low and High gas concentration value to specify the limits for the analog output. Set these limits to rescale the instrument analog output, corresponding to 0–20 mA or 4–20 mA, for use with peripheral equipment, such as a recorder or plotter. Choose Ok to save the new limits, or Cancel to exit without saving the new values.

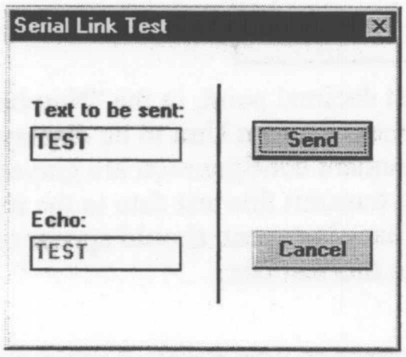
1.4.7 Program Troubleshooting

If your analyzer is behaving improperly — failing to calibrate, giving inappropriate measurement values, etc. — and you have attempted to rectify the problem by servicing the sensor (section 1.5) to no avail, you may wish to use the Troubleshooting menu to make sure that the instrument is configured correctly for your application, and is in good working order.

The instrument needs to be connected to your PC, and in measurement mode in order to perform these tests.

1.4.7.1 Serial Link Test

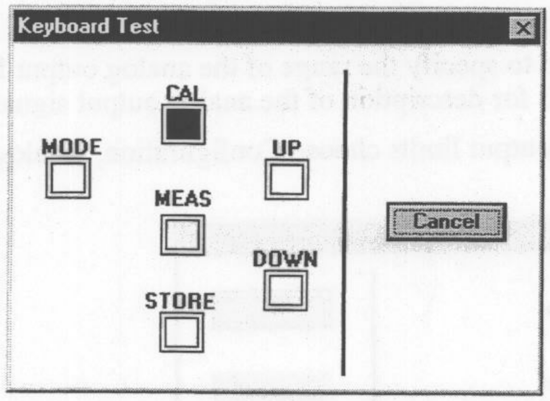
Normally, the instrument will inform you of a disconnected RS-232 or RS-422 (serial) link when appropriate. However, you can confirm a good connection with the Serial Link Test by "echoing" a test message via the instrument.



Enter text characters in the "Text to be sent:" box, then click Send. If the serial link is operating correctly, the same text will be displayed back from the instrument in the "Echo:" box. Click Cancel to exit from this test box.

1.4.7.2 Keyboard Test

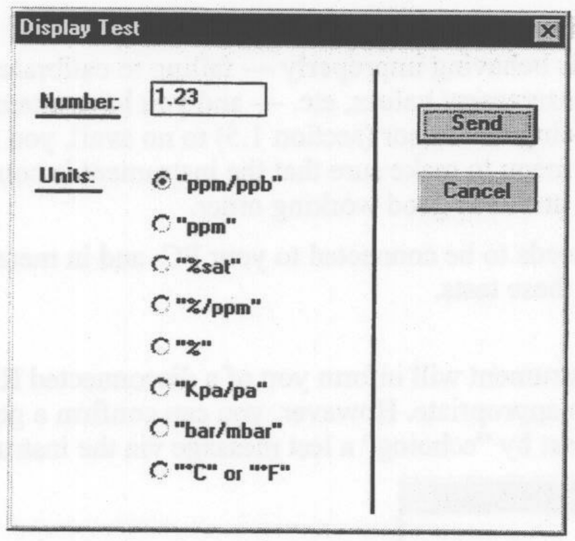
Choose Keyboard Test from the Troubleshooting menu to verify whether all the instrument buttons are functioning correctly. The following dialog box is displayed to test the instrument keyboard.



Press any one of the instrument's buttons for a full second; the associated square on the dialog box should darken (as illustrated above for the "CAL" button). Click Cancel to exit from this test box.

1.4.7.3 Display Test

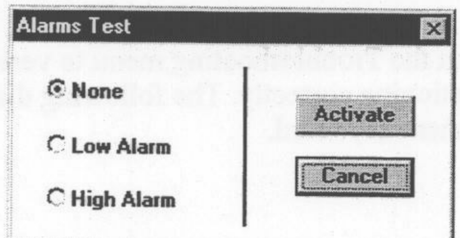
Choose the Display test command to verify the LCD display on the instrument. the following dialog box is displayed to test the instrument LCD.



Type a number, with or without decimal point, in the "Number:" box, as illustrated above, and select a measurement Unit to be displayed (units that cannot be selected because of the instrument configuration are grayed and cannot be selected). Then choose Send to transmit this test data to the instrument. The number entered, and indicator bar placement, should appear on the instrument LCD. Click Cancel to exit from this test box.

1.4.7.4 Alarms Test

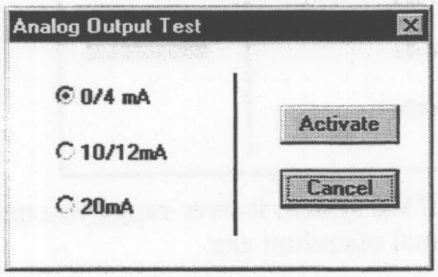
When connecting the Alarm outputs to user-supplied equipment, it may be helpful to verify the connections with a test output from the instrument. Choose the Alarms Test command to test the high and low alarm limit relays. The following dialog box allows testing of the instrument's alarm relay connections.



Choose **Low Alarm** to test the Low Alarm relay or choose **High Alarm** to test the High Alarm relay, then click on Activate. The selected alarm relay is activated and the associated output card alarm contacts provide a test output (see Alarm Relay Conditions table in section 1.4.6.12). Choose **None**, then click on Activate to verify that the alarm contacts are set for "No alarm" condition. Click Cancel to reset any relay activated and exit from this test box.

1.4.7.5 Analog Output Test

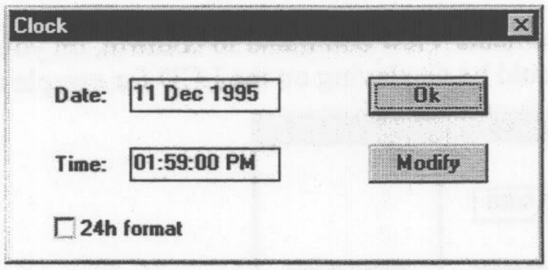
Choose the Analog Output Test command to test the analog output of the instrument. When this command is selected, an output test may be performed at the instrument's analog output connections.



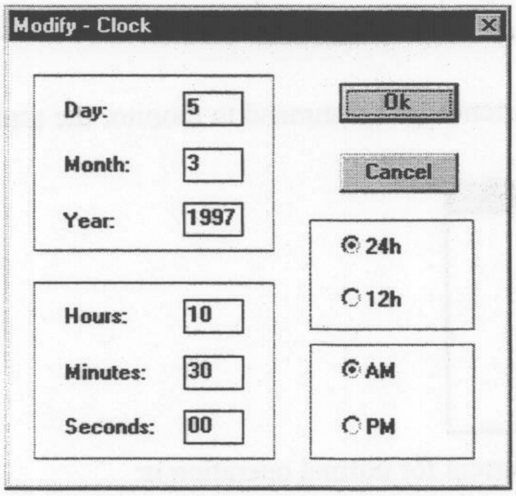
Choose **0/4 mA, 10/12 mA** or **20 mA** to select the analog level for the output test. Then click on Activate to apply the selected current level to the analog output pins. Click Cancel to remove the selected current from the output pins and exit from this test box.

1.4.7.6 Clock Settings

Choose the Clock Settings command to set the instrument's date and time.



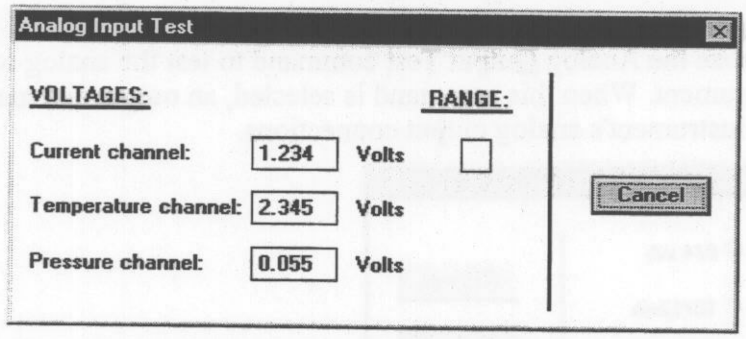
The first screen displays the current date and time set in the instrument. If this is correct, choose Ok; if either date or time must be changed, choose Modify to bring up the next screen.



Enter the current date and time and choose Ok to store the entry into the instrument. All measurements will be noted with the appropriate date and time when they are downloaded to the WIN3660 program.

1.4.7.7 Analog Voltages View

The Analog Voltages View command gives a real-time look at voltages used by the sensors to transmit information about current, temperature, and pressure to the instrument. This is useful when trying to identify an instrument or sensor problem.



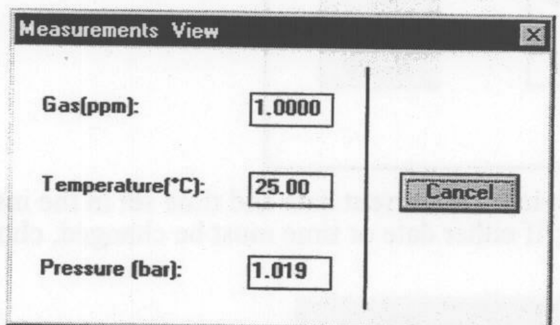
When performing this test, if the system is over-range you may receive a warning message. The limits for normal operation are:

- Current channel: 0 to +1.5 V
- Temperature channel: +10 mV to +4 V
- Pressure channel: -100mV to +100mV

The Range window on the right side of the Current channel voltage indicates one of the four instrument ranges: 0 (less sensitive) to 3 (most sensitive).

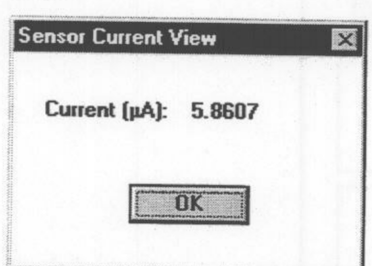
1.4.7.8 Measurements View

Choose the Measurements View command to confirm, on your PC monitor, what your instrument should be displaying on the LCD for sample measurements.



1.4.7.9 Sensor Current View

Choose the Sensor Current View command to monitor the sensor current, in real time.



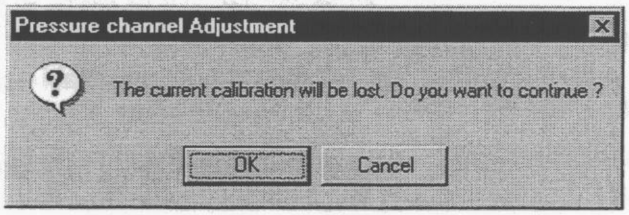
The expected sensor current for normal operation is:

- Oxygen sensor (2952A membrane): 27 µA (8.1 to 45.9 µA)
- Ozone sensor (2956A membrane): 115 µA (34.5 µA to 195.5 µA)
- Ozone sensor (29552A membrane): 25 µA (7.5 µA to 42.5 µA)

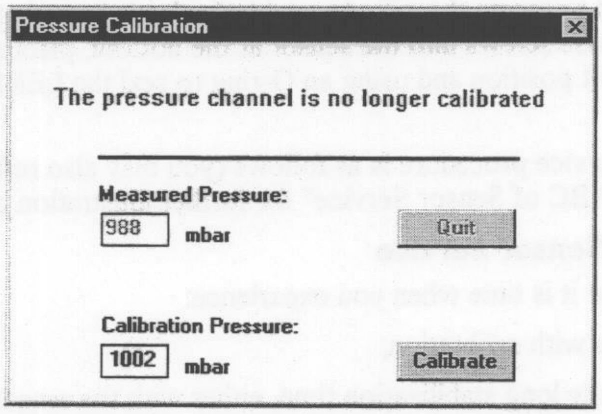
Note: Actual current should not exceed 35 µA for oxygen sensors.

1.4.7.10 Pressure Calibration

If you have access to an accurate barometer, you may wish to calibrate the instrument's internal barometric pressure sensor. Choose Pressure Calibration to start the calibration procedure. A warning message is displayed first.



Choose OK to continue. The calibration procedure then displays a Pressure Calibration dialog box. The Measured Pressure value shows the current instrument pressure reading.



Enter the current atmospheric pressure, in mbars, in the Calibration Pressure entry box. Choose Calibrate to direct the instrument to read and display the Measured Pressure using this calibration value. Choose Quit when you are satisfied with the pressure calibration to return to normal operation.

