A Badger Meter® Brand

Water Quality Monitor

Model Q45D/60 2-Wire Dissolved Oxygen Transmitter



Badger Meter

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User Manual

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INTRODUCTION

General

The Model Q45D/60 is a highly versatile online monitoring system designed for the continuous measurement of dissolved oxygen in solution. The full scale operating range of the system, 0…40 ppm, and the sensing system operates on water streams with temperatures ranging from 0…50° C.

The basic sensing element used in the dissolved oxygen monitor is a galvanic membrane sensor which measures oxygen directly.

Q45D monitors are available in three electronic versions: a loop-powered 2-wire transmitter, a dual AA battery operated portable unit with two voltage outputs, and a 5…17V DC externally powered unit with two voltage outputs. This manual refers to the loop-powered 2-wire transmitter version.

Standard System

The standard model Q45D/60 system includes two components: the Q45D analyzer and a dissolved oxygen sensor. For connection of the sensor to the electronics, a 25 foot cable is supplied. Up to an additional 1000 feet of interconnect cable may be added using part number 07-0100 junction box. All required spare parts are also provided with the basic system, including spare membranes, electrolyte, O-rings and any special hardware.

Features

- Standard Q45D/60 transmitters are fully isolated, loop-powered instruments for 2-wire DC applications.
- High accuracy, high sensitivity system measures from 0.1…40.0 ppm through two internal automatic ranges.
- *Output Hold, Output Simulate, Output Alarm* and *Output Delay* functions. All forced changes in output condition include bumpless transfer to provide gradual return to online signal levels and to avoid system control shocks on both analog outputs.
- Selectable PID controller on main analog output. PID controller can operate with instrument configured as loop-power.
- Large, high contrast, custom LCD display with LED backlight provides excellent readability in any light conditions. The secondary line of display uses 5 × 7 dot matrix characters for clear message display. Two of four measured parameters may be on the display simultaneously.
- Diagnostic messages provide a clear description of any problem with no confusing error codes to look up. Messages are also included for diagnosing calibration problems.
- Quick and easy one-point calibration method, air calibration method and sensor zero-cal. To provide high accuracy, all calibration methods include stability monitors that check temperature and main parameter stability before accepting data.
- High accuracy three-wire Pt100 temperature input. Temperature element can be user calibrated.
- Security lock feature to prevent unauthorized tampering with transmitter settings. All settings can be viewed while locked, but they cannot be changed.



Equipment bearing this marking may not be discarded by traditional methods in the European community after August 12, 2005, per EU Directive 2002/96/EC. End users must return old equipment to the manufacturer for proper disposal.

Q45D/60 System Specifications

Displayed Parameters	Main input, 0.1…40.0 ppm %Saturation, 0…999.9% Sensor temperature, –10.0…50.0° C (14…122° F) Sensor signal, –40…2000 mV DC Loop current, 4.00…20.00 mA Sensor slope/offset Model number and software version PID Controller Status
Main Parameter Ranges	Manual selection of one of the following display ranges: 0.00…40.00 ppm 0.00…40.00 mg/L 0.0…999.9% Saturation
Display	0.75 in. (19.05 mm) high 4-digit main display with sign 12-digit secondary display, 0.30 in. (7.62 mm) 5 × 7 dot matrix
Keypad	4-key membrane type with tactile feedback, polycarbonate with UV coating.
Weight	1 lb (0.45 kg)
Ambient Temperature	Analyzer Service, –20…60° C (–4…140° F) Sensor Service, –5…55° C (23…131° F) Storage, –5…70° C (23…158° F)
Ambient Humidity	0…95%, indoor/outdoor use, non-condensing to rated ambient temperature range
Altitude	Up…2000 m (6562 ft)
Electrical Certification	Ordinary location, cCSAus (certified to both CSA and UL standards), pollution degree 2, installation category 2
EMI/RFI Influence	Designed to EN 61326-1
Output Isolation	600V galvanic isolation
Filter	Adjustable 0…9.9 minutes additional damping to 90% step input
Temperature Input	Pt1000 RTD with automatic compensation
Sensor	2-electrode galvanic membrane sensor for direct measurement of oxygen
Sensor Materials	Noryl, PVC and stainless steel
Sensor Cable	Submersible: 15 ft (4.6 m) or 30 ft (9.1 m) Flow Sensor: 25 ft (7.6 m) cable with 6-pin plug
Max. Sensor-to-Analyzer Distance	1000 ft (305 m), with junction box
Power	16…35V DC
Enclosure	NEMA 4X, polycarbonate, stainless steel hardware, weatherproof and corrosion resistant, HWD: 4.40 in. (111.76 mm) x 4.40 in. (111.76 mm) x 3.50 in. (88.90 mm)
Mounting Options	Wall or pipe mount bracket standard. Bracket suitable for either 1.50 in. or 2.00 in. I.D. U-bolts for pipe mounting.
Conduit Openings	Two PG-9 openings with gland seals
DC Cable Type	Belden twisted-pair, shielded, 22 gauge or larger
Insertion Loss	16V DC

Q45D/60 Performance Specifications

Accuracy	0.2% of selected range or better
Repeatability	0.05% of selected range or better
Sensitivity	0.05% of selected range
Non-Linearity	0.1% of selected range
Warm-Up Time	3 seconds to rated performance (electronics only)
Supply Voltage Effects	±0.05% span
Instrument Response Time	60 seconds to 90% of step input at lowest damping

ANALYZER MOUNTING

General

All Q45 Series instruments offer maximum mounting flexibility. A bracket is included with each unit that allows mounting to walls or pipes. In all cases, choose a location that is readily accessible for calibrations. Also consider that it may be necessary to use a location where solutions can be used during the calibration process. To take full advantage of the high contrast display, mount the instrument in a location where the display can be viewed from various angles and long distances.

Locate the instrument in close proximity to the point of sensor installation—this allows easy access during calibration. The sensor-to-instrument distance should not exceed 100 feet. To maximize signal-to-noise ratio however, work with the shortest sensor cable possible. The standard cable length of the oxygen sensor is 25 feet.

See *Figure 1* and *Figure 2 on page 8* for detailed dimensions of each type of system.

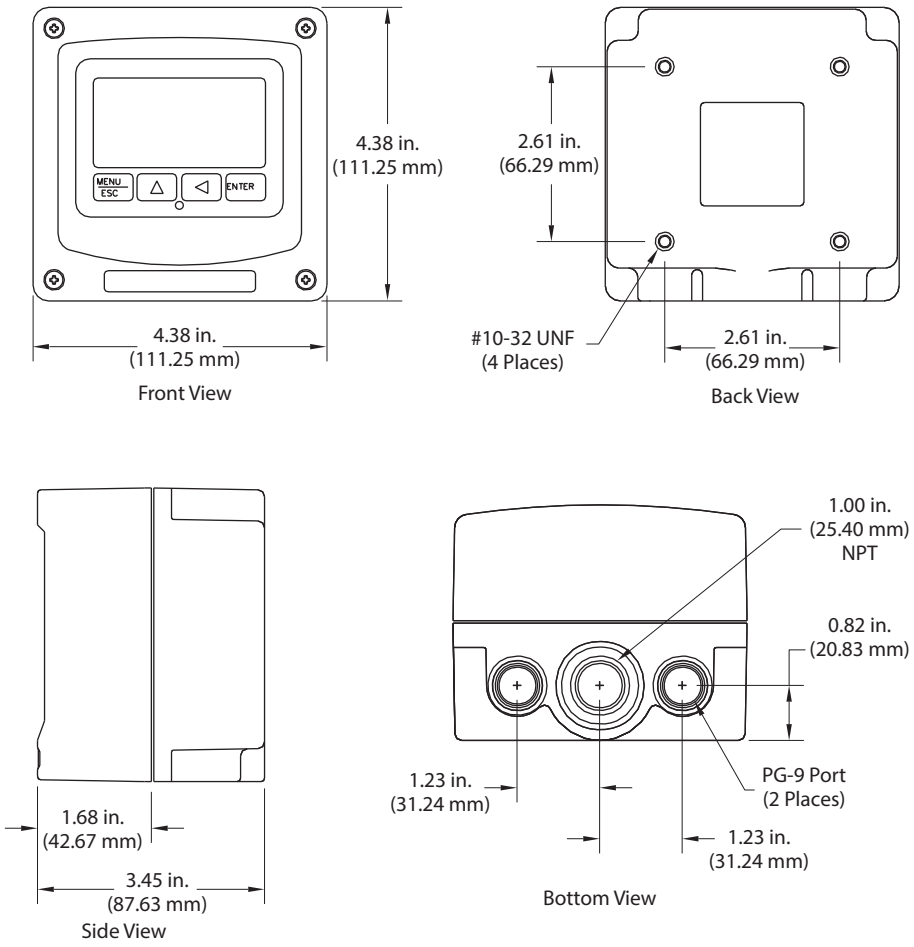


Figure 1: Enclosure dimensions

Wall or Pipe Mount

A PVC mounting bracket with attachment screws is supplied with each transmitter. See *Figure 2* for dimensions. The multipurpose bracket is attached to the rear of the enclosure using the four flat head screws. The instrument is then attached to the wall using the four outer mounting holes in the bracket. These holes are slotted to accommodate two sizes of U-bolts that may be used to pipe mount the unit. Slots accommodate U-bolts designed for 1-1/2 or 2 inch pipe. The actual center to center dimensions for the U-bolts are shown in *Figure 2*.

NOTE: These slots are for U-bolts with 1/4-20 threads. The 1-1/2 inch pipe U-bolt (2 inch I.D. clearance) is available from Badger Meter in type 304 stainless steel (part number 47-0005).