1.5 Maintenance (sensor service)

***Important Note:** The sensor service procedures described in this section (incorporating 1.5.1 through 1.5.9) are to be disregarded by those who have contracted a "Sensor Rental" program offered by some Orbisphere offices.*

Normally, only the oxygen or ozone sensor requires service. If the indicating instrument is properly connected, handled with reasonable care, and kept clean, it should give you no mechanical or electrical problems.

For the sensor, membrane wear and chemical reactions require that a specific maintenance procedure should be performed from time to time. We cannot dictate a specific maintenance schedule for your application, since operating conditions can vary considerably. But experience should make the intervals apparent, using the guidelines below.

You will need to locate the cylindrical, black plastic base that is supplied with the sensor. The base screws into the sensor at the bottom, placing the sensor in a secure, upright position and using an O-ring to seal the LEMO-10 connector from moisture.

The sensor service procedure is as follows (you may also refer to the Orbisphere poster "The ABC of Sensor Service" for further illustration of this procedure).

1.5.1 When to Perform a Sensor Service

You will know it is time when you experience:

- difficulties with calibration,
- an unusually long stabilization time, either with the sensor exposed to an air-saturated medium or to changing gas concentration conditions, or
- "noisy" or drifting signals under what you believe to be constant gas concentration conditions.

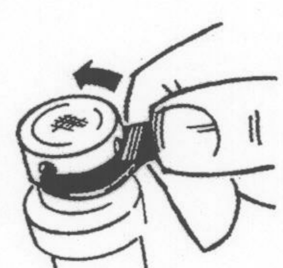
1.5.2 Remove Sensor from Sample

Remove the sensor cable by unscrewing the LEMO connector at the end of the sensor handle. Then hold the sensor handle in one hand, and carefully unscrew the collar and pull the sensor out of its socket or out of the flow chamber. When a sensor is to be removed from a flow chamber or sensor socket, take care that no hazard will be created by the sensor's absence. (In particular, when using a sensor socket to measure in liquid samples, make sure to drain all liquid from the pipe.)

Place the sensor in its plastic base, screwing it down securely but not tight enough to strip the plastic threads. An O-ring in the base provides a watertight seal for the sensor's LEMO-10 connector.

1.5.3 Prepare Sensor for Cleaning

Carefully unscrew the protection cap, using the metal tool supplied with your recharge kit. Take care not to lose the grill and washers inside. The protection cap includes washers, and for some applications, a Dacron mesh and a stainless steel grill — if you are unfamiliar with these components, check the exploded sensor diagram in section 1.6.1 or on the ABC poster.



Removing protection cap

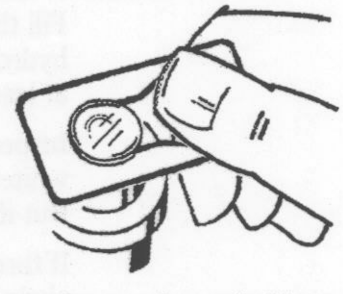
You may want to check back to the sensor diagram in section 1.2, and note the order of sensor head components shown:

- Membrane holding ring;
- Membrane; and

- The sensor's membrane support.

(The sensor mask may be installed as well.)

Pry off the membrane holding ring either with your fingers or, if the ring has a wide outer groove, with the model 28116 tool included with your recharge kit.

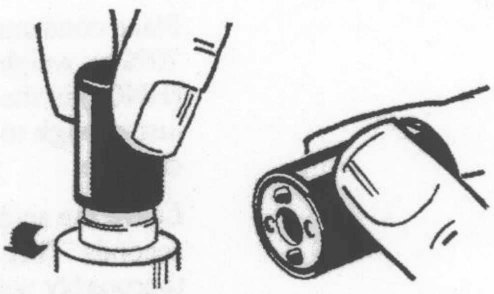


Removing membrane holding ring

Take care to avoid contact with the electrolyte in the sensor. It can irritate skin, so rinse hands with plenty of tap water during this procedure. Note too that the electrolyte can permanently stain clothing, so exercise care in handling.

Throw out the membrane (and mask, if applicable), keep the holding ring, and shake out any electrolyte.

Using the membrane support tool, match up the prongs of the tool to two of the holes in the membrane support. Turn counterclockwise to remove this support. Note: Each membrane support is individually machined at the factory to match its sensor. It is *ESSENTIAL* when servicing several sensors at a time to keep the appropriate membrane support matched to its respective sensor.



Using membrane support tool to remove membrane support

Rinse the membrane support with water. If discolored, you may elect to clean it with concentrated (approximately 70% by weight, *but no stronger*) nitric acid (HNO_3) for about 30 seconds, rinsing with water after the process is completed. The discoloration does not affect performance, but cleaning permits better viewing of the sensor.

> **WARNING: Nitric acid is dangerous!** Should your skin come into contact with nitric acid, wash immediately and thoroughly with water.

Empty and rinse the electrolyte reservoir with water.

1.5.4 Electrochemical Cleaning

The optional model 32301 Sensor Cleaning and Regeneration Center employs an electrochemical cleaning technique. This method reverses any chemical reactions that take place in the sensor during normal operation, and easily removes the electrode deposits that reduce sensor efficiency. The cleaning center also allows a check of the sensor's electronics to verify that the system is working correctly. See the model 32301 operator's manual for instructions on its proper use. Note that the plastic base supplied with the sensor must be removed to use the 32301 cleaning center.

Or, you may use the chemical cleaning and polishing method described in the following section. This method also works efficiently as a preliminary approach to the cleaning center's electrochemical cleaning procedure.

1.5.5 Chemical Cleaning

Depending on the appearance of the sensor electrodes you can try either of the following two cleaning procedures, ammonia or nitric acid cleaning. If the electrodes appear fairly clean and bright, try the ammonia cleaning procedure; if very dirty or discolored, use the nitric acid cleaning procedure.

Note: If the following procedures are not closely adhered to, there is a risk of shortening your sensor's useful life.

1.5.5.1 Ammonia Cleaning Procedure

Fill the sensor electrolyte reservoir with a solution of 25% by weight ammonium hydroxide (NH_4OH) in water and leave for 10 minutes. Then rinse with water for at least one minute.

Inspect the sensor head. The counter electrode (anode) should be a uniform, silver-white color. If it is clean, rinse the electrolyte reservoir with water for a full minute. But if the sensor head is still discolored, repeat the above procedure.

If three consecutive cleanings do not produce the desired result, you should use the nitric acid cleaning procedure described below.

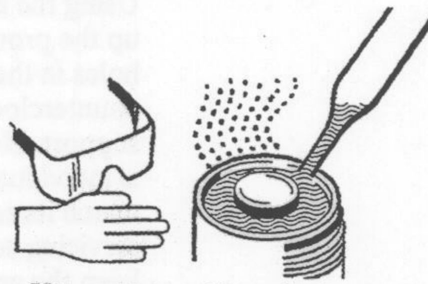
1.5.5.2 Nitric Acid Cleaning Procedure

Rinse out the sensor head with water and proceed as follows.

Place concentrated (up to approximately 70% by weight, *but no stronger*) nitric acid (HNO_3) in the sensor electrolyte reservoir, just enough to cover the anode only, not the cathode.

Leave the acid in place for **no longer** than 5 seconds. Then empty out the acid and rinse thoroughly with water.

If the anode is still not completely clean, alternate between nitric acid and ammonium hydroxide cleanings.



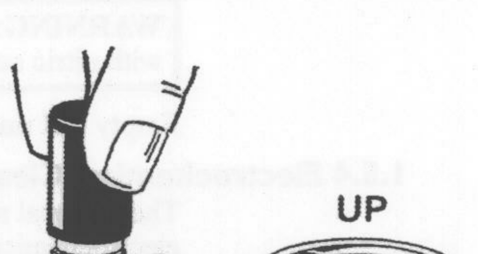
Using nitric acid to clean sensor electrode
*Note: **Always use protective gloves and goggles!***

> **WARNING:** Nitric acid is dangerous! **Should your skin come into contact with nitric acid, wash immediately and thoroughly with water.**

1.5.6 Polish Sensor Face

After cleaning, screw on the membrane support, "finger tight," using its mounting tool. (Note: The support has one smooth side with a groove, and one side that is raised in the center, as shown. *Make sure the smooth side with a groove faces out* when installed.)

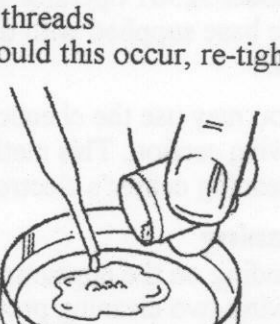
Because there is a danger of over tightening the plastic threads, the sensor has a safety feature that causes the membrane support to "skip" its threads harmlessly if over tightened. Should this occur, re-tighten with less force.



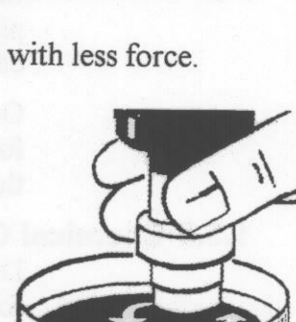
Tightening membrane support (note proper orientation, grooved side "up")

Place the polishing cloth in its dish on a flat surface and shake a little polishing powder onto the cloth, adding enough clean water to make a loose, watery mixture.

Holding the sensor vertically, and using a circular motion, polish



Mixing polishing powder and water on polishing cloth

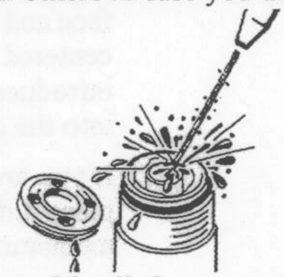


Polishing sensor with circular motion

the sensor face for at least 30 seconds, until the gold cathode is clean and shiny. (This step may need to be repeated several times.) Make sure to avoid skin contact with the polishing cloth; it should be kept free of dust and grease.

Remove the membrane support with its tool, as shown above in section 1.5.3 (taking care not to mix the membrane support with others in case you are servicing several sensors at once). Thoroughly rinse the membrane support and the sensor to remove all traces of polishing powder.

Inspect the groove between the gold cathode and the guard ring electrode for polishing powder deposits. You may want to rinse away these deposits with a strong jet of distilled water.



Using a jet of distilled water to clean groove between cathode and guard ring electrode

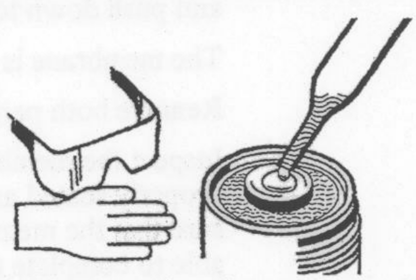
1.5.7 Final Electrode Cleaning (ozone sensor only)

Once the ozone sensor has been thoroughly cleaned, alternating if necessary between ammonia and nitric treatments (or electrochemical treatments, if you are using a model 32301 cleaning center), and the sensor face has been polished, a final nitric acid treatment should be applied, as follows.

Put a few drops of water in the sensor electrolyte reservoir, just enough to cover the anode only, not the cathode. The gold cathode must be completely dry.

Keeping the sensor on its base and vertical, place a few drops of nitric acid onto the gold cathode, sufficient to cover only the cathode and its guard ring. Avoid adding enough nitric acid so that it spills onto the anode as well.

Wait about 5 seconds, then rinse thoroughly with water.



Using nitric acid to clean sensor cathode
*Note: **Always use protective gloves and goggles!***

> **WARNING:** Nitric acid is dangerous! **Should your skin come into contact with nitric acid, wash immediately and thoroughly with water.**

1.5.8 Replace Membrane

Replace the membrane support with its tool — remember, only "finger tight" — and make sure that the side with a groove faces out when installed.

Fill the sensor head with electrolyte (*note: use model 2959 electrolyte for oxygen sensors, model 2969 electrolyte for ozone sensors*) through the membrane support, using the syringe from your recharge kit. It helps to tilt the sensor slightly, filling the head from the lowest of the four holes facing you. Do this slowly, forcing the air out through the top hole.

Continue filling the reservoir, returning the sensor to vertical, until an overflow of electrolyte adheres to the surface of the sensor face.

Filling with electrolyte

Take out the black plastic membrane mounting tool included with your recharge kit. You will note that the tool is in two parts, a plunger and a hollow, cylindrical guide.

Place the mounting tool's cylindrical guide over the sensor head, around the sensing face so that it rests on the sensor's shoulder.

Place a membrane on the sensor face and check that it lies flat and is centered. To avoid air bubbles, introduce the membrane at an angle into the guide.

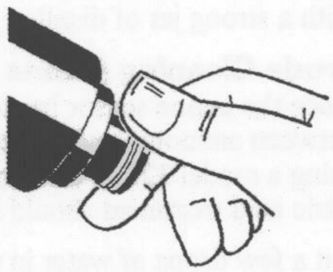
Placing guide on sensor

Placing membrane on sensor face

If you are using a sensor mask, place it directly on top of the membrane, in the guide.

Now, pick up the mounting tool's plunger. Slide your membrane holding ring onto the beveled edge of the plunger.

Insert the plunger, with holding ring, into the open hole of the guide, and push down to a stop.



Placing membrane holding ring on plunger

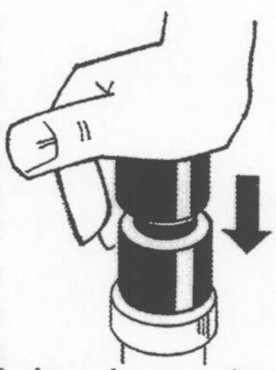
Inserting plunger into guide

The membrane is mounted.

Remove both parts of the membrane mounting tool.

Inspect the membrane holding ring to be sure that it's properly seated and pushed in all the way, and make sure that the membrane is smooth. If not, you may be able to complete the process by pushing down with your fingers. If this does not work, replace the membrane.

Note that the O-ring that forms a seal between holding ring and sensor should be replaced if the holding ring turns easily.



Pushing plunger to finish membrane mounting.

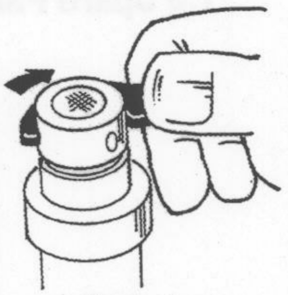
Check that there are no air bubbles beneath the surface of the membrane. If there are, you must replace the membrane.

Wash excess electrolyte off the sensor and wipe dry. Then unscrew the black plastic base, taking care not to get the sensor's LEMO-10 connector wet.

1.5.9 Put Sensor Back into Service

Re-connect the sensor to its cable, by screwing in the cable's connector to the rear of the sensor.

Then replace the screw-on protection cap. The protection cap may include washers only, or it may include Dacron mesh or a water separation filter, and a stainless steel grille. *Please check that these components are clean and dry before installation.* If you are unfamiliar with these components' assembly order, check the diagram shown in this manual's section 1.6.1.



Replacing protection cap

The protection cap should be tightened finger tight, and then secured with an extra 1/8 to 1/4 turn with its metal wrench, included with your recharge kit.

After giving the membrane at least 30 minutes to relax, calibrate the system (see section 1.3).

Once the sensor has been calibrated, place the sensor back into the sample, using its collar to secure it into place if appropriate. Your sensor should be ready to begin making measurements.

1.6 Spare Parts

The following is a listing of materials you may require to maintain your analyzer. Be sure to mention the model number and item description when ordering. Note that an exploded sensor and protection cap diagram follows.

Model Number	Item Description
28113	Membrane mounting tool
28114	Tool for removing membrane support
28116	Tool for removing membrane holding ring
29501	Sensor socket
2959	Electrolyte for oxygen sensors (50 ml)
2969	Electrolyte for ozone sensors (50 ml)
2978	Polishing powder and cloth
311xx.xx	Oxygen sensor
313xx.xx	Ozone sensor
32001.xxx	Flow chamber
32003	ProAcc insertion/extraction valve
32301	Electrochemical Sensor Cleaning and Regeneration Center
32502.03	Sensor cable, 2 LEMO-10 connectors (length, 3 meters)
32541.mm	Cable for RS-232 data link, LEMO-10 and D-type 9-pin connectors ("mm" = length, standard length 3 meters)
32542.mmm	Cable for RS-422 data link, LEMO-10 and D-type 9-pin connectors ("mmm" = length, standard length 10 meters)
32502.mm	Sensor cable, 2 LEMO-10 connectors ("mm" = length, standard length 3 meters)
32685	WIN3660 Windows program software (on floppy disk)
32906	PC COM port board for RS-422

Recharge Kits:

Recharge kits include membranes, electrolyte, membrane holding ring, and tools required to service the sensor.

For Oxygen Sensor:

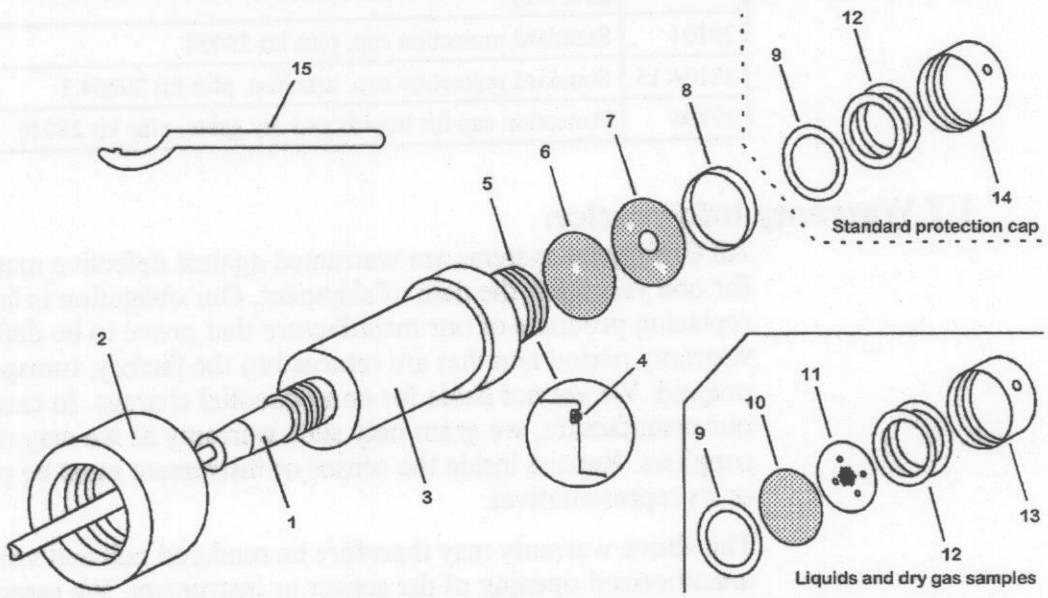
32701	2935A membranes, 29228 holding ring, 2959 electrolyte
32702	2952A membranes, 29228 holding ring, 2959 electrolyte
32703	2956A membranes, 29228 holding ring, 2959 electrolyte
32704	2958A membranes, 29228 holding ring, 2959 electrolyte
32705	29521A membranes, 29231 holding ring, 2959 electrolyte
32706	29522A membranes, 29229 holding ring, 2959 electrolyte
32707	2995A membranes, 29228 holding ring, 2959 electrolyte
32711	2935A membranes, 29026A mask, 29229 holding ring, 2959 electrolyte
32712	2952A membranes, 29026A mask, 29229 holding ring, 2959 electrolyte
32713	2956A membranes, 29026A mask, 29229 holding ring, 2959 electrolyte
32714	2958A membranes, 29026A mask, 29229 holding ring, 2959 electrolyte
32717	2995A membranes, 29026A mask, 29229 holding ring, 2959 electrolyte

For Ozone Sensor:

32731	2956A membranes, 29027A mask, 29229.05 holding ring, 2969 electrolyte
32732	29552A membranes, 29027A mask, 29229.05 holding ring, 2969 electrolyte

1.6.1 Sensor and Protection Cap Diagram

All sensors are supplied with a screw-on protection cap. The standard protection cap, model 29104, improves the sensor's membrane sealing. the model 29106 protection cap, for "Liquids and Dry Gas Samples," also includes a stainless steel grill and a Dacron mesh. The grill prevents the membrane from lifting under such harsh conditions as measuring in carbonated samples or high sample pressures.



Model 311xx or 313xx sensor, exploded view, with protection cap components.

Position	311xx (O_2) Reorder #	313xx (O_3) Reorder #	Description
1			LEMO-10 connector, sensor cable
2	28104		Sensor collar
3			Sensor handle
4	29039.0	29039.1	EPDM sensor head O-ring Viton sensor head O-ring
5			Sensor head
6	2956A, 29552A, 2958A, 2952A, 2995A, 29521A, or 2935A	2956A or 29552A	Membranes (25 pcs) (model depends on application)
7	29026A	29027A	Tedlar masks (25 pcs) Saran masks (25 pcs)
8	29228 29229 29231	29229.05	Membrane holding ring for membranes 2956A, 2958A, 2952A, 2995A, 2935A Membrane holding ring for membrane 29552A, or for combination of a mask and membranes 2956A, 2958A, 2952A, 2995A, 2935A Membrane holding ring for membrane 29521A
9	28003	28003 28508.1	Silicone washers (3 pcs) Viton washers (3 pcs)
10	29049		Dacron mesh (10 pcs)
11	29060		0.20 mm grill
12	28002		Tefzel washers (6 pcs)
13	29106		Protection cap kit for liquids and dry gases
14	29104	29104.15	Standard protection cap kit
15	28504		Wrench for protection cap

(Note that the Tefzel washers are clearer and thinner than the Silicone washers, and twice as many Tefzel washers are supplied in a kit.)

Protection Caps and Kits:

29046	Gaskets, grill, meshes, washers, and O-ring for protection cap 29106 (28002, 29060, 29049, 28003, 29039.0)
29054	Gaskets, washers, and O-ring for protection cap 29104 (28002, 28003, 29039.0)
29054.1	Gaskets, washers, and O-ring for protection cap 29104.15 (28002, 28508.1, 29039.1)
29104	Standard protection cap, plus kit 29054
29104.15	Standard protection cap, titanium, plus kit 29054.1
29106	Protection cap for liquids and dry gases, plus kit 29046

1.7 Warranty Information

All Orbisphere systems are warranted against defective materials and workmanship for one year from the date of shipment. Our obligation is limited to repairing or replacing products of our manufacture that prove to be defective during the warranty period and that are returned to the factory, transportation charges prepaid. We are not liable for consequential charges. In case of components not of our manufacture, we grant only such warranty as we may receive from our suppliers. Repairs inside the sensor or instrument must be performed by Orbisphere or its representatives.

The above warranty may therefore be rendered null and void in the event of unauthorized opening of the sensor or instrument. We reserve the right to make improvements to our products at any time without incurring any liability to purchasers of earlier models.

1.7.1 About this Manual

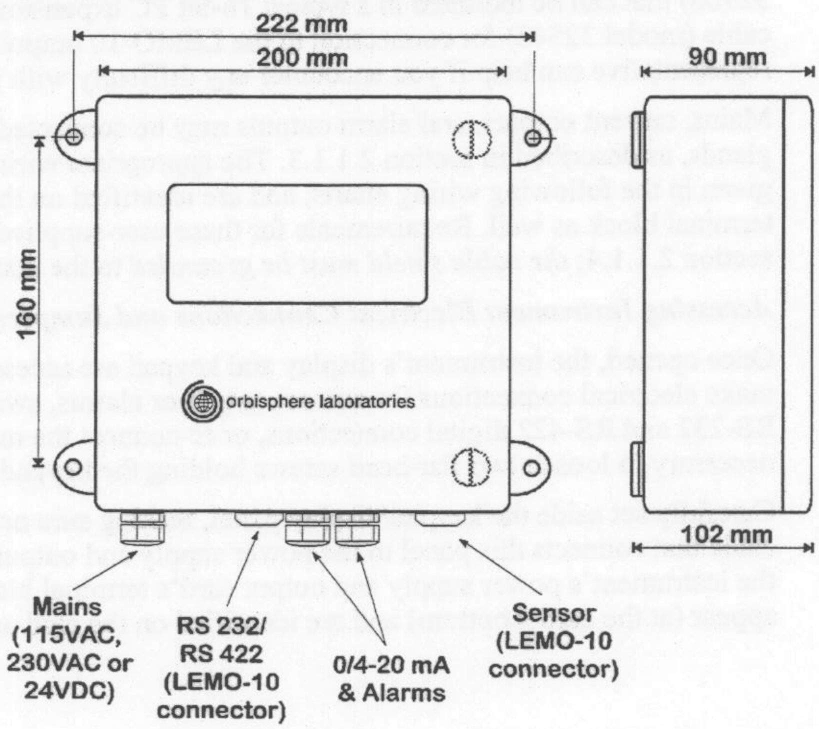
The information in this manual has been carefully checked and is believed to be accurate. However, Orbisphere Laboratories assumes no responsibility for any inaccuracies that may be contained in this manual. In no event will Orbisphere Laboratories be liable for direct, indirect, special, incidental, or consequential damages resulting from any defect or omission in this manual, even if advised of the possibility of such damages. In the interest of continued product development, Orbisphere Laboratories reserves the right to make improvements in this manual and the products it describes at any time, without notice or obligation.