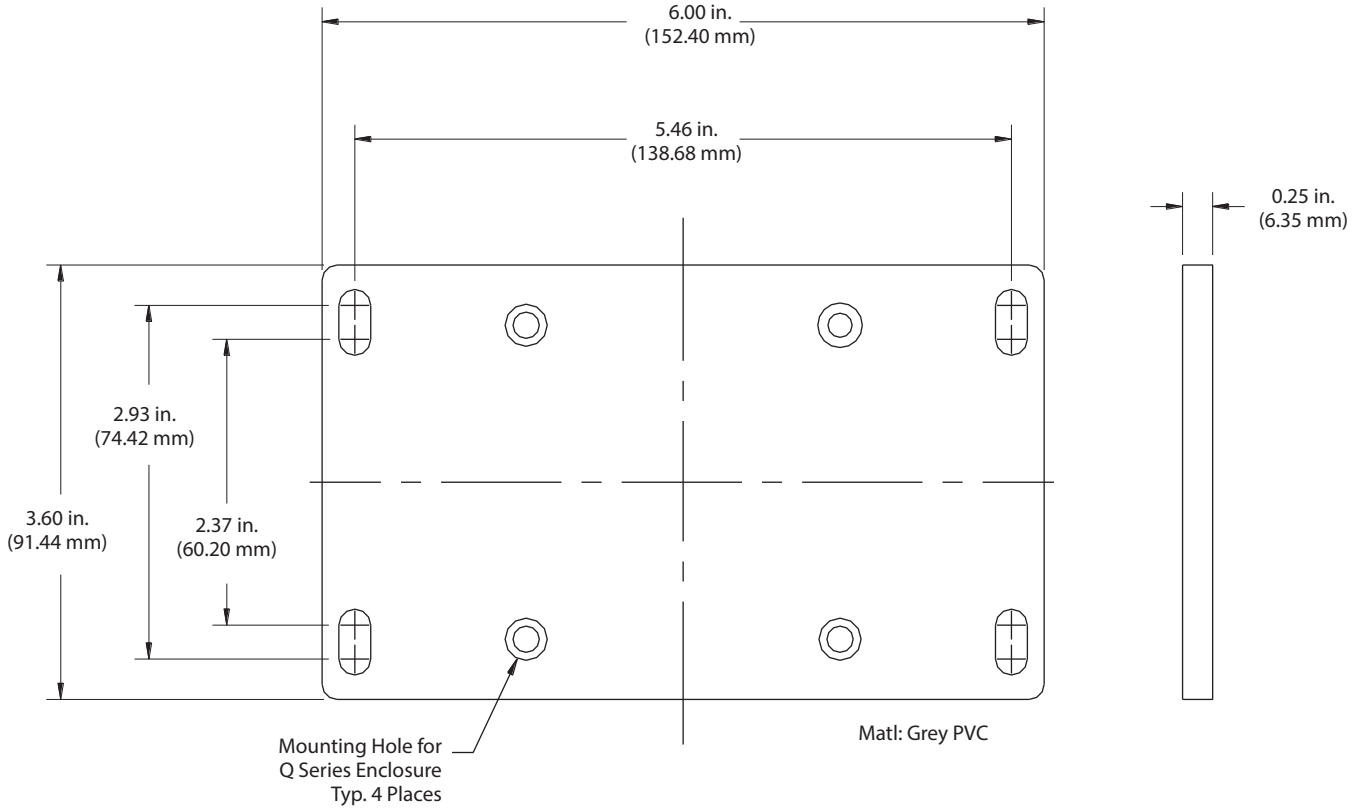


Figure 2: Wall or pipe mount bracket

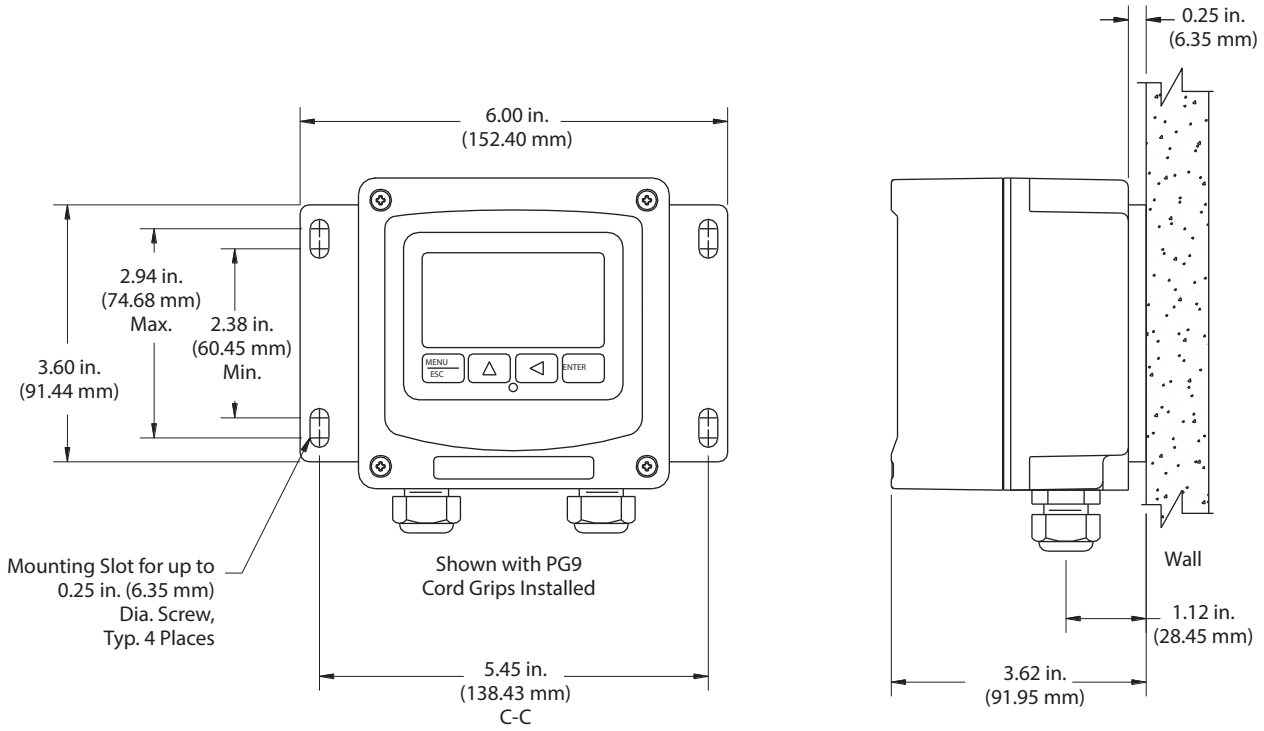
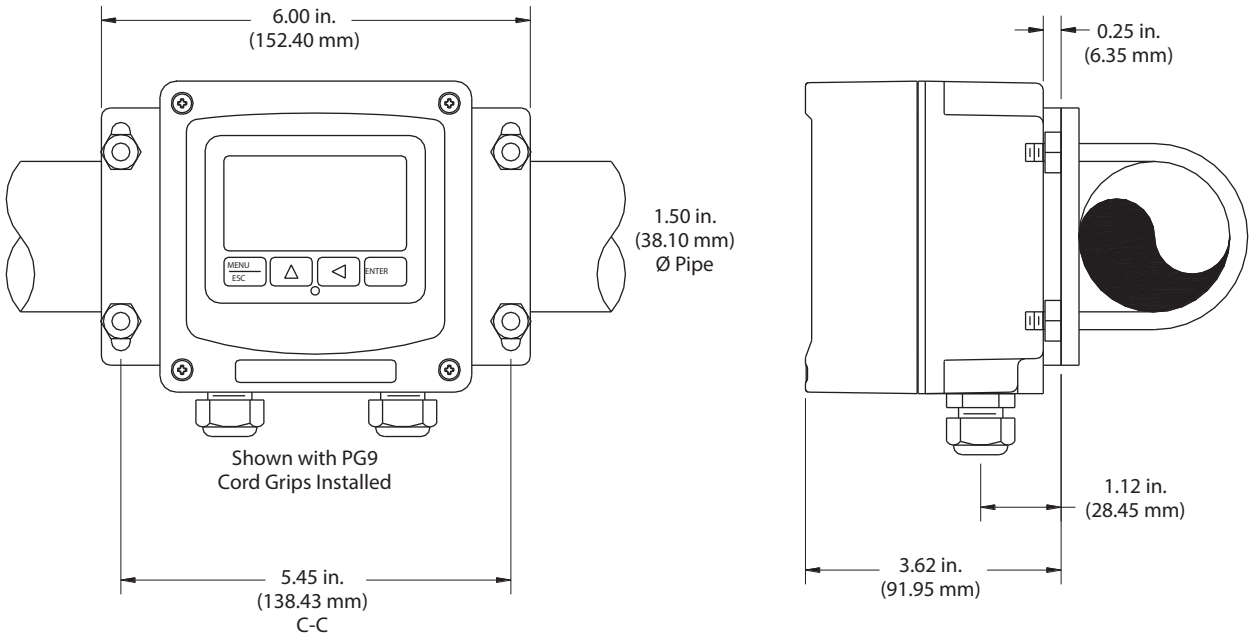


Figure 3: Wall mounting diagram



NOTE: Mounting plate hole spacing can support up to 2.00 in. (50.80 mm) Ø pipe max.

Figure 4: Pipe mounting diagram

SENSOR MOUNTING

General

Select a location within the maximum sensor cable length for mounting of the sensor. Locating the sensor within 25 feet of the transmitter is generally preferred for ease of operation and calibration.

Submersion Mounting

Most applications for dissolved oxygen (D.O.) monitoring are done using a submersible sensor. This method can be used where flow is reasonably constant and hydraulic head does not vary more than about 10 feet. Oxygen sensors can never be used in completely stagnant conditions. A flow velocity of at least 0.3 feet per second is normally required for measurement.

Submersible sensors are mounted to a 1 in. pipe using a standard 1 in. PVC thread by thread pipe coupling. The mounting pipe can be secured to standard 1-1/2 in. or 2 in. pipe rail using a mounting bracket kit available from Badger Meter (part number 00-0628) as shown in *Figure 5*.

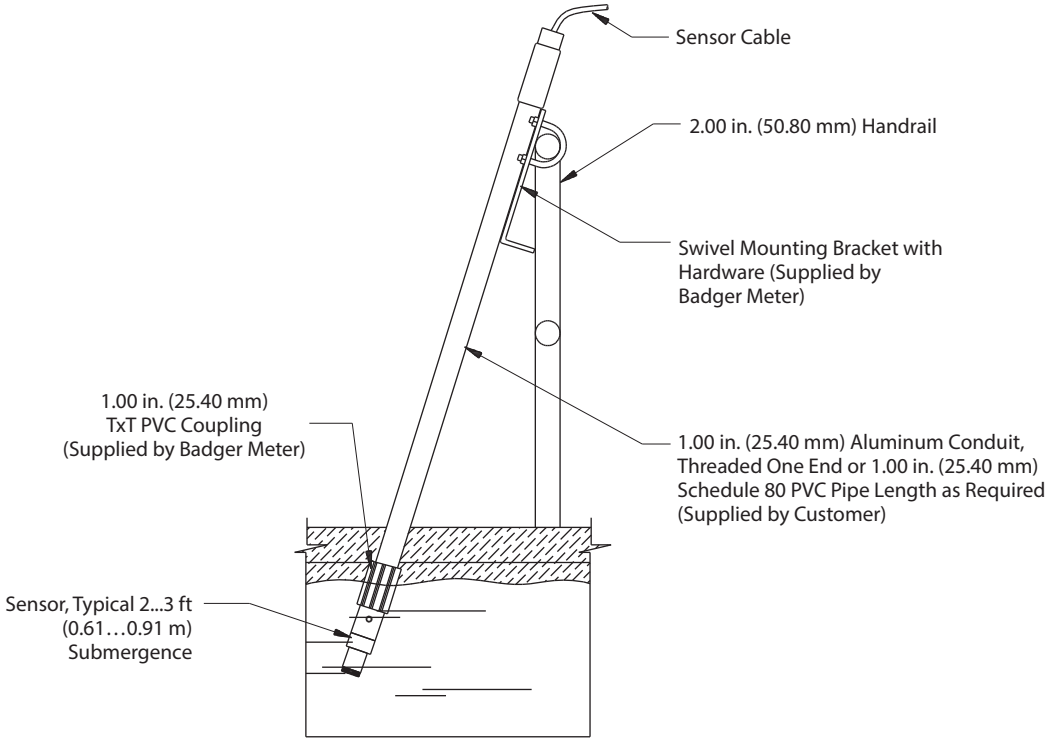


Figure 5: Submersible sensor mounting

Flowcell Mounting

For applications requiring measurement in a flowing water line, a flowcell assembly and a flow-type sensor should be used. Two flowcell types are available. Applications that allow an open flow system can best be satisfied using the constant-head flowcell (part number 00-0043). This flowcell is open to atmosphere and the drain is a gravity drain that must go to waste.

For applications where inline measurement is required, flowcell (part number 00-1522) should be used. This flowcell allows pressurized sample to flow to the sensor but provision must be made for controlling the flow at 300…500 cc/min. Sample pressure can be variable provided pressure changes are relatively slow. Rapid pressure changes cause a spike in the measured D.O. value.

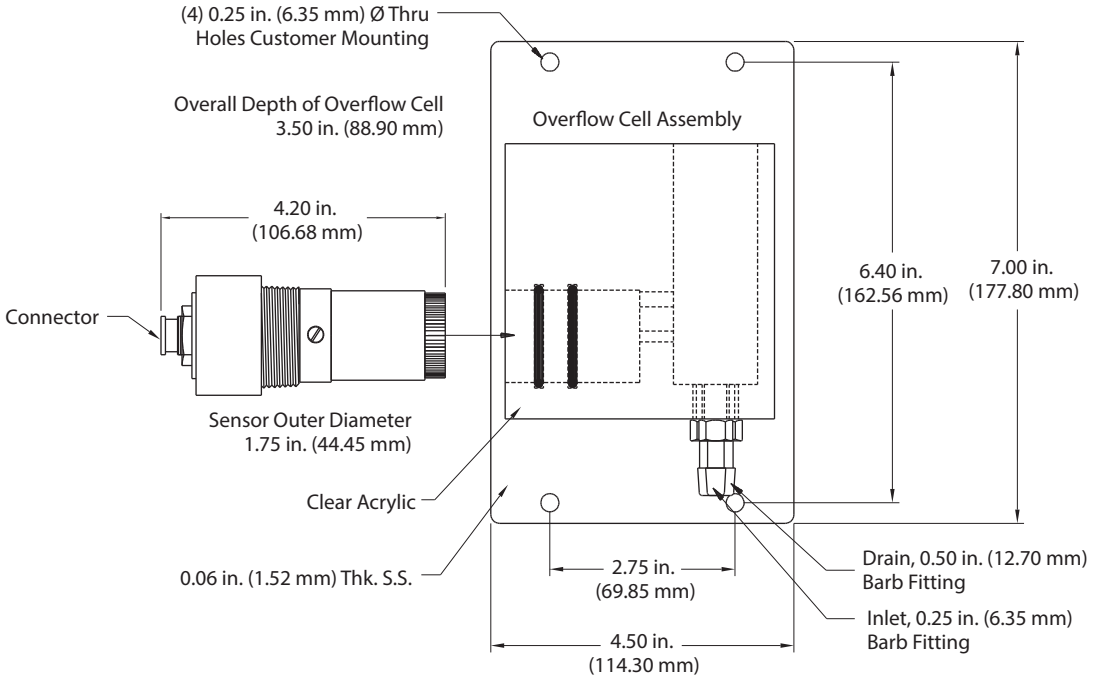


Figure 6: Constant-head flowcell

Sealed Flowcell

Applications where the sample inlet flow is well controlled can use a simpler sealed flowcell. Using this flowcell requires that flow be controlled externally to about 400 cc/min. Variable flow rate or variable pressure causes unstable readings in this flowcell. Badger Meter offers a special flow control element (part number 55-0048) that can be used ahead of this flowcell on the incoming sample line. It controls the inlet flow rate at 400 cc/min. with inlet pressure variations from 5…150 PSIG. A 50 micron y-strainer ahead of the flow control element is recommended. The sealed flowcell provides a drain vent with check valve to avoid pulling a vacuum on the flow chamber.