2. Installation Guidelines

This section should provide you with all the necessary information to prepare for and install your 3660 Analyzer. Note that additional technical information is included in section 3. If you still have any questions or encounter any difficulties, contact your Orbisphere representative.

2.1 Instrument Installation

The instrument enclosure is typically surface mounted, either to a wall or a panel, by means of four attachment points. The dimensions for the enclosure and the spacing for the attachments are given as follows:



Note that the instrument is hinged at its left side and that a minimum of 200 mm front panel clearance is required to open completely. The front panel is secured shut by two flat-head screws. It will be necessary to open this panel to operate the instrument's keypad and mechanical on/off mains switch.

Also, four possible connection points, for mains, instrument-to-PC serial port, analog and alarm outputs, and oxygen or ozone sensor, are at the instrument's bottom; an additional 150 mm must be permitted for cable access.

2.1.1 Indicating Instrument Electrical Connections

The installation of a 3660 instrument should only be performed by personnel specialized and authorized to work on electrical installations, in accordance with relevant European and/or national regulations.

In accordance with safety standard EN 61010-1, it must be possible to disconnect the power supply of a 3660 instrument in its immediate vicinity.

A power supply cable, type H05VV-F 3 X 0.75 mm^2, must be used. The length of the cable should be three meters maximum and it should have a separable plug (with three connectors, L+N+PE), without a locking device, to mate with a socket outlet in the building. The cable and the plug must conform to an appropriate European standard.

Both sensor and PC connections are made via pre-wired LEMO-10 connectors, which snap in and out of their respective instrument receptacles. These connectors are keyed so that they cannot be inadvertently switched. Wiring identification for these connectors is described in sections 2.1.1.1 and 2.1.1.2.

For instrument-to-PC connections of 12 meters or less, an RS-232 cable is adequate. However, if the distance between the two is greater, it will be necessary to use an RS-422 connection, which can run as long as 1 kilometers without any loss in signal sensitivity. The instrument is easily converted to provide this type of digital output, as described in section 2.1.2.

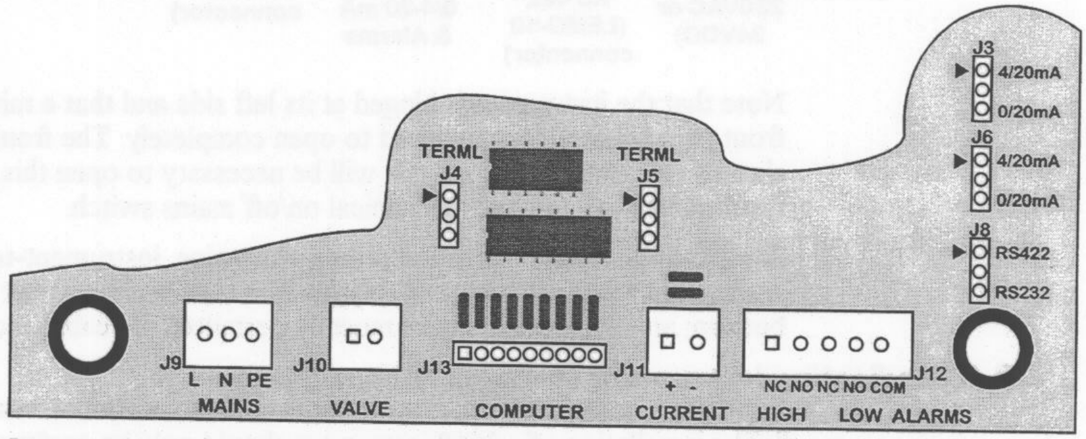
If using the RS-422 connection, it is likely your PC will require a separate communications port for this purpose. Orbisphere can supply a card (model 32906) that can be mounted in a typical 16-bit PC expansion slot, and a mating cable (model 32542) for connection to the LEMO-10 output. Your Orbisphere representative can help if you encounter any difficulty with your connection.

Mains, current outputs, and alarm outputs may be connected via waterproof glands, as described in section 2.1.1.3. The appropriate wiring identifications are given in the following wiring charts, and are identified on the power supply card terminal block as well. Requirements for these user-supplied cables are given in section 2.1.1.4; *the cable shield must be grounded* to the instrument case.

Accessing Instrument Electrical Connections and Jumpers

Once opened, the instrument's display and keypad are accessible. If you need to make electrical connections for current output or alarms, switch between available RS-232 and RS-422 digital connections, or re-connect the mains, it will be necessary to loosen two flat-head screws holding the keypad and display.

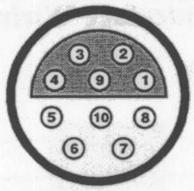
Carefully set aside the keypad/display panel, making sure not to disconnect the cable that connects this panel to the power supply and output card. Once removed, the instrument's power supply and output card's terminal block connections appear (at the card's bottom) and are identified on the card as follows:



Instrument power supply and output card connections and jumpers

> Make sure you have switched off the power supply before changing any jumper settings or making any connections to the instrument!
>
> Before connecting cables inside the instrument, make sure that they are disconnected from any power supply.

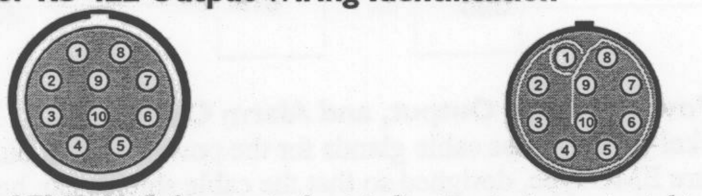
2.1.1.1 Oxygen or Ozone Sensor Wiring Identification



LEMO-10 connector (at indicating instrument)

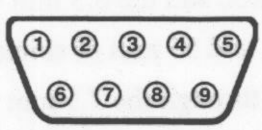
Pin 1: Guard ring electrode
Pin 3: Temperature measurement
Pin 4: Anode (Counter electrode)
Pin 6: Temperature measurement
Pin 9: Cathode (Working electrode)
(Pins 2, 5, 7, 8 & 10 not used)

2.1.1.2 RS-232 or RS-422 Output Wiring Identification



LEMO-10 (left, receptacle at indicating instrument; right, solder-end of LEMO plug)

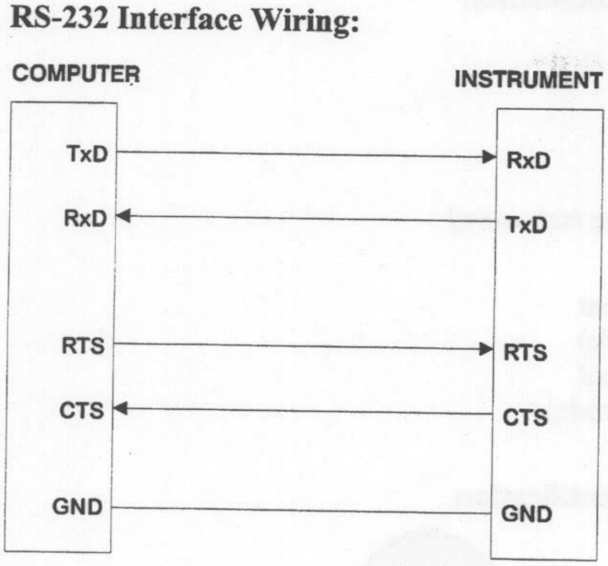
LEMO 10-Pin	RS-232 Signal	RS-422 Signal
1	TXD	RXD+
2		RXD-
3	RXD	TXD+
4		TXD-
5	CTS	CTS+
6		CTS-
7	RTS	RTS+
8		RTS-
9	GND	
10		

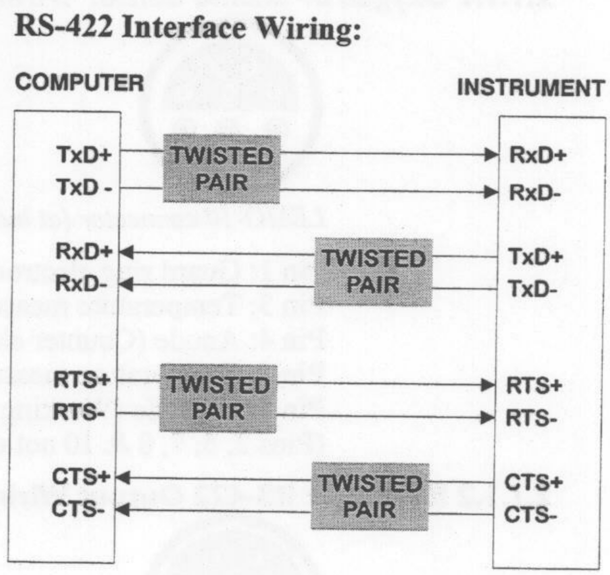


RS-232/RS-422, 9 pin connector (male)

D type 9-Pin	RS-232 Signal	RS-422 Signal *
1		
2	RXD	RTS+
3	TXD	RTS-
4		RXD+
5	GND	RXD-
6		CTS+
7	RTS	CTS-
8	CTS	TXD+
9		TXD-

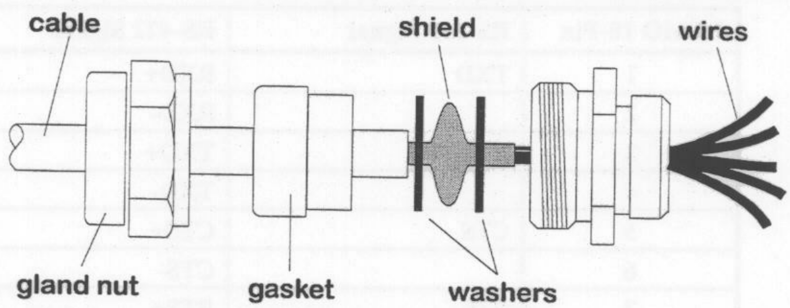
* The RS-422 pin designations listed are for the model 32542 cable and model 32906 RS-422 PC card only.





2.1.1.3 Installation of Power, Analog Output, and Alarm Cables

The nickel-plated, brass cable glands for the power, analog output, and alarm cables are EMC type, designed so that the cable shields can be directly attached to the instrument box. Typical cable installation is illustrated below.



1. Unscrew the cable gland nut. You will find a rubber gasket, then a metal washer with an interior diameter of 8.3 mm, and then another metal washer with an interior diameter of 7.5 mm.
2. Pass the cable through the nut, the gasket, and the 8.3 mm washer.
3. Strip off 70 mm of external insulation, and 55 mm of shielding.
4. Pass the cable prepared in this fashion through the 7.5 mm washer.
5. Pinch the shield so that its entire circumference is pressed between the two washers (see illustration above).
6. Pass the cable into the box blocking the cable gland.
7. Reattach and tighten the cable gland nut.
8. Strip the wires about 8 mm from their ends.
9. Attach the wires to the corresponding terminal block connections (refer to the instrument card diagram in section 2.1.1).
   - **Grounded Power Supply** — attach the wires to the "Mains" terminal block, J9, as follows for the type of power source:
     - 115 and 230 volt AC power: PE = Earth; N = Neutral; L = Live.
     - 10-30 volt DC power: PE = Earth; N = Ground; L = 10-30 VDC.
   - **Analog Current Output** — attach the applicable wires to the "+" and "–" terminals of the "Current" terminal block, J11. (See section 1.3.2.3, Analog Output Signal.)

- **Alarm Contacts** — attach the "hot" alarm wire to either the NO or the NC contact, and the return wire to the COM terminal of the "High Low Alarms" terminal block, J12. (See section 1.3.2.4, Alarm Relay Output.)

2.1.1.4 User-supplied Cabling Requirements

Cables for the analog output, alarm output, and RS-232 or RS-422 connections should be "control" cables (that is, not power cables) with twisted copper wires and screen, and meeting the specifications in the table below:

External diameter	4–8 mm
Wire (core) area	.14–.25 mm^2
Insulation	PVC
Nominal voltage	250 V
Absolute max. voltage	1200 V
Absolute max. current	1.5–2.5 A
Wire resistance	70–140 Ω/km
Capacitance, Wire	100 pF/m
@ 800 Hz Screen	240 pF/m

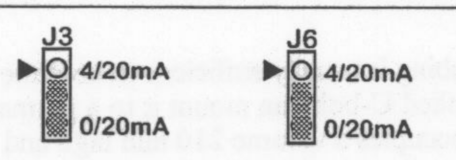
Please note that *the cable shield must be grounded* to the instrument case, as illustrated in section 2.1.1.3.

2.1.2 Analog Output or RS-232/RS-422 Jumper Settings

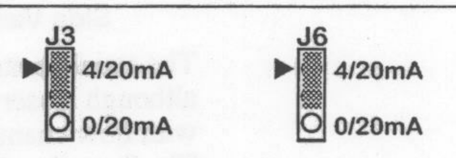
Some users may find it necessary to change the instrument's analog current output or RS-232/RS-422 jumper settings. This requires that the front panel display and keypad be removed, as explained in section 2.1.1, to access the instrument power supply and output card.

The jumpers one sees on the output card at positions J3, J4, J5, J6, and J8 are set to reflect the expected requirement for 4–20 mA (or 0–20 mA) recorder current output, and for RS-232 (or RS-422) instrument-to-PC connection.

For example, if you need to change the analog output for a chart recorder requiring a 0–20mA signal or for a chart recorder requiring a 4–20 mA signal, the jumpers at position J3 and J6 should be set as follows:

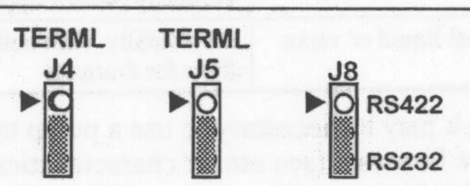


Jumper setting for 0–20 mA current

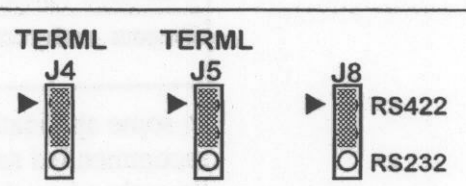


Jumper setting for 4–20 mA current

If you need to switch from RS-232 to RS-422 (or vice versa) you should reset the jumpers at positions J4, J5, and J8 as shown:



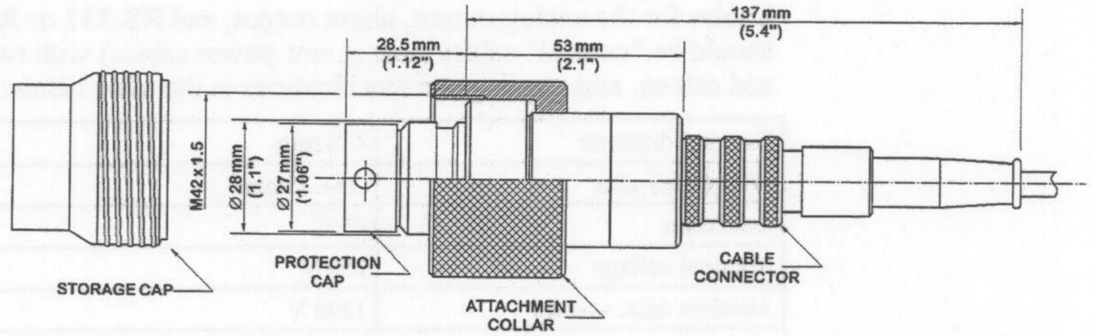
Jumper setting for RS-232 output



Jumper setting for RS-422 output

2.2 Sensor Installation

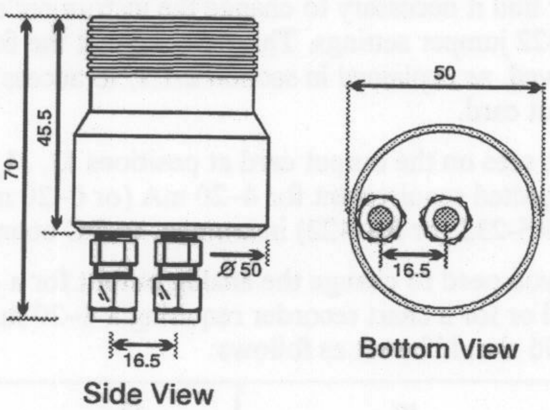
The oxygen or ozone sensor may be mounted in a sample by means of a flow chamber, a sensor socket, or a ProAcc insertion/extraction valve, as described in the sections below.



The sensor and 3660 instrument interface via a 10-pin LEMO connector. The standard sensor cable length is three meters, but longer cable of up to 500 meters can be provided without any loss in signal sensitivity.

2.2.1 Model 32001.x Flow Chamber Installation

The model 32001.x flow chamber is used to draw liquid and gaseous samples past the sensor. It connects to 6 mm or ¼" stainless steel tubing by means of two Swagelok fittings. If necessary, copper or plastic tubing with very low permeability can be substituted.

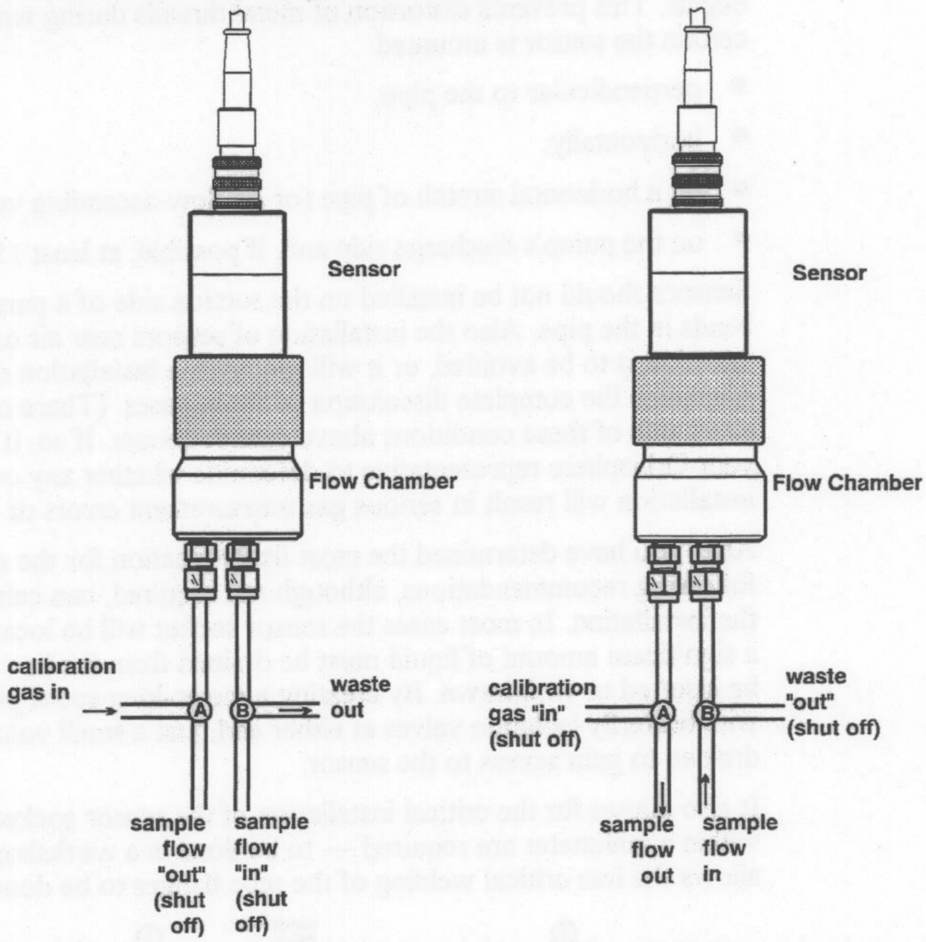


The stainless steel tubing is usually sufficient to hold the assembly firmly in place, although a user-supplied U-bolt can mount it to a permanent fixture. The sensor with flow chamber occupies a volume 210 mm high and 50 mm across and deep. The flow chamber/sensor assembly should be mounted either vertically or horizontally, under the following conditions:

Sample	Flow Chamber Orientation
Gaseous or liquid	Vertically (sensor uppermost)
Gaseous, with occasional liquid or vapor	Horizontally, with outlet valve under inlet, to allow for drainage

In some applications it may be necessary to use a pump to provide the recommended sample flow rate (see sensor characteristics, section 3.1) through the flow chamber. A peristaltic pump is recommended for dissolved ozone measurement applications, at least three meters from the outlet side of the flow chamber. Do not exceed double the recommended flow rates listed in section 3.1.

The diagrams below show how to introduce, if required, both calibration gas and normal sample media to the flow chamber. "A" and "B" represent 3-way valves. Calibration gas is sent in through the sample "out" port and waste gas is sent out through the sample "in" port, as shown (left). Back in normal operation (right), the calibration gas inlets and outlets are shut off.

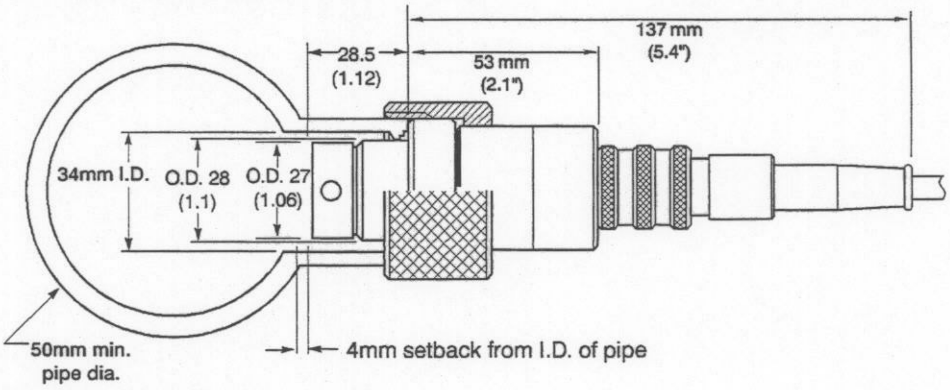


Introducing calibration gas and samples via a model 32001 flow chamber

When switching from a liquid sample to a span gas, make sure the front end of the sensor is clean and dry. It may take several hours for drying under slow gas flow conditions. To speed up the drying, it may be faster to pull the sensor out of the flow chamber, rinse the grill with water, and blow it dry with compressed gas.

2.2.2 Model 29501 Sensor Socket Installation

The model 29501 sensor socket enables the sensor to be installed into any stainless steel pipe with a diameter greater than 50 mm. The sensor, with protection cap, extends 28 mm into the sensor socket. When cutting the sensor socket to fit the radius of your pipe, you should allow for a 4 mm setback between your pipe's inner diameter and the top of the sensor.



Sensor socket mounting — side view

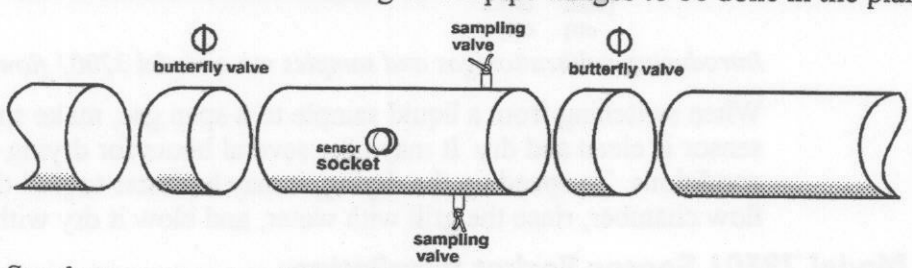
Be sure to remove the sensor socket's two O-rings prior to pipe welding. Also, you should make sure you re-attach the sensor socket collar (included) before welding begins. This prevents distortion of metal threads during welding. You must make certain the sensor is mounted:

- perpendicular to the pipe;
- horizontally;
- on a horizontal stretch of pipe (or on flow-ascending vertical pipe); and
- on the pump's discharge side and, if possible, at least 15 meters downstream.

Sensors should not be installed on the suction side of a pump, or close to valves or bends in the pipe. Also the installation of sensors near air or carbon dioxide injection is to be avoided, or it will require the installation of a frit that will guarantee the complete dissolution of those gases. (There may be locations where every one of these conditions above cannot be met. If so, it is best to consult with your Orbisphere representative to determine whether any compromises in installation will result in serious gas measurement errors or other difficulties.)

After you have determined the most likely location for the sensor socket, the following recommendations, although not required, can enhance the versatility of the installation. In most cases the sensor socket will be located in a position where a significant amount of liquid must be drained from the line before the sensor can be inserted or withdrawn. By creating a meter-long spool piece, as shown below, with butterfly isolation valves at either end, just a small volume of liquid need be drained to gain access to the sensor.