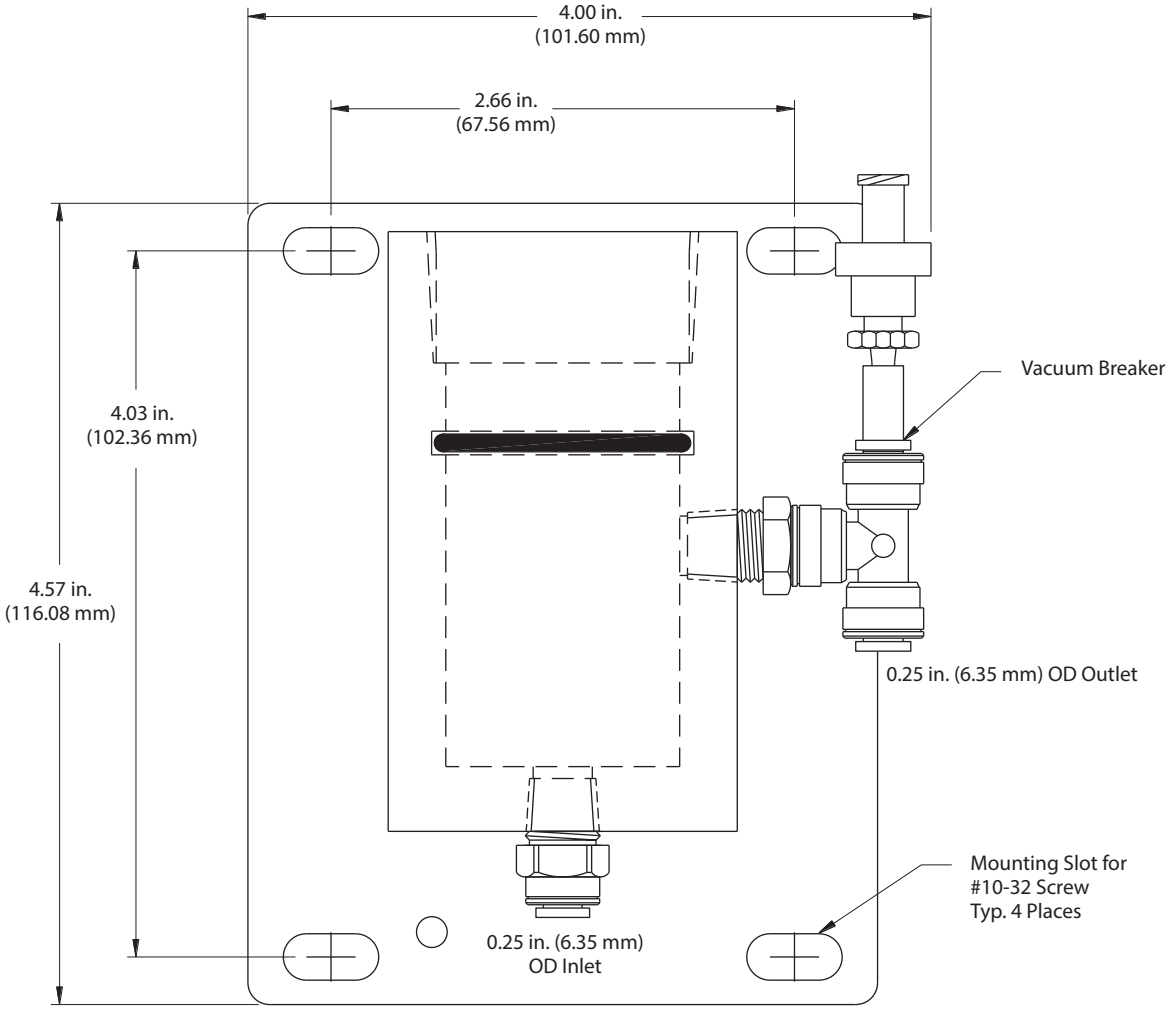


Figure 7: Sealed flowcell

ELECTRICAL INSTALLATION

General

The Q45 is powered in one of three ways, depending on the version purchased. The 2-wire version is a 16…35V DC powered transmitter. The battery powered unit is supplied with two C cell batteries. The 5…17V DC externally powered transmitter is designed for low power operation for solar power applications. Please verify the type of unit before connecting any power.

⚠ WARNING

DO NOT CONNECT AC LINE POWER TO THE 2-WIRE MODULE. SEVERE DAMAGE COULD RESULT.

IMPORTANT NOTES:

1. Use wiring practices that conform to all national, state and local electrical codes. For proper safety as well as stable measuring performance, it is important that the earth ground connection be made to a solid ground point from Terminal 12 (see *Figure 8 on page 14*).
2. Do NOT run sensor cables or instrument 4…20 mA output wiring in the same conduit that contains AC power wiring. AC power wiring should be run in a dedicated conduit to prevent electrical noise from coupling with the instrumentation signals.
3. This analyzer must be installed by specifically trained personnel in accordance with relevant local codes and instructions contained in this operating manual. Observe the analyzer's technical specifications and input ratings.

Two-Wire

In the two-wire configuration, a separate DC power supply must be used to power the instrument. The exact connection of this power supply is dependent on the control system into which the instrument connects. See *Figure 8* for further details. Any twisted pair shielded cable can be used for connection of the instrument to the power supply. Route signal cable away from AC power lines, adjustable frequency drives, motors or other noisy electrical signal lines. Do not run sensor or signal cables in conduit that contains AC power lines or motor leads.

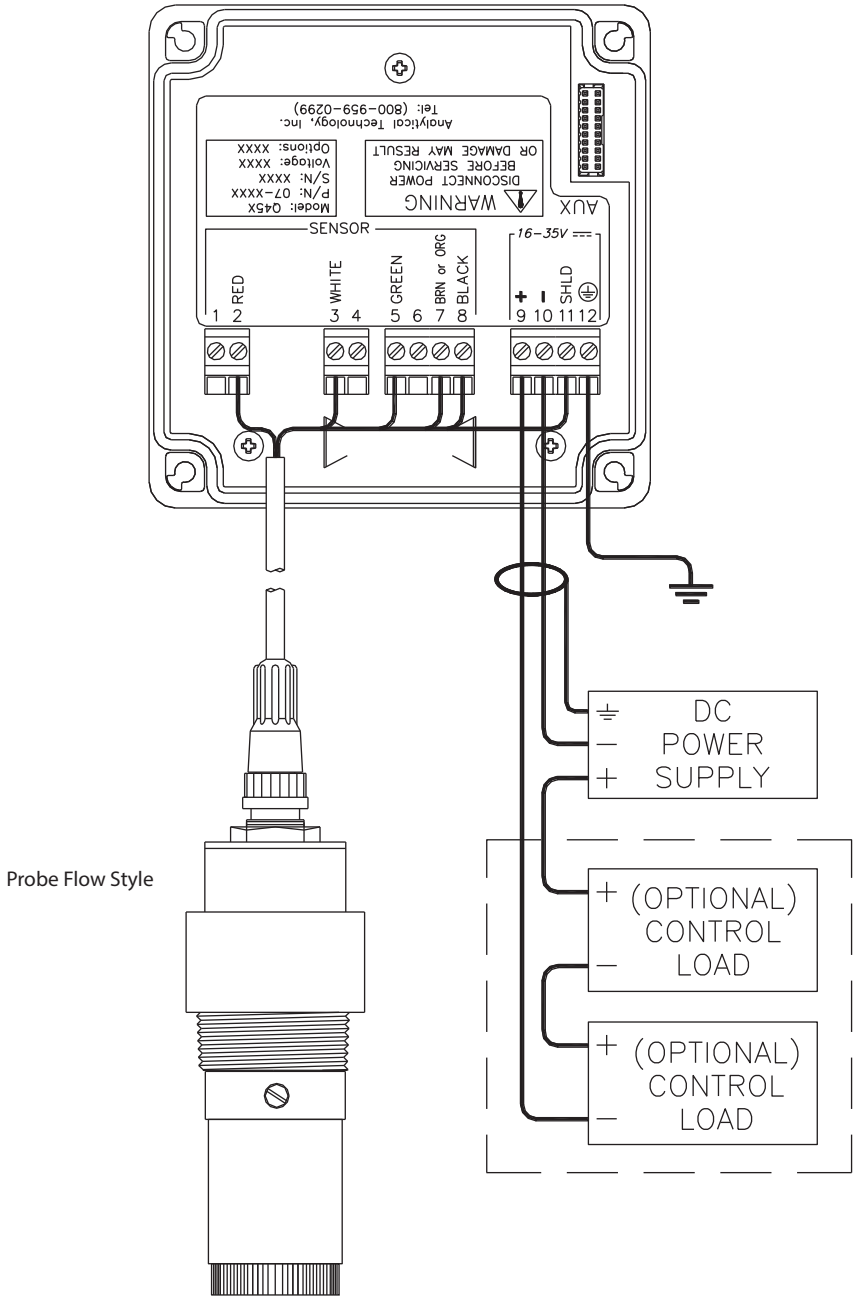


Figure 8: Loop-power connection

NOTE: Voltage between Terminals 9 and 10 MUST be between 16…35V DC.

NOTE: Earth ground into Terminal 12 is HIGHLY recommended. This connection can greatly improve stability in electrically noisy environments.

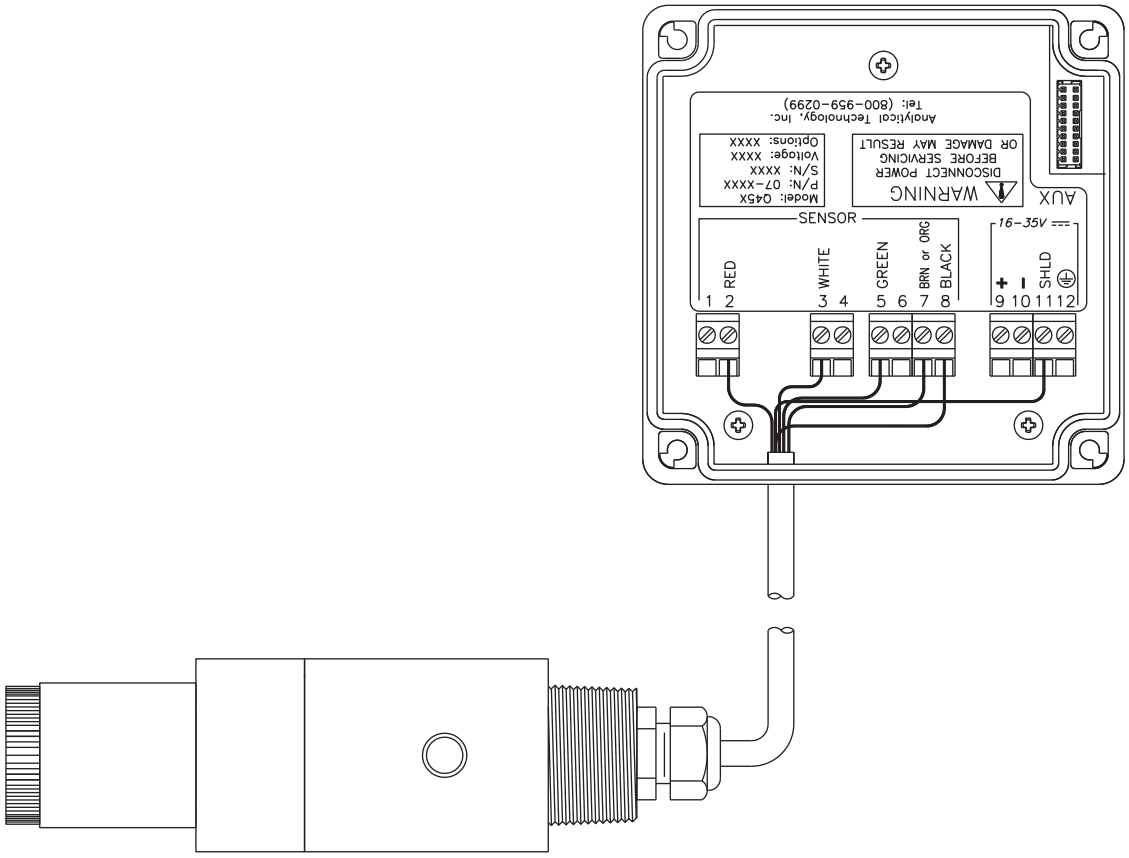


Figure 9: Submersible sensor connection

Load Drive

In the two-wire configuration, the load-drive level is dependent on the DC supply voltage provided to the controller.

The two-wire instrument can operate on a power supply voltage between 16…35V DC. The available load drive capability can be calculated by applying the formula:

V/I=R, where V=load drive voltage, I=maximum loop current (in Amperes) and R=maximum resistance load (in Ohms).

To find the load drive voltage of the two-wire Q45, subtract 16V DC from the actual power supply voltage being used (the 16V DC represents insertion loss). For example, if a 24V DC power supply is being used, the load drive voltage is 8V DC.

The maximum loop current of the two-wire Q45 is always 20.00 mA, or .02 A. Therefore:

$$\frac{\textbf{(Power Supply Voltage – 16)}}{\textbf{.02}} = \mathbf{R_{MAX}}$$

For example, if the power supply voltage is 24V DC, first subtract 16V DC and then divide the remainder by .02. **8/.02 = 400**; therefore, a 400 Ohms maximum load can be inserted into the loop with a 24V DC power supply.

Similarly, the following values can be calculated:

Power Supply Voltage	Total Load
16.0V DC	0 Ω
20.0V DC	200 Ω
24.0V DC	400 Ω
30.0V DC	700 Ω
35.0V DC	950 Ω

Sensor Wiring

The sensor cable can be quickly connected to the Q45 terminal strip by matching the wire colors on the cable to the color designations on the label in the monitor. A junction box is also available to provide a break point for long sensor cable runs. Route the signal cable away from AC power lines, adjustable frequency drives, motors or other noisy electrical signal lines. Do not run sensor or signal cables in conduit that contains AC power lines or motor leads.

Direct Sensor Connection

Sensor connections are made in accordance with *Figure 8 on page 14*. The sensor cable can be routed into the enclosure through one of the cord grips supplied with the unit. Routing sensor wiring through conduit is only recommended if a junction box is to be used. Some loose cable is needed near the installation point so that the sensor can be inserted and removed easily from the flowcell.

Cord grips used for sealing the cable should be snugly tightened after electrical connections have been made to prevent moisture incursion. When stripping cables, leave adequate length for connections in the transmitter enclosure as shown in *Figure 10*. The standard 25 foot sensor cable normally supplied with the system is already stripped and ready for wiring. This cable can be cut to a shorter length if desired to remove extra cable in a given installation. Do not cut the cable so short as to make installation and removal of the sensor difficult.

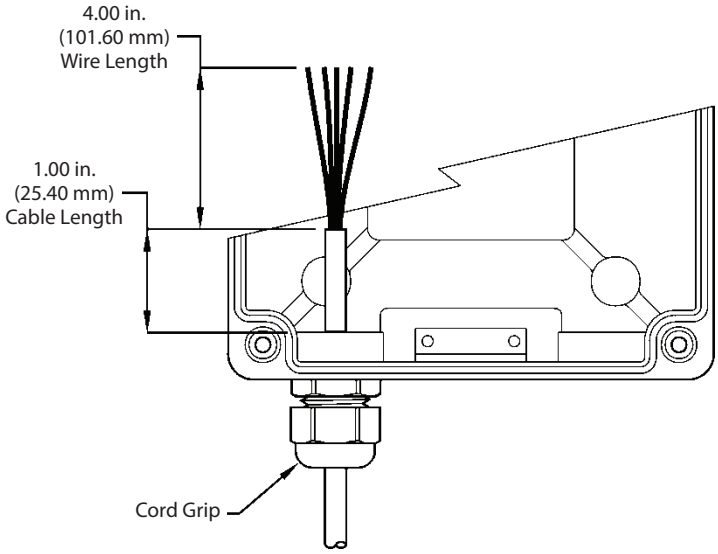


Figure 10: Sensor cable preparation

Once inside the enclosure, the individual colored sensor cable leads can be connected directly to the SENSOR connection terminals by matching the wire colors. On Q45D older systems, there may exist a YELLOW wire label on the sensor terminal strip rather than the wire color ORANGE or BROWN, which are used now. If your system has a YELLOW label, connect orange/brown from the sensor to that point.

Junction Box Connection

For installations where the sensor is to be located more than 25 feet from the monitor (max. 100 feet), a junction box must be used. The junction box is shown in *Figure 11* and is supplied with a 1/2 inch conduit hub on one end and a sensor cable gland on the other end.

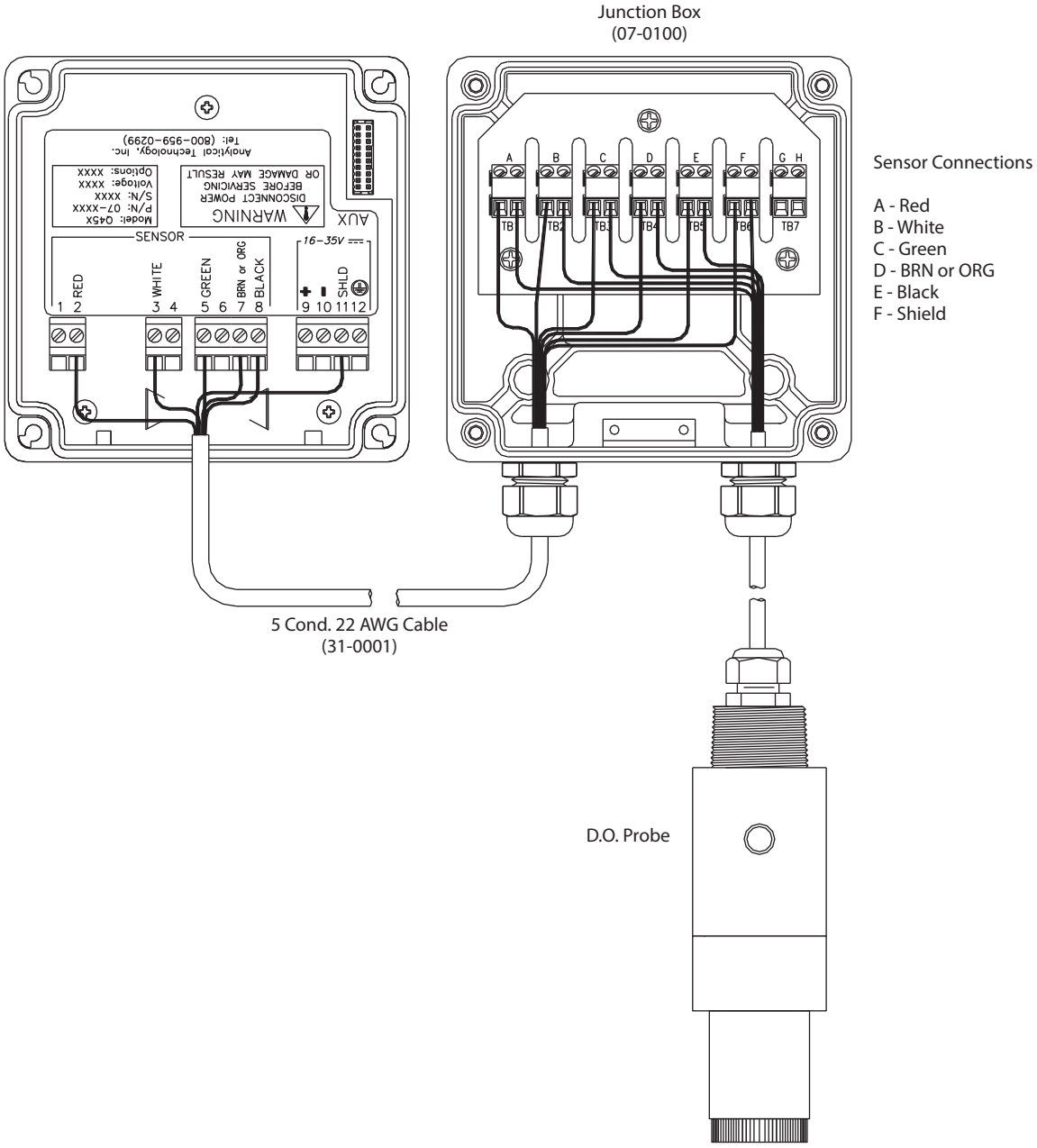


Figure 11: Junction box interconnect wiring

SENSOR ASSEMBLY

Oxygen Sensor Preparation

The oxygen sensor supplied with the Q45D transmitter is shipped dry. It does not operate until it is prepared by adding electrolyte and a membrane. Preparation of the sensor for operation must be done carefully. The procedure should be done by a qualified technician, and it should only be done when the system is ready for operation. Until then, it is best to leave the sensor in the condition in which it is received.

Submersible oxygen sensors are made up of two separate parts: a submersion holder that also contains the temperature compensating element and a sensing module. The sensing module screws into the holder, with an O-ring providing a water tight connection. *Figure 12* shows the assembly.

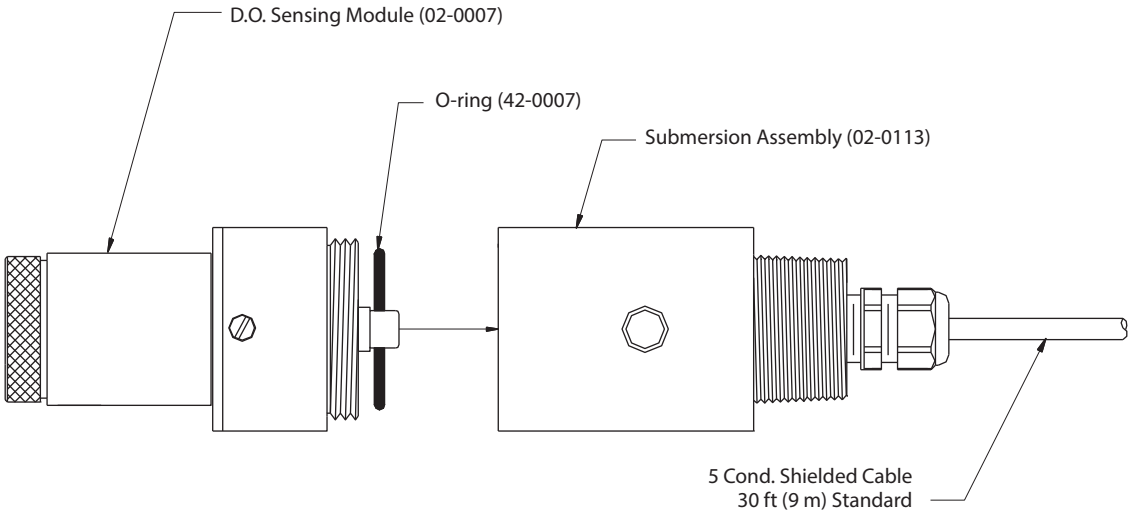


Figure 12: Submersible sensor assembly

Sensing modules contain the main measuring components and are the main component requiring service. *Figure 13* shows an exploded view of the D.O. sensing module.