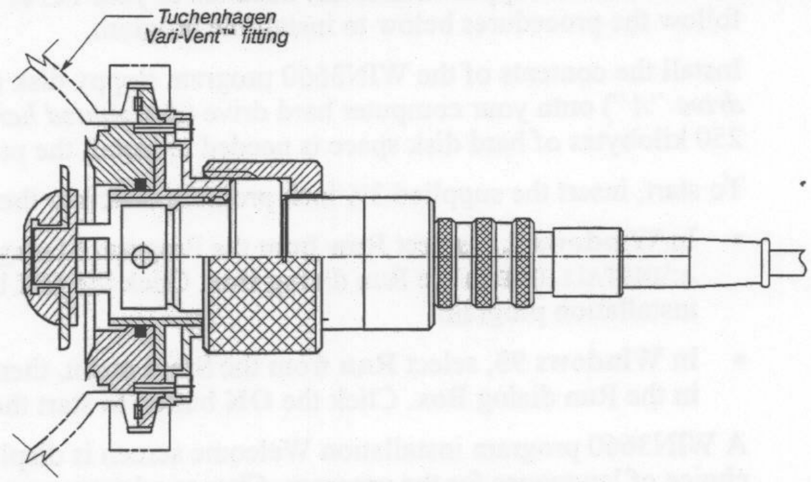
It also allows for the critical installation of the sensor socket — where tolerances within a millimeter are required — to be done in a workshop environment, and allows the less critical welding of the pipe flanges to be done in the plant.



Spool piece recommendation

2.2.3 Model 32003 ProAcc Insertion/Extraction Valve Installation

The model 32003 ProAcc permits a sensor to be inserted or removed from a pipe while the sample is still flowing. It clamps to the Tuchenhagen Varivent in-line access unit. (This device is available from the manufacturer to fit from one- to six-inch outer diameter pipe.) The ProAcc is held into place by a stainless steel clamp.



Sensor installed in a ProAcc — cross section view

Since the sensor is mounted directly in-line, location requirements are as stated above for the sensor socket (section 2.2.2.)

To insert the sensor, screw on the sensor's collar until coming to a stop. This places the sensor in-line. Removal is accomplished by unscrewing the collar. This valve can withstand line pressures of up to 20 bars, with or without the sensor in place.

2.3 WIN3660 Program Installation

The "WIN3660" application program, operating under Microsoft Windows®, provides a simple way to configure the system, and to display, acquire, and store data using a personal computer (PC).

In the event this application is not installed in your PC or not working properly, follow the procedures below to install the program.

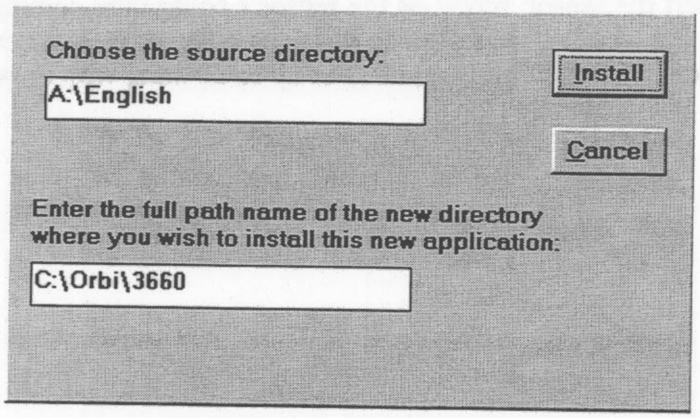
Install the contents of the WIN3660 program floppy disk (*designated here as drive "A"*) onto your computer hard drive (*designated here as drive "C"*). About 250 kilobytes of hard disk space is needed to install the program system.

To start, insert the supplied 3½ inch program disk into the PC's floppy disk drive.

- In **Windows 3.1**, select **Run** from the Program Manager **File** Menu, then enter A:\INSTALL.EXE in the Run dialog Box. Click the **OK** button to start the installation program.
- In **Windows 95**, select **Run** from the **Start** menu, then enter A:\INSTALL.EXE in the Run dialog Box. Click the **OK** button to start the installation program.

A WIN3660 program installation Welcome screen is displayed first, providing a choice of languages for the program. Choose a language and then click the "» »" button to start the installation.

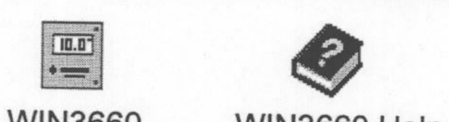
Next, a dialog box asks you to enter the source and destination directories for this installation.



The default installation source is the floppy disk directory that contains the program files for the selected language, and the default destination is a new directory labeled C:\Orbi\3660. If you wish to place the WIN3660 files in a different directory, enter the full directory path in the dialog box.

Click the **Install** button to continue installation.

When finished, a new Windows Program Group labeled "Orbisphere" is created with two entries: the WIN3660 program and WIN3660 Help.



Select the WIN3660 icon to start the WIN3660 program; use the WIN3660 Help icon for program help.

3. Technical Information

3.1 System Specifications

Indicating Instrument

Power Requirements	115/230 VAC ±10% @ 50/60 Hz, or 10–36 VDC
Power Consumption	20 VA, maximum
Isolated Current Output (software adjustable)	0–20 mA or 4–20 mA R maximum: 500 Ω
Serial Output	RS-232 or RS-422 Baud rate: 9600; Stop Bit: 1; Start Bit: 0; Parity: None
High and Low Alarm Relays (software adjustable) hysteresis ±1% of the high limit	Max. current: 2 A Max. voltage: 125 V Max. power: 50 W, 50 VA
Operating Limits	-10 to +50 °C
Dimensions (W x H x D)	200 mm x 200 mm x 90 mm
Weight	2.5 kg
Enclosure Rating	IP 65 / NEMA 4x, all stainless steel

Oxygen Sensor

Accuracy (with standard 2952A membrane)	± 1% or ±1 ppb, whichever is greater
Measurement Range	1 ppb–80 ppm
Signal Drift	<0.5% of reading between service
Response Time (90% change at 25°C)	30 seconds
Maximum Sampling Pressure	Model 31110 sensor: 20 bars Model 31120 sensor: 50 bars
Maximum Operating Temperature	100 °C
Temperature Compensation Range	-5 to 60 °C
Dimensions (length x diameter)	80 mm x 40 mm
Weight	0.2 kg
Enclosure Rating	IP 68 / NEMA 6P
Optimum Flow Rate (via 32001 flow chamber, with protection cap and grill)	100 ml/minute

Ozone Sensor

Accuracy	±1% or ±5ppb/1 Pa, whichever is greater
Measurement Range	Membrane 2956A: 5 ppb–50 ppm Membrane 29552A: 5 ppb–100 ppm
Signal Drift	<1% of reading between service
Response Time (90% change at 25°C)	Membrane 2956A: 30 seconds Membrane 29552A: 6 minutes
Maximum Sampling Pressure	100 bars
Maximum Operating Temperature	100 °C
Temperature Compensation Range	0 to 50 °C
Dimensions (length x diameter)	80 mm x 40 mm
Weight	0.2 kg
Enclosure Rating	IP 68 / NEMA 6P
Optimum Flow Rate (via 32001 flow chamber, with protection cap and grill)	Membrane 2956A: 350 ml/minute Membrane 29552A: 100 ml/minute

Instrument Configurations

Model No.	Gas Measured	Temp Units	Display ranges	Standard Membrane	CO_2 Insensitive	Thermal Cutoff
3660.100	Dissolved O_2	°C	0.1–99.9 ppb, 100–999 ppb, 1.00–9.99 ppm, or 10.0–99.9 ppm	2952A	No	Yes
3660.101	Dissolved O_2	°F		2952A	No	Yes
3660.102	Dissolved O_2	°C		2952A	Yes	Yes
3660.103	Dissolved O_2	°F		2952A	Yes	Yes
3660.104	Dissolved O_2	°C	0.001–0.999 ppm, 1.00–9.99 ppm, or 10.0–99.9 ppm	2952A	Yes	Yes
3660.105	Dissolved O_2	°F		2952A	Yes	Yes
3660.106	Gaseous O_2	°C	0.1–99.9 ppm, 100–999 ppm, 0.100–0.999%, 1.00–9.99 %, or 10.0–99.9 %	2952A	Yes	Yes
3660.107	Gaseous O_2	°F		2952A	Yes	Yes
3660.108	Gaseous O_2	°C	0.001–0.999 %, 1.00–9.99 %, or 10.0–99.9 %	2952A	Yes	Yes
3660.109	Gaseous O_2	°F		2952A	Yes	Yes
3660.300	Dissolved O_3	°C	1–999 ppb, 1.00–9.99 ppm, or 10.0–99.9 ppm	2956A	No	No
3660.301	Dissolved O_3	°F		2956A	No	No
3660.302	Dissolved O_3	°C	0.001–0.999 ppm, 1.00–9.99 ppm, or 10.0–99.9 ppm	29552A	No	No
3660.303	Dissolved O_3	°F		29552A	No	No

Sensor Configurations

Model No.	Description
31110.02	Oxygen sensor, all PEEK, high sensitivity execution, with silver guard ring, ceramic valve seat, EPDM O-ring, and protection cap
31120.01	Oxygen sensor, parts in contact with sample in stainless steel, all other parts in PEEK, high sensitivity execution, with silver guard ring, ceramic valve seat, EPDM O-ring, and protection cap
31330.15	Ozone sensor, all parts in contact with sample in titanium, all other parts metal, with platinum guard ring, ceramic valve seat, Viton O-ring, and titanium protection cap

Standard Sensor Cable Specifications

Casing	Fire-retardant Elastolan
Maximum Temperature	80 °C
Cable Diameter	6.1 mm ±0.3 mm. 10 each stranded wires of 26 AWG, individually insulated with polyethylene, 90% shielded by tinned copper braid.
Maximum Pulling Tension	7 kg
Resistivity	138 Ω/km
Minimum Bend Radius	15 times cable diameter

3.2 Theory of Operation

The oxygen or ozone sensor circuitry performs four functions:

- Applying a constant voltage to the anode,
- Measuring the current flowing through the sensor,
- Compensating this current for sample temperature variations,
- Converting these resulting signals into a scaled current or voltage.

The anode is held positive with respect to the cathode. Current flowing through the sensor due to oxygen or ozone reduction at the cathode is converted to a voltage by an amplifier, the proportionality between voltage and current being determined by the feedback resistance of this amplifier.

The output voltage is essentially a function of oxygen or ozone activity (partial pressure), temperature, and membrane permeability. Corrections for variations in membrane permeability are made when the sensor is calibrated. The temperature compensation circuit accounts for temperature variations. Hence the output voltage varies only with oxygen or ozone concentration.

Appendix 1. Table of Oxygen Concentrations (ppm) – in water-saturated air

Temperature, °C, in left-hand column; barometric pressure, mbar, on top row.

1000 mbar = 1 bar = 750.1 Torr = 750.1 mm Hg = 29.53 inches Hg = 0.987 Atm = 14.5 psi = 100 kPa