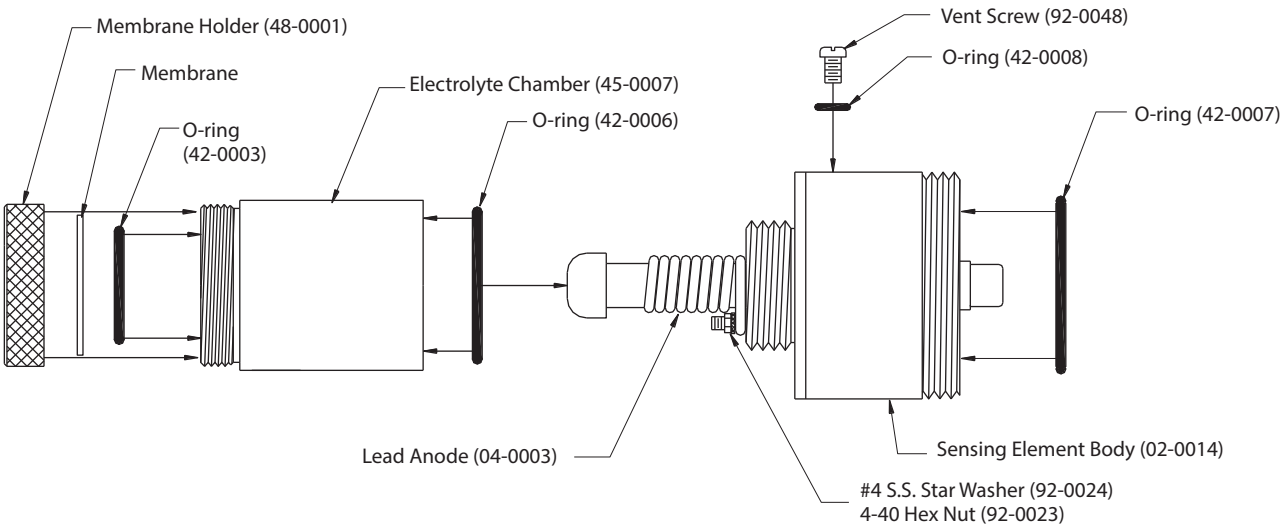


Figure 13: Submersible sensor module exploded view

Follow the procedure below to prepare the D.O. sensor module for operation:

1. Unscrew the electrolyte chamber from the assembled sensor and also remove the vent screw from the side of the sensor body.
2. Remove the front nut from the bottom of the chamber and discard the protective membrane. O-rings are contained in grooves on both the bottom and top of the chamber. Be sure that these O-rings remain in place.
3. From the package of membranes (either 2 mil or 5 mil) supplied with the sensor, place a new membrane into the front nut, holding the membrane by its edge to avoid fingerprint oil from contaminating the membrane. The membrane is clear and is separated from other membranes by a light blue paper spacer.
4. Screw the front nut on to the chamber until you feel the O-ring compress. Hand-tight compression is all that is needed. Do not use tools to tighten. The membrane should be flat across the bottom of the chamber without wrinkles.
5. Fill the chamber with electrolyte until the level reaches the bottom of the internal threads.
6. Slowly screw the chamber onto the sensor body. A small amount of electrolyte runs out of the hole from which the vent screw was removed. Place a paper towel around the sensor to absorb the electrolyte overflow. The electrolyte is harmless and does not irritate skin. Tighten the chamber until the O-ring at the top of the chamber is compressed. Once again, do not use tools to tighten.
7. Shake excess electrolyte from the vent hole on the side of the sensor and replace the vent screw.

The sensor is now ready for operation. The membrane should be stretched tightly across the tip of the sensor.

⚠CAUTION

WHEN HANDLING THE ASSEMBLED SENSOR, DO NOT SET THE SENSOR ON ITS TIP OR DAMAGE TO THE MEMBRANE COULD RESULT. SEVERE IMPACTS ON THE TIP OF THE SENSOR FROM DROPPING OR OTHER MISUSE MAY CAUSE PERMANENT DAMAGE TO THE SENSOR.

Flow Type D.O. Sensor

The D.O. sensor designed for use in flow applications is similar in construction to *Figure 13 on page 20*. The method for sensor preparation is basically the same as described in *"Oxygen Sensor Preparation" on page 19*.

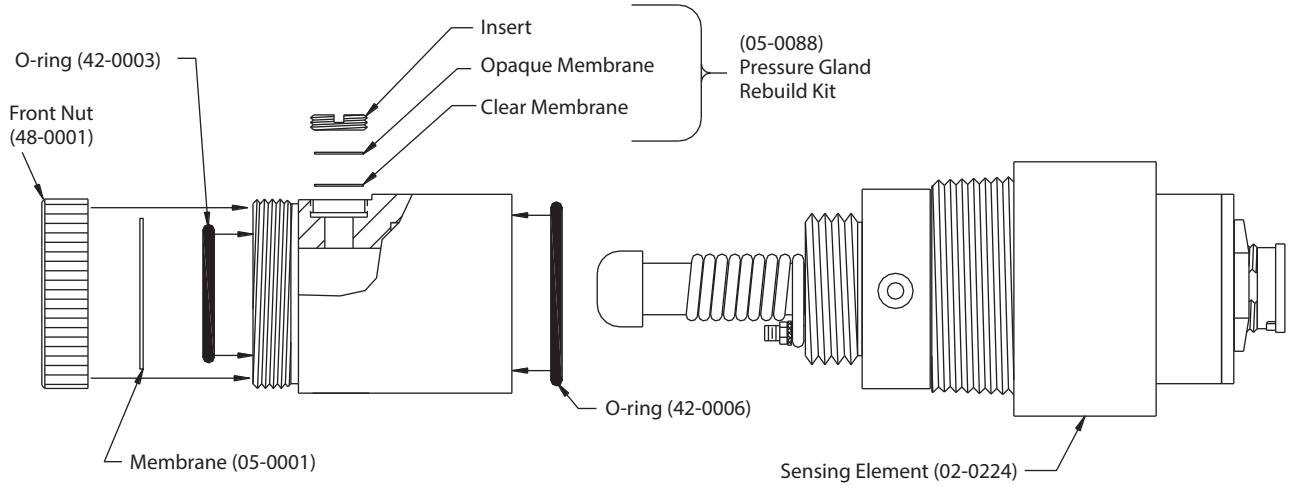


Figure 14: Flow type D.O. sensor assembly

CONFIGURATION

User Interface

The user interface for the Q45 Series instrument consists of a custom display and a membrane keypad. All functions are accessed from this user interface (no internal jumpers or pots, for example).

When power is first applied, you may notice the display does not turn on immediately. This is normal. There is a 5 second start routine that runs before the display illuminates. In addition, you may notice an occasional "flicker" of the display, occurring about twice an hour. This is the result of a display processor refresh program that provides long-term display integrity and always occurs during normal operation of the instrument.

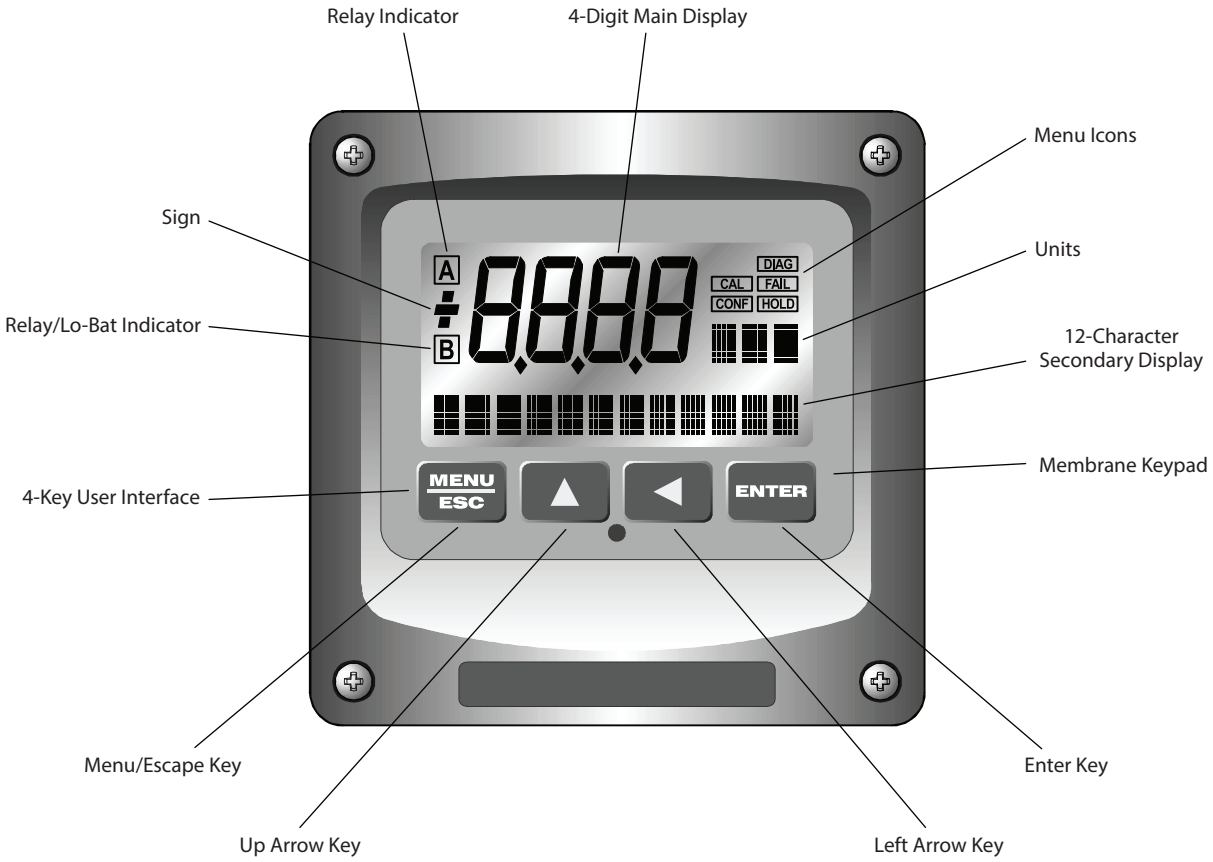


Figure 15: User interface

Keys

All user configurations occur through the use of four membrane keys. These keys are used as follows:

MENU/ESC	Scroll through the menu section headers or to escape from anywhere in software. The escape sequence allows the user to back out of any changes in a logical manner. Using the escape key aborts all changes to the current screen and backs the user out one level in the software tree. The manual refers to this key as either MENU or ESC, depending upon its particular function. In the battery-powered version of the Q45, this is also the ON button.
UP (arrow)	Scroll through individual list or display items and change number values.
LEFT (arrow)	Move the cursor from right to left during changes to a number value.
ENTER	Select a menu section or list item for change and to store any change.

Display

The large custom display provides clear information for general measurement use and user configuration. There are three main areas of the display: the main parameter display, the secondary message line and the icon area.

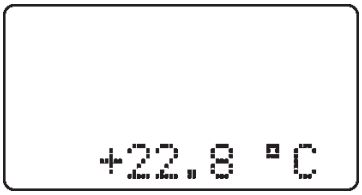
Main Parameter

During normal operation, the main parameter display indicates the present process input with sign and units. This main display may be configured to display any of the main measurements that the system provides. During configuration, this area displays other useful set-up information to the user.



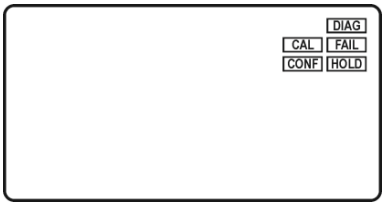
Lower Line

During normal operation, the lower line of the display indicates user-selected secondary measurements that the system is making. This also includes calibration data from the last calibration sequence and the transmitter model number and software version. During configuration, the lower line displays menu items and set-up prompts to the user. Finally, the lower line displays error messages when necessary. For a description of all display messages, see *"Display Messages" on page 41*.



Icon Area

The icon area contains display icons that assist the user in setup and indicate important states of system functions. The *CAL*, *CONFIG* and *DIAG* icons are used to tell the user what branch of the software tree the user is in while scrolling through the menu items. This improves software map navigation. Upon entry into a menu, the title is displayed (such as *CAL*), and then the title disappears to make way for the actual menu item. However, the icon stays on.



HOLD

The *HOLD* icon indicates that the current output of the transmitter has been put into output hold. In this case, the output is locked to the last input value measured when the *HOLD* function was entered. *HOLD* values are retained even if the unit power is cycled.

FAIL

The *FAIL* icon indicates the system diagnostic function has detected a problem that requires immediate attention. This icon is automatically cleared once the problem has been resolved.

Software

The software of the Q45D transmitter is organized in an easy to follow menu-based system. All user settings are organized under five menu sections: *Measure, Calibration [CAL], Configuration [CONFIG], Control [CONTROL]* and *Diagnostics [DIAG]*.

NOTE: The default *Measure* menu is display-only and has no menu icon.

Software Navigation

Within the *CAL, CONFIG, CONTROL* and *DIAG* menu sections is a list of selectable items. Once a menu section (such as *CONFIG*) has been selected with the MENU key, the user can access the item list in this section by pressing either the **ENTER** key or the **UP** arrow key. The list items can then be scrolled through using the **UP** arrow key. Once the last item is reached, the list wraps around and the first list item is shown again. The items in the menu sections are organized such that more frequently used functions are first, while more permanent function settings are later in the list. See *Figure 16 on page 25* for a visual description of the software.

Each list item allows a change to a stored system variable. List items are designed in one of two forms: simple single variable, or multiple variable sequence. In the single variable format, the user can quickly modify one parameter. For example, changing temperature display units from °F to °C. In the multiple variable sequence, variables are changed as the result of some process. For example, the calibration of oxygen generally requires more than one piece of information to be entered. The majority of the menu items in the software consist of the single variable format type.

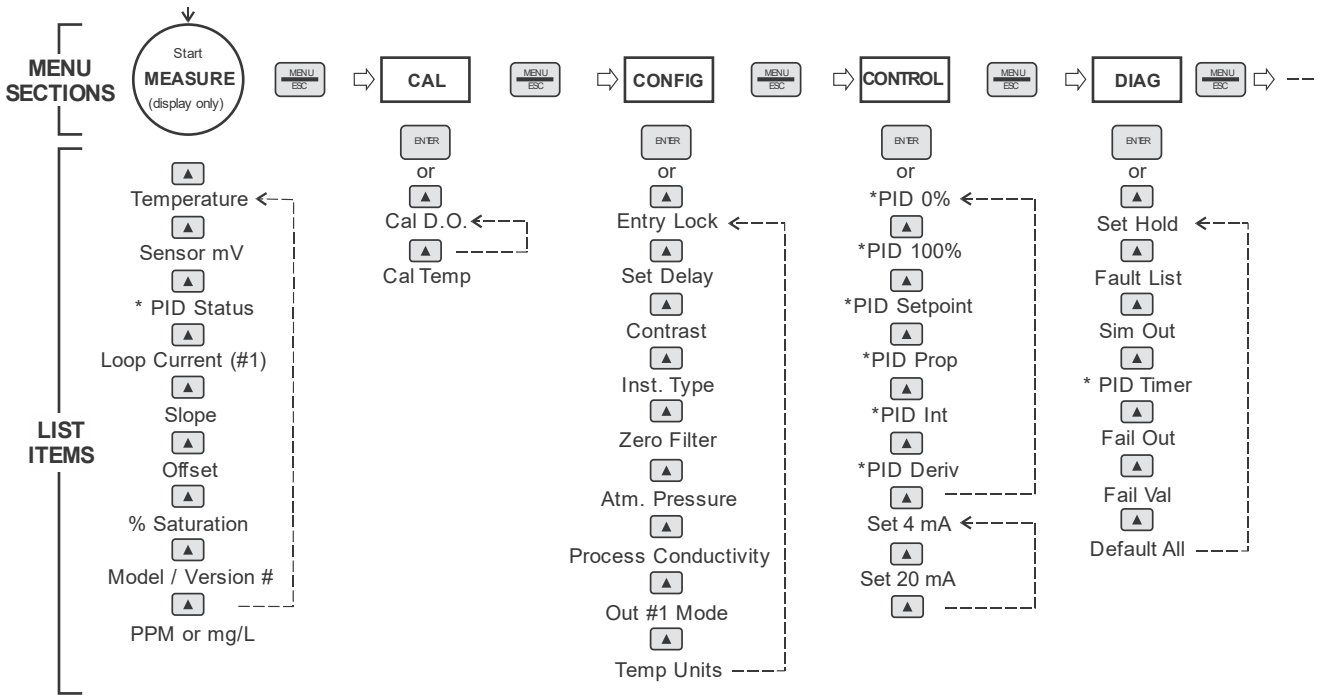
Any data that may be changed flashes. This flashing indicates *User Entry* mode and is initiated by pressing the **ENTER** key. The **UP** arrow key increases a flashing digit from 0…9. The **LEFT** arrow key moves the flashing digit from right to left. Once the change has been completed, pressing **ENTER** again stores the variable and stops the flashing. Pressing **ESC** aborts the change and also exits *User Entry* mode.

The starting (default) screen is always the *Measure* menu. The **UP** arrow key is used to select the desired display. From anywhere in this section the user can press the **MENU** key to select one of the four menu sections.

The UP arrow icon next to all list items on the display is a reminder to scroll through the list using the **UP** arrow key.

To select a list item for modification, first select the proper menu with the **MENU** key. Scroll to the list item with the **UP** arrow key and then press the **ENTER** key. This tells the system that the user wishes to perform a change on that item. For single item type screens, once the user presses the **ENTER** key, part or all of the variable begins to flash, indicating that the user may modify that variable using the arrow keys. However, if the instrument is locked, the transmitter displays the message "Locked!" and does not enter *User Entry* mode. The instrument must be unlocked by entering the proper code value to allow authorized changes to user entered values. Once the variable has been reset, pressing the **ENTER** key again causes the change to be stored and the flashing to stop. The message "Accepted!" displays if the change is within pre-defined variable limits. If the user decides not to modify the value after it has already been partially changed, pressing the **ESC** key aborts the modification and returns the entry to its original stored value.

In a menu item that is a multiple variable sequence type, once the **ENTER** key is pressed there may be several prompts and sequences that are run to complete the modification. The **ESC** key can always be used to abort the sequence without changing any stored variables.



* If PID is enabled on Iout1

NOTE: Some menu items are dependent on specifications in other menus. Therefore see appropriate text descriptions for details.

Figure 16: Software map

Measure Menu [MEASURE]

The default menu for the system is the display-only menu *MEASURE*. This menu is a display-only measurement menu and has no changeable list items. When left alone, the instrument automatically returns to this menu after approximately 30 minutes. While in the default menu, the **UP** arrow allows the user to scroll through the secondary variables on the lower line of the display. A brief description of the fields in the basic transmitter version is as follows:

Transmitter Measure Screens:

25.7° C Temperature display. Can be displayed in °C or °F, depending on user selection. A small "m" on the left side of the screen indicates the transmitter has automatically jumped to a manual 25° C setting due to a failure with the temperature signal input.

320 mV Raw sensor signal. Useful for diagnosing problems.

100% 20.00 mA *PID Status* screen (if enabled) shows the present controller output level on the left and actual transmitter current on the right. The controller can be placed in manual while viewing this screen by pressing and holding the **ENTER** key for 5 seconds until a small flashing "m" appears on the screen. At that point the controller output can be adjusted up or down using the **UP** and **LEFT** arrow keys. To return to automatic operation, press and hold the **ENTER** key for 5 seconds and the "m" disappears.

20.00 mA Transmitter output current.

Slope = 100% Sensor output response vs. ideal calibration. This value updates after each calibration. As the sensor ages, the slope reading decays indicating sensor aging. Useful for resolving sensor problems.

Offset = 0.0 mV Sensor output signal at a zero ppm input. This value updates after a zero calibration has been performed. Useful for resolving sensor problems.

% Saturation The most common display of D.O. in water is either PPM or mg/L units. However, the same PPM value at different water temperatures can represent quite different concentrations of oxygen in terms of the percent of saturation. This display simply indicates the % of oxygen saturation represented by the current PPM or mg/L display.

Q45D v4.02 Transmitter software version number.

0.00 PPM D.O. reading in PPM (or mg/L if selected under "Instr Type")

NOTE: A display test (all segments ON) can be actuated by pressing and holding the **ENTER** key while viewing the model/version number on the lower line of the display.

The *MEASURE* screens are intended to be used as a very quick means of looking up critical values during operation or troubleshooting.

Calibration Menu [CAL]

The *Calibration* menu contains items for frequent calibration of user parameters. There are two items in this list: *Cal D.O.* and *Cal Temp*.

Cal D.O. The oxygen calibration function allows the user to adjust the transmitter span reading to match a reference solution or to set the sensor zero point. See *"Calibration" on page 31* for more details.

Cal Temp The temperature calibration function allows the user to adjust the offset of the temperature response by a small factor of ±5° C. The temperature input is factory calibrated to very high accuracy. However, long cable lengths and junction boxes may degrade the accuracy of the temperature measurement in some extreme situations. Therefore, this feature is provided as an adjustment. See *"Calibration" on page 31* for more details.

Configuration Menu [CONFIG]

The *Configuration* menu contains all of the general user settings:

Entry Lock This function allows the user to lock out unauthorized tampering with instrument settings. All settings may be viewed while the instrument is locked, but they cannot be modified. The *Entry Lock* feature is a toggle-type setting. That is, entering the correct code locks the transmitter and entering the correct code again unlocks it. The code is preset at a fixed value. Press **ENTER** to initiate *User Entry* mode and the first digit flashes. Use the arrow keys to modify value. See *page 45* for the Q45D lock/unlock code. Press **ENTER** to toggle lock setting once code is correct. Incorrect codes do not change state of lock condition.

Set Delay The delay function sets the amount of damping on the instrument. This function allows the user to apply a first order time delay function to the oxygen measurements being made. Both the display and the output value are affected by the degree of damping. Functions such as calibration are not affected by this parameter. The calibration routines contain their own filtering and stability monitoring functions to minimize the calibration timing. Press **ENTER** to initiate *User Entry* mode and the value flashes. Use the arrow keys to modify value; range is 0.1…9.9 minutes. Press **ENTER** to store the new value.

Contrast This function sets the contrast level for the display. The custom display is designed with a wide temperature range, Super-Twist Nematic (STN) fluid.

The STN display provides the highest possible contrast and widest viewing angle under all conditions. Contrast control of this type of display is generally not necessary, so contrast control is provided as a means for possible adjustment due to aging at extreme ranges. In addition, the display has an automatic temperature compensation network. Press **ENTER** to initiate *User Entry* mode and the value flashes. Use the arrow keys to modify the value; range is 0…8 (0 being lightest). Press **ENTER** to update and store the new value.

Instr Type This function allows the user to change the type of measurement to be displayed in the primary display area. The user may select "1 PPM", "2 mg/L" or "3 %Sat". There is not a great deal of difference between type 1 and 2 settings as PPM and mg/L measurement units are pretty close to the same. However, programming for type 3 percent saturation changes the measured parameter to read a dissolved oxygen value that represents the percent of oxygen saturation at a given temperature. When this unit of measurement is selected, the main analog output and all alarm and control functions relates to this measurement. While a PPM measurement is displayed on the lower line, it is no longer the primary variable being measured by the system. Press **ENTER** to initiate *User Entry* mode and the selected value flashes. Use the **UP** arrow key to modify the desired display value. Press **ENTER** to store the new value.

Zero Filter The Q45D allows the user to program a value near zero below which the monitor reads zero. Because sensors rarely have a perfect zero stability, this zero filter eliminates occasional displays of numbers that are not meaningful. For instance, setting a zero filter at 0.03 PPM D.O. causes any measured values of 0.01 or 0.02 PPM to be displayed as 0.00 PPM.

Atm Pres The Q45D instrument uses the atmospheric pressure value as an input for the calculation of a theoretical ppm value during a saturation calibration. The input default units are in Hg (inches Mercury) since these units are easy to obtain from most local weather services. This value is only required to be entered during initial installation. It does not need to be modified at every calibration. Press **ENTER** to initiate *User Entry* mode and the entire value flashes. Use the arrow keys to modify the value; range is 20.00…31.50 in Hg.

A reference table is provided in *"Barometric Pressure Conversion" on page 43* to convert to Hg from several other common air pressure units. Press **ENTER** to store the new value.

Proc Cond The Q45D instrument also uses the process conductivity value as an input for the calculation of a theoretical ppm value during a saturation calibration. This value is only required to be entered during initial installation. It does not need to be modified at every calibration. Press **ENTER** to initiate *User Entry* mode and the value flashes. Use the arrow keys to modify the value; range is 0.00…76.00 mS/cm. Press **ENTER** to store the new value.