T/P	900	905	910	915	920	925	930	935	940	945
0	12.99	13.06	13.13	13.21	13.28	13.35	13.43	13.50	13.57	13.64
1	12.63	12.70	12.77	12.84	12.91	12.98	13.05	13.12	13.19	13.26
2	12.28	12.35	12.42	12.49	12.56	12.63	12.70	12.77	12.83	12.90
3	11.96	12.02	12.09	12.16	12.22	12.29	12.36	12.42	12.49	12.56
4	11.64	11.71	11.77	11.84	11.90	11.97	12.03	12.10	12.16	12.23
5	11.34	11.40	11.47	11.53	11.59	11.66	11.72	11.79	11.85	11.91
6	11.05	11.11	11.18	11.24	11.30	11.36	11.42	11.49	11.55	11.61
7	10.78	10.84	10.90	10.96	11.02	11.08	11.14	11.20	11.26	11.32
8	10.51	10.57	10.63	10.69	10.75	10.81	10.87	10.93	10.99	11.05
9	10.26	10.32	10.38	10.43	10.49	10.55	10.61	10.66	10.72	10.78
10	10.02	10.07	10.13	10.19	10.24	10.30	10.36	10.41	10.47	10.53
11	9.79	9.84	9.90	9.95	10.01	10.06	10.12	10.17	10.23	10.28
12	9.56	9.62	9.67	9.72	9.78	9.83	9.89	9.94	9.99	10.05
13	9.35	9.40	9.45	9.51	9.56	9.61	9.66	9.72	9.77	9.82
14	9.14	9.19	9.25	9.30	9.35	9.40	9.45	9.50	9.56	9.61
15	8.94	8.99	9.04	9.10	9.15	9.20	9.25	9.30	9.35	9.40
16	8.75	8.80	8.85	8.90	8.95	9.00	9.05	9.10	9.15	9.20
17	8.57	8.62	8.67	8.72	8.76	8.81	8.86	8.91	8.96	9.01
18	8.39	8.44	8.49	8.54	8.58	8.63	8.68	8.73	8.77	8.82
19	8.22	8.27	8.31	8.36	8.41	8.46	8.50	8.55	8.60	8.64
20	8.06	8.10	8.15	8.19	8.24	8.29	8.33	8.38	8.42	8.47
21	7.90	7.94	7.99	8.03	8.08	8.12	8.17	8.21	8.26	8.30
22	7.74	7.79	7.83	7.88	7.92	7.97	8.01	8.05	8.10	8.14
23	7.60	7.64	7.68	7.73	7.77	7.81	7.86	7.90	7.94	7.99
24	7.45	7.49	7.54	7.58	7.62	7.67	7.71	7.75	7.79	7.84
25	7.31	7.36	7.40	7.44	7.48	7.52	7.57	7.61	7.65	7.69
26	7.18	7.22	7.26	7.30	7.34	7.39	7.43	7.47	7.51	7.55
27	7.05	7.09	7.13	7.17	7.21	7.25	7.29	7.33	7.37	7.42
28	6.92	6.96	7.00	7.04	7.08	7.12	7.16	7.20	7.24	7.28
29	6.80	6.84	6.88	6.92	6.96	7.00	7.04	7.08	7.12	7.15
30	6.68	6.72	6.76	6.80	6.84	6.87	6.91	6.95	6.99	7.03
31	6.56	6.60	6.64	6.68	6.72	6.76	6.79	6.83	6.87	6.91
32	6.45	6.49	6.53	6.56	6.60	6.64	6.68	6.72	6.75	6.79
33	6.34	6.38	6.42	6.45	6.49	6.53	6.56	6.60	6.64	6.68
34	6.23	6.27	6.31	6.34	6.38	6.42	6.45	6.49	6.53	6.56
35	6.13	6.17	6.20	6.24	6.27	6.31	6.35	6.38	6.42	6.46
36	6.03	6.06	6.10	6.13	6.17	6.21	6.24	6.28	6.31	6.35
37	5.93	5.96	6.00	6.03	6.07	6.10	6.14	6.17	6.21	6.25
38	5.83	5.86	5.90	5.93	5.97	6.00	6.04	6.07	6.11	6.14
39	5.73	5.77	5.80	5.84	5.87	5.91	5.94	5.98	6.01	6.04
40	5.64	5.67	5.71	5.74	5.78	5.81	5.85	5.88	5.91	5.95
41	5.55	5.58	5.62	5.65	5.68	5.72	5.75	5.78	5.82	5.85
42	5.46	5.49	5.52	5.56	5.59	5.62	5.66	5.69	5.73	5.76
43	5.37	5.40	5.44	5.47	5.50	5.53	5.57	5.60	5.63	5.67
44	5.28	5.31	5.35	5.38	5.41	5.45	5.48	5.51	5.54	5.58
45	5.20	5.23	5.26	5.29	5.33	5.36	5.39	5.42	5.45	5.49
46	5.11	5.14	5.17	5.21	5.24	5.27	5.30	5.33	5.37	5.40
47	5.03	5.06	5.09	5.12	5.15	5.19	5.22	5.25	5.28	5.31
48	4.94	4.98	5.01	5.04	5.07	5.10	5.13	5.16	5.19	5.23
49	4.86	4.89	4.92	4.96	4.99	5.02	5.05	5.08	5.11	5.14

(1st of 4)

Table of Oxygen Concentrations (ppm) — Continued

Temperature, °C, in left-hand column; barometric pressure, mbar, on top row.

T/P	950	955	960	965	970	975	980	985	990	995
0	13.72	13.79	13.86	13.93	14.01	14.08	14.15	14.22	14.30	14.37
1	13.34	13.41	13.48	13.55	13.62	13.69	13.76	13.83	13.90	13.97
2	12.97	13.04	13.11	13.18	13.25	13.32	13.38	13.45	13.52	13.59
3	12.62	12.69	12.76	12.83	12.89	12.96	13.03	13.09	13.16	13.23
4	12.29	12.36	12.42	12.49	12.55	12.62	12.68	12.75	12.82	12.88
5	11.98	12.04	12.10	12.17	12.23	12.29	12.36	12.42	12.49	12.55
6	11.67	11.74	11.80	11.86	11.92	11.98	12.05	12.11	12.17	12.23
7	11.38	11.44	11.50	11.56	11.62	11.69	11.75	11.81	11.87	11.93
8	11.10	11.16	11.22	11.28	11.34	11.40	11.46	11.52	11.58	11.64
9	10.84	10.90	10.95	11.01	11.07	11.13	11.18	11.24	11.30	11.36
10	10.58	10.64	10.70	10.75	10.81	10.86	10.92	10.98	11.03	11.09
11	10.34	10.39	10.45	10.50	10.56	10.61	10.67	10.72	10.78	10.83
12	10.10	10.16	10.21	10.26	10.32	10.37	10.43	10.48	10.53	10.59
13	9.88	9.93	9.98	10.03	10.09	10.14	10.19	10.25	10.30	10.35
14	9.66	9.71	9.76	9.81	9.87	9.92	9.97	10.02	10.07	10.12
15	9.45	9.50	9.55	9.60	9.65	9.70	9.75	9.80	9.86	9.91
16	9.25	9.30	9.35	9.40	9.45	9.50	9.55	9.60	9.65	9.70
17	9.06	9.10	9.15	9.20	9.25	9.30	9.35	9.40	9.44	9.49
18	8.87	8.92	8.96	9.01	9.06	9.11	9.16	9.20	9.25	9.30
19	8.69	8.74	8.78	8.83	8.88	8.92	8.97	9.02	9.06	9.11
20	8.52	8.56	8.61	8.65	8.70	8.75	8.79	8.84	8.88	8.93
21	8.35	8.39	8.44	8.48	8.53	8.57	8.62	8.66	8.71	8.76
22	8.19	8.23	8.28	8.32	8.36	8.41	8.45	8.50	8.54	8.59
23	8.03	8.07	8.12	8.16	8.21	8.25	8.29	8.34	8.38	8.42
24	7.88	7.92	7.97	8.01	8.05	8.09	8.14	8.18	8.22	8.27
25	7.73	7.78	7.82	7.86	7.90	7.94	7.99	8.03	8.07	8.11
26	7.59	7.63	7.68	7.72	7.76	7.80	7.84	7.88	7.92	7.97
27	7.46	7.50	7.54	7.58	7.62	7.66	7.70	7.74	7.78	7.82
28	7.32	7.36	7.40	7.44	7.48	7.52	7.56	7.60	7.64	7.68
29	7.19	7.23	7.27	7.31	7.35	7.39	7.43	7.47	7.51	7.55
30	7.07	7.11	7.15	7.19	7.22	7.26	7.30	7.34	7.38	7.42
31	6.95	6.99	7.02	7.06	7.10	7.14	7.18	7.22	7.25	7.29
32	6.83	6.87	6.90	6.94	6.98	7.02	7.06	7.09	7.13	7.17
33	6.71	6.75	6.79	6.83	6.86	6.90	6.94	6.98	7.01	7.05
34	6.60	6.64	6.68	6.71	6.75	6.79	6.82	6.86	6.90	6.93
35	6.49	6.53	6.56	6.60	6.64	6.67	6.71	6.75	6.78	6.82
36	6.39	6.42	6.46	6.49	6.53	6.56	6.60	6.64	6.67	6.71
37	6.28	6.32	6.35	6.39	6.42	6.46	6.49	6.53	6.56	6.60
38	6.18	6.21	6.25	6.28	6.32	6.35	6.39	6.42	6.46	6.49
39	6.08	6.11	6.15	6.18	6.22	6.25	6.29	6.32	6.36	6.39
40	5.98	6.02	6.05	6.08	6.12	6.15	6.19	6.22	6.25	6.29
41	5.89	5.92	5.95	5.99	6.02	6.05	6.09	6.12	6.16	6.19
42	5.79	5.83	5.86	5.89	5.93	5.96	5.99	6.03	6.06	6.09
43	5.70	5.73	5.77	5.80	5.83	5.86	5.90	5.93	5.96	6.00
44	5.61	5.64	5.67	5.71	5.74	5.77	5.80	5.84	5.87	5.90
45	5.52	5.55	5.58	5.62	5.65	5.68	5.71	5.75	5.78	5.81
46	5.43	5.46	5.49	5.53	5.56	5.59	5.62	5.65	5.69	5.72
47	5.34	5.38	5.41	5.44	5.47	5.50	5.53	5.57	5.60	5.63
48	5.26	5.29	5.32	5.35	5.38	5.41	5.45	5.48	5.51	5.54
49	5.17	5.20	5.23	5.27	5.30	5.33	5.36	5.39	5.42	5.45

(2nd of 4)

Table of Oxygen Concentrations (ppm) — Continued

Temperature, °C, in left-hand column; barometric pressure, mbar, on top row.

T/P	1000	1005	1010	1015	1020	1025	1030	1035	1040	1045
0	14.44	14.52	14.59	14.66	14.73	14.81	14.88	14.95	15.02	15.10
1	14.04	14.11	14.18	14.25	14.32	14.40	14.47	14.54	14.61	14.68
2	13.66	13.73	13.80	13.87	13.93	14.00	14.07	14.14	14.21	14.28
3	13.29	13.36	13.43	13.50	13.56	13.63	13.70	13.76	13.83	13.90
4	12.95	13.01	13.08	13.14	13.21	13.27	13.34	13.40	13.47	13.53
5	12.61	12.68	12.74	12.80	12.87	12.93	12.99	13.06	13.12	13.19
6	12.29	12.36	12.42	12.48	12.54	12.60	12.67	12.73	12.79	12.85
7	11.99	12.05	12.11	12.17	12.23	12.29	12.35	12.41	12.47	12.53
8	11.70	11.75	11.81	11.87	11.93	11.99	12.05	12.11	12.17	12.23
9	11.42	11.47	11.53	11.59	11.65	11.70	11.76	11.82	11.88	11.94
10	11.15	11.20	11.26	11.32	11.37	11.43	11.49	11.54	11.60	11.65
11	10.89	10.94	11.00	11.05	11.11	11.17	11.22	11.28	11.33	11.39
12	10.64	10.70	10.75	10.80	10.86	10.91	10.97	11.02	11.07	11.13
13	10.40	10.46	10.51	10.56	10.62	10.67	10.72	10.77	10.83	10.88
14	10.18	10.23	10.28	10.33	10.38	10.43	10.49	10.54	10.59	10.64
15	9.96	10.01	10.06	10.11	10.16	10.21	10.26	10.31	10.36	10.41
16	9.75	9.80	9.84	9.89	9.94	9.99	10.04	10.09	10.14	10.19
17	9.54	9.59	9.64	9.69	9.74	9.79	9.83	9.88	9.93	9.98
18	9.35	9.39	9.44	9.49	9.54	9.59	9.63	9.68	9.73	9.78
19	9.16	9.20	9.25	9.30	9.35	9.39	9.44	9.49	9.53	9.58
20	8.98	9.02	9.07	9.11	9.16	9.21	9.25	9.30	9.34	9.39
21	8.80	8.85	8.89	8.94	8.98	9.03	9.07	9.12	9.16	9.21
22	8.63	8.68	8.72	8.76	8.81	8.85	8.90	8.94	8.99	9.03
23	8.47	8.51	8.55	8.60	8.64	8.68	8.73	8.77	8.82	8.86
24	8.31	8.35	8.39	8.44	8.48	8.52	8.57	8.61	8.65	8.69
25	8.16	8.20	8.24	8.28	8.32	8.37	8.41	8.45	8.49	8.53
26	8.01	8.05	8.09	8.13	8.17	8.21	8.26	8.30	8.34	8.38
27	7.86	7.90	7.95	7.99	8.03	8.07	8.11	8.15	8.19	8.23
28	7.72	7.76	7.80	7.84	7.89	7.93	7.97	8.01	8.05	8.09
29	7.59	7.63	7.67	7.71	7.75	7.79	7.83	7.87	7.91	7.95
30	7.46	7.50	7.54	7.58	7.61	7.65	7.69	7.73	7.77	7.81
31	7.33	7.37	7.41	7.45	7.48	7.52	7.56	7.60	7.64	7.68
32	7.21	7.25	7.28	7.32	7.36	7.40	7.43	7.47	7.51	7.55
33	7.09	7.12	7.16	7.20	7.24	7.27	7.31	7.35	7.39	7.42
34	6.97	7.01	7.04	7.08	7.12	7.15	7.19	7.23	7.26	7.30
35	6.86	6.89	6.93	6.96	7.00	7.04	7.07	7.11	7.15	7.18
36	6.74	6.78	6.82	6.85	6.89	6.92	6.96	6.99	7.03	7.07
37	6.64	6.67	6.71	6.74	6.78	6.81	6.85	6.88	6.92	6.95
38	6.53	6.56	6.60	6.63	6.67	6.70	6.74	6.77	6.81	6.84
39	6.42	6.46	6.49	6.53	6.56	6.60	6.63	6.67	6.70	6.74
40	6.32	6.36	6.39	6.43	6.46	6.49	6.53	6.56	6.60	6.63
41	6.22	6.26	6.29	6.32	6.36	6.39	6.43	6.46	6.49	6.53
42	6.13	6.16	6.19	6.23	6.26	6.29	6.33	6.36	6.39	6.43
43	6.03	6.06	6.10	6.13	6.16	6.19	6.23	6.26	6.29	6.33
44	5.94	5.97	6.00	6.03	6.07	6.10	6.13	6.16	6.20	6.23
45	5.84	5.87	5.91	5.94	5.97	6.00	6.04	6.07	6.10	6.13
46	5.75	5.78	5.81	5.85	5.88	5.91	5.94	5.97	6.01	6.04
47	5.66	5.69	5.72	5.76	5.79	5.82	5.85	5.88	5.91	5.95
48	5.57	5.60	5.63	5.67	5.70	5.73	5.76	5.79	5.82	5.85
49	5.48	5.51	5.55	5.58	5.61	5.64	5.67	5.70	5.73	5.76

(3rd of 4)

Table of Oxygen Concentrations (ppm) — Continued

Temperature, °C, in left-hand column; barometric pressure, mbar, on top row.