NOTE: If the solution conductivity does not change dramatically during the calibration process, leave a default setting of 00.50 mS/cm. For ultrapure water applications, set this value to 0.00. For sea water applications, set this value to 53.00.

Iout#1 Mode This function sets analog Output #1 to either track PPM, mg/L, oxygen (default), % Saturation, or enables the PID controller to operate on the oxygen input in either PPM, mg/L or % Saturation. Press **ENTER** to initiate *User Entry* mode and the entire value flashes. Use the **UP** arrow key to modify the desired value. Selections include 1 – for oxygen tracking or 2 – PID for oxygen PID control. Press **ENTER** to store the new value.

Temp Units This function sets the display units for temperature measurement. Press **ENTER** to initiate *User Entry* mode and the entire value flashes. Use the **UP** arrow key to modify the desired display value. The choices are **°F** and **°C**. Press **ENTER** to store the new value.

Control Menu

The *Control* menu contains all of the output control user settings.

Set 4 mA
Set 20 mA
[Iout1=D.O.]

These functions set the main 4 and 20 mA current loop output points for the transmitter. The units displayed depend on the selection made in the *CONFIG* menu for *Iout #1* mode.

The value stored for the 4 mA point may be higher or lower than the value stored for the 20 mA point. The entry values are limited to values within the range specified in "Set Range." The 4 mA and the 20 mA point must be separated by at least 1% of this range. Use the **LEFT** arrow key to select the first digit to be modified. Then use the **UP** and **LEFT** arrow keys to select the desired numerical value. Press **ENTER** to store the new value.

Set PID 0%
Set PID 100%
[Iout1=PID]

If the PID is enabled, this function sets the minimum and maximum controller end points. Unlike the standard 4…20 mA output, the controller does not "scale" output values across the endpoints. Rather, the endpoints determine where the controller would normally force minimum or maximum output in an attempt to recover the setpoint (even though the controller can achieve 0% or 100% anywhere within the range).

If the 0% point is lower than the 100% point, then the controller action is "reverse" acting. That is, the output of the controller increases if the measured value is less than the setpoint, and the output decreases if the measured value is larger than the setpoint. Flipping the stored values in these points reverses the action of the controller to "direct" mode.

The entry value is limited to a value within the range specified in "Set Range." The 0% and the 100% point must be separated by at least 1% of this range. Use the **LEFT** arrow key to select the first digit to be modified. Then use the **UP** and **LEFT** arrow keys to select the desired numerical value. Press **ENTER** to store the new value.

PID Setpnt
[Iout1=PID]

PID Setpnt is the measured value which the controller is attempting to maintain by adjusting output value. It is the nature of the PID controller that it never actually gets to the exact value and stops. The controller is continually making smaller and smaller adjustments as the measured value gets near the setpoint.

PID Prop
[Iout1=PID]

Proportional gain factor. The proportional gain value is a multiplier on the controller error (difference between measured value and setpoint value). Increasing this value makes the controller more responsive.

PID Int
[Iout1=PID]

Integral is the number of "repeats-per-minute" of the action of the controller. It is the number of times per minute that the controller acts on the input error. At a setting of 2.0 rpm, there are two repeats every minute. If the integral is set to zero, a fixed offset value is added to the controller (manual reset). Increasing this value makes the controller more responsive.

PID Deriv
[Iout1=PID]

Derivative is a second order implementation of Integral, used to suppress "second-order" effects from process variables. These variables may include items like pumps or mixers that may have minor impacts on the measured value. The derivative factor is rarely used in water treatment process, and therefore, it is best in most cases to leave it at the default value. Increasing this value makes the controller more responsive.

Diagnostics Menu [DIAG]

The *Diagnostics* menu contains all of the user settings that are specific to the system diagnostic functions, as well as functions that aid in troubleshooting application problems.

Set Hold

The *Set Hold* function locks the current loop output values on the present process value. This function can be used prior to calibration, or when removing the sensor from the process to hold the output in a known state. Once *HOLD* is released, the outputs return to their normal state of following the process input. The transfer out of *HOLD* is bumpless on both analog outputs. That is, the transfer occurs in a smooth manner rather than as an abrupt change. An icon on the display indicates the *HOLD* state, and the *HOLD* state is retained even if power is cycled. Press **ENTER** to initiate *User Entry* mode and the entire value flashes. Use the **UP** arrow key to modify the desired value, selections are **ON** for engaging the *HOLD* function and **OFF** to disengage the function. Press **ENTER** to store the new value.

The *Set Hold* function can also hold at an output value specified by the user. To customize the hold value, first turn the *HOLD* function on. Press the **ESC** key to go to the *DIAG* menu and scroll to *Sim Output* using the **UP** arrow key. Press **ENTER**. Follow the instructions under *"Sim Out"*

Fault List

The *Fault List* screen is a read-only screen that allows the user to display the cause of the highest priority failure. The screen indicates the number of faults present in the system and a message detailing the highest priority fault present.

NOTE: Some faults can result in multiple displayed failures due to the high number of internal tests occurring. As faults are corrected, they are immediately cleared.

Faults are not stored; therefore, they are immediately removed if power is cycled. If the problem causing the faults still exists, however, faults display again after power is re-applied and a period of time elapses during which the diagnostic system re-detects them. The exception to this rule is the calibration failure. When a calibration fails, no corrupt data is stored. Therefore, the system continues to function normally on the data that was present before the calibration was attempted.

After 30 minutes or if power to the transmitter is cycled, the failure for calibration clears until calibration is attempted again. If the problem still exists, the calibration failure reoccurs. Press **ENTER** to initiate view of the highest priority failure. The display automatically returns to normal after a few seconds.

PID Timer

This function sets a timer to monitor the amount of time the PID controller remains at 0% or 100%. This function only appears if the PID controller is enabled. If the timer is set to 0000, the feature is effectively disabled. If the timer value is set to any number other zero, a *FAIL* condition occurs if the PID controller remains at 0% or 100% for the timer value. If one of the relays is set to *FAIL* mode, this failure condition can be signaled by a changing relay contact.

Press **ENTER** to initiate *User Entry* mode and the entire value flashes. Use the **UP** arrow key to modify desired value; range of value is 0…9999 seconds. Press **ENTER** to store the new value.

Sim Out

The *Sim Out* function allows the user to simulate the oxygen level of the instrument in the user selected display range. The user enters a ppm value directly onto the screen, and the output responds as if it were actually receiving the signal from the sensor. This allows the user to check the function of attached monitoring equipment during setup or troubleshooting. Escaping this screen returns the unit to normal operation. Press **ENTER** to initiate the *User Entry* mode and the rightmost digit of the value flashes. Use the arrow keys to modify desired value.

The starting display value is the last read value of the input. The output is under control of the *SIM* screen until the **ESC** key is pressed.

NOTE: If the *HOLD* function is engaged before the *Sim Output* function is engaged, the simulated output remains the same even when the **ESC** key is pressed. Disengage the *HOLD* function to return to normal output.

Fail Out

This function enables the user to define a specified value that the main current output goes to under fault conditions. When the Relay Option Board is installed, the display reads "Fail Out #1." When enabled to **ON**, the output may be forced to the current value set in *Fail Val* (next item). With the *Fail Out* setting of ON and a *Fail Val* setting of 6.5 mA, any alarm condition causes the current loop output to drop outside the normal operating range to exactly 6.5 mA, indicating a system failure that requires attention.

Press **ENTER** to initiate *User Entry* mode and the entire value flashes. Use the **UP** arrow key to modify desired value. Selections are **ON**, **OFF**. Press **ENTER** to store the new value.

Fail Val

Sets the output failure value for Iout#1. When *Fail Out* above is set to **ON**, this function sets value of the current loop under a *FAIL* condition.

Press **ENTER** to initiate *User Entry* mode and the entire value flashes. Use the **UP** arrow key to modify desired value. Selections are between 4mA…20mA. Press **ENTER** to store the new value.

Default All

The *Default All* function allows the user to return the instrument back to factory default data for all user settings or for just the calibration default. It is intended to be used as a last resort troubleshooting procedure. All user settings or the calibration settings are returned to the original factory values. Hidden factory calibration data remains unchanged. Press **ENTER** to initiate *User Entry* mode and select either *CAL* or *ALL* with the **UP** arrow key. The default *CAL* routine resets the zero offset to 0.0 nA and resets the slope to 100%. The default *ALL* routine resets all program variables to factory default and should be used with care since it changes any user settings that were programmed in the field.

CALIBRATION

Oxygen Calibration

Once power is applied, the sensor must be given time to stabilize. This is best done by following the zeroing procedure below. Establishing a stable zero is critical to the proper operation of the monitor. A complete calibration includes zeroing and spanning the sensor. It is generally unnecessary to set the zero at every calibration, however, it should be done during the initial installation.

Oxygen Span Cal

The system provides three methods of D.O. calibration: 1-Point (sample), % Saturation (air cal) and Zero. These three methods are significantly different.

It is important to note that ONLY the air calibration method outlined in *"D.O. Air Span Cal (% sat)" on page 32* may be used to calibrate a D.O. monitor that has been programmed as "Instrument Type 3" in the *Configuration* menu. This type of instrument is designed to measure % Saturation and must be calibrated in air using ambient air as a 100% saturation standard.

D.O. Span Cal (1-spl)

The 1-point (sample or comparison) method is intended to be primarily used as an online calibration; however, the sensor can be removed, cleaned and then calibrated in a bucket of clean water, if necessary. During calibration, the system displays the current ppm reading and the user can manually enter a reference value from a lab sample or comparative reference instrument. In the Q45D system, the 1-point calibration adjusts the slope of the sensor output response.

1. Determine whether the calibration is done online or with the sensor removed and placed into a bucket of clean water. If the sensor is removed from the application, rinse and clean if necessary.
2. If the sensor has been removed and placed into a bucket of water, allow sensor to temperature equilibrate with the solution as much as possible. With the sensor coming from an application which differs greatly in temperature, the user may have to wait as much as 20 minutes. If the sensor is online, the user may want to set the output *HOLD* feature prior to calibration to lock out any output fluctuations.
3. Scroll to the *CAL* menu section using the **MENU** key and press **ENTER** or the **UP** arrow key. "Cal D.O." is displayed.
4. Press the **ENTER** key. The screen displays a flashing "1-spl" for 1-point sample, a "2-%sat" for saturation calibration or a "3-zer" for zero calibration. Using the **UP** arrow key, set a "1-spl" calibration and press **ENTER**.
5. The system now begins acquiring data for the calibration value. As data is gathered, the units for ppm and temperature may flash. Flashing units indicate that this parameter is unstable. The calibration data point acquisition stops only when the data remains stable for a pre-determined amount of time. This can be overridden by pressing **ENTER**. If the data remains unstable for 10 minutes, the calibration fails and the message "Cal Unstable" displays.
6. The screen displays the last measured ppm value and a message displays prompting the user for the lab value. The user must then modify the screen value with the arrow keys and press **ENTER**. The system then performs the proper checks.
7. If accepted, the screen displays the message "PASS" with the new slope reading, then returns to the main measurement display. If the calibration fails, a message indicating the cause of the failure is displayed and the "FAIL" icon turns on.

D.O. Air Span Cal (% sat)

D.O. Air Span Cal (% sat) is the recommended method for air temperatures greater than about 10° C. However, it requires that the sensor be removed from the process and cleaned. Once cleaned, the sensor is held in air and allowed time to adjust to the air temperature. As the sensor temperature equilibrates, the transmitter automatically calculates the new 100% saturation point using the temperature readings and the barometric pressure user data. See *"Barometric Pressure Conversion" on page 43*. This method therefore requires no user input during calibration.

NOTE: It is very important to allow enough time for the sensor to completely temperature equilibrate with the surrounding air. This time is at least 10 minutes.

This method requires that the sensor be removed from the process, cleaned and covered, shielding the sensor from direct sunlight. The sensor membrane must be dry for this procedure and not submerged in liquid. This method requires no user input during calibration; however, if this is the first time the system is being installed and calibrated, make sure to enter the proper atmospheric pressure data and process conductivity data prior to calibration.