T/P	1050	1055	1060	1065	1070	1075	1080	1085	1090	1095
0	15.17	15.24	15.31	15.39	15.46	15.53	15.60	15.68	15.75	15.82
1	14.75	14.82	14.89	14.96	15.03	15.10	15.17	15.24	15.31	15.38
2	14.35	14.42	14.49	14.55	14.62	14.69	14.76	14.83	14.90	14.97
3	13.96	14.03	14.10	14.17	14.23	14.30	14.37	14.43	14.50	14.57
4	13.60	13.66	13.73	13.79	13.86	13.92	13.99	14.06	14.12	14.19
5	13.25	13.31	13.38	13.44	13.50	13.57	13.63	13.69	13.76	13.82
6	12.91	12.98	13.04	13.10	13.16	13.22	13.29	13.35	13.41	13.47
7	12.59	12.65	12.71	12.78	12.84	12.90	12.96	13.02	13.08	13.14
8	12.29	12.35	12.41	12.46	12.52	12.58	12.64	12.70	12.76	12.82
9	11.99	12.05	12.11	12.17	12.22	12.28	12.34	12.40	12.45	12.51
10	11.71	11.77	11.82	11.88	11.94	11.99	12.05	12.11	12.16	12.22
11	11.44	11.50	11.55	11.61	11.66	11.72	11.77	11.83	11.88	11.94
12	11.18	11.24	11.29	11.34	11.40	11.45	11.51	11.56	11.61	11.67
13	10.93	10.99	11.04	11.09	11.14	11.20	11.25	11.30	11.36	11.41
14	10.69	10.74	10.80	10.85	10.90	10.95	11.00	11.06	11.11	11.16
15	10.46	10.51	10.56	10.62	10.67	10.72	10.77	10.82	10.87	10.92
16	10.24	10.29	10.34	10.39	10.44	10.49	10.54	10.59	10.64	10.69
17	10.03	10.08	10.13	10.17	10.22	10.27	10.32	10.37	10.42	10.47
18	9.82	9.87	9.92	9.97	10.01	10.06	10.11	10.16	10.21	10.25
19	9.63	9.67	9.72	9.77	9.81	9.86	9.91	9.95	10.00	10.05
20	9.44	9.48	9.53	9.57	9.62	9.67	9.71	9.76	9.80	9.85
21	9.25	9.30	9.34	9.39	9.43	9.48	9.52	9.57	9.61	9.66
22	9.07	9.12	9.16	9.21	9.25	9.30	9.34	9.38	9.43	9.47
23	8.90	8.95	8.99	9.03	9.08	9.12	9.16	9.21	9.25	9.29
24	8.74	8.78	8.82	8.87	8.91	8.95	8.99	9.04	9.08	9.12
25	8.58	8.62	8.66	8.70	8.75	8.79	8.83	8.87	8.91	8.96
26	8.42	8.46	8.50	8.55	8.59	8.63	8.67	8.71	8.75	8.79
27	8.27	8.31	8.35	8.39	8.43	8.48	8.52	8.56	8.60	8.64
28	8.13	8.17	8.21	8.25	8.29	8.33	8.37	8.41	8.45	8.49
29	7.98	8.02	8.06	8.10	8.14	8.18	8.22	8.26	8.30	8.34
30	7.85	7.89	7.93	7.96	8.00	8.04	8.08	8.12	8.16	8.20
31	7.72	7.75	7.79	7.83	7.87	7.91	7.95	7.98	8.02	8.06
32	7.59	7.62	7.66	7.70	7.74	7.78	7.81	7.85	7.89	7.93
33	7.46	7.50	7.53	7.57	7.61	7.65	7.68	7.72	7.76	7.80
34	7.34	7.37	7.41	7.45	7.49	7.52	7.56	7.60	7.63	7.67
35	7.22	7.26	7.29	7.33	7.36	7.40	7.44	7.47	7.51	7.55
36	7.10	7.14	7.17	7.21	7.25	7.28	7.32	7.35	7.39	7.43
37	6.99	7.02	7.06	7.10	7.13	7.17	7.20	7.24	7.27	7.31
38	6.88	6.91	6.95	6.98	7.02	7.05	7.09	7.12	7.16	7.19
39	6.77	6.80	6.84	6.87	6.91	6.94	6.98	7.01	7.05	7.08
40	6.66	6.70	6.73	6.77	6.80	6.84	6.87	6.90	6.94	6.97
41	6.56	6.59	6.63	6.66	6.70	6.73	6.76	6.80	6.83	6.86
42	6.46	6.49	6.53	6.56	6.59	6.63	6.66	6.69	6.73	6.76
43	6.36	6.39	6.43	6.46	6.49	6.52	6.56	6.59	6.62	6.66
44	6.26	6.29	6.33	6.36	6.39	6.42	6.46	6.49	6.52	6.56
45	6.17	6.20	6.23	6.26	6.29	6.33	6.36	6.39	6.42	6.46
46	6.07	6.10	6.13	6.17	6.20	6.23	6.26	6.29	6.33	6.36
47	5.98	6.01	6.04	6.07	6.10	6.14	6.17	6.20	6.23	6.26
48	5.89	5.92	5.95	5.98	6.01	6.04	6.07	6.10	6.14	6.17
49	5.79	5.83	5.86	5.89	5.92	5.95	5.98	6.01	6.04	6.07

(4th of 4)

Appendix 2. Table of Dissolved Ozone Concentrations (ppm) in water

Temperature, °C, in left-hand column; total pressure, kPa, on top row.

100 kPa = 1 bar = 1000 mbar = 750.1 Torr = 750.1 mm Hg = 29.53 inches Hg = 0.987 Atm = 14.5 psi

T/P	90	92	94	96	98	100	102	104	106	108	110
0	7.864	8.038	8.213	8.388	8.563	8.737	8.912	9.087	9.262	9.436	9.611
1	7.613	7.782	7.951	8.120	8.289	8.459	8.628	8.797	8.966	9.135	9.305
2	7.372	7.535	7.699	7.863	8.027	8.191	8.355	8.518	8.682	8.846	9.010
3	7.140	7.298	7.457	7.616	7.774	7.933	8.092	8.250	8.409	8.568	8.726
4	6.917	7.071	7.224	7.378	7.532	7.685	7.839	7.993	8.147	8.300	8.454
5	6.702	6.851	7.000	7.149	7.298	7.447	7.596	7.745	7.894	8.043	8.192
6	6.496	6.640	6.785	6.929	7.073	7.218	7.362	7.507	7.651	7.795	7.940
7	6.297	6.437	6.577	6.717	6.857	6.997	7.137	7.277	7.417	7.557	7.697
8	6.106	6.242	6.378	6.513	6.649	6.785	6.920	7.056	7.192	7.328	7.463
9	5.922	6.054	6.185	6.317	6.449	6.580	6.712	6.843	6.975	7.107	7.238
10	5.745	5.873	6.000	6.128	6.256	6.383	6.511	6.639	6.766	6.894	7.022
11	5.574	5.698	5.822	5.946	6.070	6.194	6.317	6.441	6.565	6.689	6.813
12	5.410	5.530	5.650	5.770	5.890	6.011	6.131	6.251	6.371	6.492	6.612
13	5.251	5.368	5.484	5.601	5.718	5.834	5.951	6.068	6.185	6.301	6.418
14	5.098	5.211	5.325	5.438	5.551	5.665	5.778	5.891	6.004	6.118	6.231
15	4.951	5.061	5.171	5.281	5.391	5.501	5.611	5.721	5.831	5.941	6.051
16	4.809	4.915	5.022	5.129	5.236	5.343	5.450	5.557	5.663	5.770	5.877
17	4.671	4.775	4.879	4.983	5.087	5.190	5.294	5.398	5.502	5.606	5.709
18	4.539	4.640	4.741	4.842	4.942	5.043	5.144	5.245	5.346	5.447	5.548
19	4.441	4.509	4.607	4.705	4.803	4.901	4.999	5.097	5.195	5.294	5.392
20	4.288	4.383	4.479	4.574	4.669	4.764	4.860	4.955	5.050	5.146	5.241
21	4.169	4.262	4.354	4.447	4.539	4.632	4.725	4.817	4.910	5.003	5.095
22	4.054	4.144	4.234	4.324	4.414	4.504	4.594	4.685	4.775	4.865	4.955
23	3.943	4.031	4.118	4.206	4.293	4.381	4.469	4.556	4.644	4.731	4.819
24	3.836	3.921	4.006	4.091	4.177	4.262	4.347	4.432	4.517	4.603	4.688
25	3.732	3.815	3.898	3.981	4.064	4.147	4.229	4.312	4.395	4.478	4.561
26	3.632	3.712	3.793	3.874	3.954	4.035	4.116	4.197	4.277	4.358	4.439
27	3.535	3.613	3.692	3.770	3.849	3.928	4.006	4.085	4.163	4.242	4.320
28	3.441	3.518	3.594	3.671	3.747	3.823	3.900	3.976	4.053	4.129	4.206
29	3.350	3.425	3.499	3.574	3.648	3.723	3.797	3.872	3.946	4.021	4.095
30	3.263	3.335	3.408	3.480	3.553	3.625	3.698	3.770	3.843	3.915	3.988
31	3.178	3.249	3.319	3.390	3.461	3.531	3.602	3.672	3.743	3.814	3.884
32	3.096	3.165	3.234	3.302	3.371	3.440	3.509	3.578	3.646	3.715	3.784
33	3.017	3.084	3.151	3.218	3.285	3.352	3.419	3.486	3.553	3.620	3.687
34	2.940	3.005	3.070	3.136	3.201	3.266	3.332	3.397	3.462	3.528	3.593
35	2.865	2.929	2.993	3.056	3.120	3.184	3.247	3.311	3.375	3.438	3.502
36	2.793	2.855	2.917	2.979	3.041	3.103	3.166	3.228	3.290	3.352	3.414
37	2.723	2.784	2.844	2.905	2.965	3.026	3.086	3.147	3.207	3.268	3.328
38	2.656	2.715	2.774	2.833	2.892	2.951	3.010	3.069	3.128	3.187	3.246
39	2.590	2.648	2.705	2.763	2.820	2.878	2.935	2.993	3.050	3.108	3.166
40	2.527	2.583	2.639	2.695	2.751	2.807	2.863	2.920	2.976	3.032	3.088
41	2.465	2.520	2.574	2.629	2.684	2.739	2.794	2.848	2.903	2.958	3.013
42	2.405	2.459	2.512	2.566	2.619	2.672	2.726	2.779	2.833	2.886	2.940
43	2.347	2.399	2.452	2.504	2.556	2.608	2.660	2.712	2.765	2.817	2.869
44	2.291	2.342	2.393	2.444	2.495	2.546	2.597	2.648	2.698	2.749	2.800
45	2.237	2.286	2.336	2.386	2.435	2.485	2.535	2.585	2.634	2.684	2.734
46	2.184	2.232	2.281	2.329	2.378	2.426	2.475	2.524	2.572	2.621	2.669
47	2.133	2.180	2.227	2.275	2.322	2.369	2.417	2.464	2.512	2.559	2.606
48	2.083	2.129	2.175	2.222	2.268	2.314	2.360	2.407	2.453	2.499	2.546
49	2.034	2.080	2.125	2.170	2.215	2.261	2.306	2.351	2.396	2.441	2.487

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Instrument LCD message entries in **bold**
Illustration entries in *italics*