1. Remove the sensor from the process. Clean and rinse if necessary with water, paying particular attention to cleaning the membrane.
2. Cover the sensor (if necessary) to shield it from the direct rays of the sun. Remember, the membrane must not be submerged. It must be in the air letting the sensor hang (membrane downward) while powered.
3. Allow the system to operate undisturbed for at least 20 minutes. If the system is stable, the value on the display increases to some ppm value and remains at that level. At that point, calibration can continue.
4. Scroll to the *CAL* menu section using the **MENU** key and press **ENTER** or the **UP** arrow key. "Cal D.O." is displayed.
5. Press the **ENTER** key. The screen displays a flashing "1-spl" for 1-point, a "2-%sat" for saturation air calibration or a "3-zer" for zero calibration. Using the **UP** arrow key, set for a "2-%sat" span calibration and press **ENTER**.
6. The display prompts the user to hold the sensor in air and press **ENTER**. If the sensor has already been removed from the process and reached temperature equilibrium, press the **ENTER** key.
7. The system now begins acquiring data for the calibration value. As data is gathered, the units for ppm and temperature may flash. Flashing units indicate that this parameter is unstable.
8. The calibration data point acquisition stops only when the data remains stable for a pre-determined amount of time (approximately 15…20 seconds). This can be overridden by pressing **ENTER**. If the data remains unstable for 10 minutes, the calibration fails and the message "Cal Unstable" displays.
9. If accepted, the screen displays the message "PASS" with the new sensor slope reading. Then it returns to the main measurement display. If the calibration fails, a message indicating the cause of the failure is displayed and the "FAIL" icon turns on.
10. The range of acceptable values for sensor slope is 20…250%. It may be necessary to rebuild the sensor as described in *"Sensor Assembly" on page 19*.

Should the slope value remain out of range and result in calibration failures, review the *"Troubleshooting" on page 39*, then contact Technical Support for further assistance.

Dissolved Oxygen Zero Cal

Dissolved oxygen sensors have extremely low offset outputs at zero. For this reason, it is normally sufficient to simply leave the zero at the factory default of 0 mV. As an alternative, an electronic zero can be set by disconnecting the sensor from the cable and performing the steps below.

The steps below assume that the sensor has been prepared in accordance with *"Sensor Assembly" on page 19*.

NOTE: The 10 hour waiting time in step 2 below is not required if the monitor has been running for 24 hours prior to zeroing. If the unit has been running with the sensor connected, the sensor normally returns to a stable zero within 15 minutes.

1. Remove the sensor from the application if necessary. Clean and rinse if required.
2. Place about an inch of zero solution in a small beaker or other convenient container and immerse the tip of the sensor. Allow the sensor to sit undisturbed for at least one hour. Suspend sensor, DO NOT LET SENSOR SIT ON TIP.
3. Scroll to the *CAL* menu section using the **MENU** key and press **ENTER** or the **UP** arrow key. "Cal D.O." is displayed.
4. Press the **ENTER** key. The screen displays a flashing "1-spl" for 1-point, a "2-%sat" for saturation air calibration or a "3-zer" for zero calibration. Press **ENTER**.
5. The system now begins acquiring data for the sensor zero calibration value. As data is gathered, the units for sensor millivolts (mV) and temperature may flash. Flashing units indicate that this parameter is unstable. The calibration data point acquisition stops only when the data remains stable for a pre-determined amount of time. This can be overridden by pressing **ENTER**. If the data remains unstable for 10 minutes, the calibration fails and the message "Cal Unstable" is displayed.
6. If accepted, the screen displays the message "PASS" with the new sensor zero reading (offset), then it returns to the main measurement display. If the calibration fails, a message indicating the cause of the failure is displayed and the "FAIL" icon turns on. The range of acceptable value for sensor offset is –40 mV…40 mV. Should a *FAIL* occur, carefully inspect the sensor for a tear in the membrane. It is probably necessary to rebuild the sensor as described in *"Sensor Assembly" on page 19*. Should the offset value remain high and result in calibration failures, review *"Troubleshooting" on page 39*, and then contact Technical Support at Badger Meter for further assistance.

   The sensor offset value in mV from the last zero calibration is displayed on the lower line of the *Default* menus for information purposes.

Temperature Calibration

The temperature calibration sequence is essentially a 1-point offset calibration that allows adjustments of approximately ±5° C.

The sensor temperature may be calibrated online, or the sensor can be removed from the process and placed into a known solution temperature reference. In any case, it is critical that the sensor be allowed to reach temperature equilibrium with the solution in order to provide the highest accuracy. When moving the sensor between widely different temperature conditions, it may be necessary to allow the sensor to stabilize as much as one hour before the calibration sequence is initiated. If the sensor is online, the user may want to set the output *HOLD* feature prior to calibration to lock out any output fluctuations.

1. Scroll to the *CAL* menu section using the **MENU** key and press **ENTER** or the **UP** arrow key.
2. Press the **UP** arrow key until "Cal Temp" is displayed.
3. Press the **ENTER** key. The message "Place sensor in solution then press ENTER" displays. Move the sensor into the calibration reference (if it hasn't been moved already) and wait for temperature equilibrium to be achieved. Press **ENTER** to begin the calibration sequence.
4. The calibration data gathering process begins. The message "Wait" flashes as data is accumulated and analyzed. The "°C" or "°F" symbol may flash periodically if the reading is too unstable.
5. The message "Adjust value - press ENTER" displays, and the rightmost digit begins to flash, indicating that the value can be modified. Using the **UP** and **LEFT** arrow keys, modify the value to the known ref solution temperature. Adjustments up to ±5° C from the factory calibrated temperature are allowed. Press **ENTER**.

Once completed, the display indicates "PASS" or "FAIL". If the unit fails, the temperature adjustment may be out of range, the sensor may not have achieved complete temperature equilibrium or there may be a problem with the temperature element. In the event of calibration failure, it is recommended to attempt the calibration again immediately.

PID CONTROLLER DETAILS

PID Description

PID control, like many other control schemes, are used in chemical control to improve the efficiency of chemical addition or control. By properly tuning the control loop that controls chemical addition, only the amount of chemical that is truly required is added to the system, saving money. The savings can be substantial when compared to a system that may simply be adding chemical at a constant rate to maintain some minimal addition under even the worst case conditions. The PID output controller is highly advantageous over simple control schemes that just use direct (proportional only) 4…20 mA output connections for control, since the PID controller can automatically adjust the "rate" of recovery based on the error between the setpoint and the measured value—which can be a substantial efficiency improvement.

The PID controller is basically designed to provide a "servo" action on the 4…20 mA output to control a process. If the user requires that a measured process stay as close as possible to a specific setpoint value, the controller output changes from 0…100% in an effort to keep the process at the setpoint. To affect this control, the controller must be used with properly selected control elements (valves or proper chemicals, for example) that enable the controller to add or subtract chemical rapidly enough. This is not only specific to pumps and valves, but also to line sizes or delays in the system, for example.

This section is included to give a brief description of tuning details for the PID controller and is not intended to be an exhaustive analysis of the complexities of PID loop tuning. Numerous sources are available for specialized methods of tuning that are appropriate for a specific application.

PID Algorithm

As most users of PID controllers realize, the terminology for the actual algorithm terms and even the algorithms themselves can vary between different manufacturers. This is important to recognize as early as possible, since just plugging in similar values from one controller into another can result in dramatically different results. There are various basic forms of PID algorithms that are commonly seen. The implementation here is the most common version (the ISA algorithm, commonly referred to as the "ideal" algorithm).

$$output = P\left[e(t) + \frac{1}{I}\int e(t)d(t) + D\frac{de(t)}{dt}\right]$$

Where:

output =	controller output
P =	proportional gain
I =	integral gain
D =	derivative gain
t =	time
e(t) =	controller error (e=measured variable – setpoint)

Figure 17: ISA PID Equation

The most notable feature of the algorithm is the fact the proportional gain term affects all components directly (unlike some other algorithms, like the "series" form). If a pre-existing controller uses the same form of the algorithm shown above, it is likely similar settings can be made if the units on the settings are exactly the same. Be careful of this, as many times the units are the reciprocals of each other (that is, reps-per-min, sec-per-rep).

PID stands for "proportional, integral, derivative." These terms describe the three elements of the complete controller action, and each contributes a specific reaction in the control process. The PID controller is designed to be primarily used in a "closed-loop" control scheme, where the output of the controller directly affects the input through some control device, such as a pump or valve, for example.

Although the three components of the PID are described in the setting area *"Control Menu" on page 28*, here are more general descriptions of what each of the PID elements contribute to the overall action of the controller.

P Proportional gain. With no "I" or "D" contribution, the controller output is simply a factor of the proportional gain multiplied by the input error (difference between the measured input and the controller setpoint). Because a typical chemical control loop cannot react instantaneously to a correction signal, proportional gain is typically not efficient by itself—it must be combined with some integral action to be useful. Set the "P" term to a number between 2…4 to start. Higher numbers cause the controller action to be quicker.

I Integral gain. Integral gain is what allows the controller to eventually drive the input error to zero, providing accuracy to the control loop. It must be used to affect the accuracy in the servo action of the controller. Like proportional gain, increasing integral gain results in the control action happening quicker. Set the "I" term to a number between 3…5 to start (1…2 more than "P"). Like proportional gain, increasing the integral term causes the controller action to be quicker.

D Derivative gain. The addition of derivative control can be problematic in many applications, because it greatly contributes to oscillatory behavior. In inherently slow chemical control processes, differential control is generally added in very small amounts to suppress erratic actions in the process that are non-continuous, such as pumps and valves clicking on and off. However, as a starting point for chemical process control, its best to leave the "D" term set to 0.

Based on these descriptions, the focus on tuning for chemical applications really only involves adjustment of "P" and "I" in most cases. However, increasing both increases the response of the controller. The difference is in the time of recovery. Although combinations of high "Ps" and low "Is" appear to operate the same as combinations of low "Ps" and high "Is", there is a difference in rate of recovery and stability. Because of the way the algorithm is structured, large "Ps" can have a larger impact on instability, because the proportional gain term impacts all the other terms directly. Therefore, keep proportional gain lower to start and increase integral gain to achieve the effect required.

Many of the classical tuning techniques have the user start with all values at 0, and then increase the "P" term until oscillations occur. The "P" value is then reduced to 1/2 of the oscillatory value, and the "I" term is increased to give the desired response. This can be done with the Q45D controller, with the exception that the "I" term should start no lower than 1.0.

If it appears that even large amounts of integral gain (>20) don't appreciably increase the desired response, drop "I" back to about 1.0, and increase "P" by 1.00 and start increasing "I" again. In most chemical control schemes, "I" is approximately 3 times the value of "P".

Classical PID Tuning

Unlike many high speed position applications where PID loops are commonly used, the chemical feed application employed by this instrument does not require intense mathematical exercise to determine tuning parameters for the PID. In fact, the risk of instability is far greater with overly tuned PID control schemes. In addition, many of the classical mathematical exercises can be damaging or wasteful in the use of chemicals when the process is bumped with large amounts of input error to seek a response curve. Because of this, the general adjustment guidelines described in *"PID Algorithm" on page 34* are sufficient for almost all application tuning for this instrument. Beyond this, many sources are available for classical tuning methods.

Manual PID Override Control

The Q45 electronics are equipped to allow the user to take manual control of the PID output. This is often useful when starting up a control loop, or in the event that you wish to bump the system manually to measure system response time.

To access the manual PID control, you must be in the *MEASURE* mode of operation and you must have the PID output displayed on the lower line. This line indicates "XX.X% XX.X mA" with the X values simply indicating the current values. With this display on the screen, press and hold the **ENTER** key for about 5 seconds. A small "m" shows up between the % value and the mA value. This indicates you are now in *Manual* mode.

Once in manual, you may increase the PID output by pressing the **UP** arrow key or you may decrease the output by pressing the **LEFT** arrow key. This allows you to drive the PID output to any desired setting.

To revert to normal PID control, press and hold the **ENTER** key again until the "m" indicator disappears.

Common PID Pitfalls

The most common problem occurring in PID control applications involves the false belief that proper settings on only the PID controller can balance any process to an efficient level.

Closed-loop control can only be effective if all elements in the loop are properly selected for the application, and the process behavior is properly understood. Luckily, the nature of simple chemical control processes are generally slow in nature. Therefore, even a de-tuned controller (one that responds somewhat slowly) can still provide substantial improvements to setpoint control. In fact, damaging oscillatory behavior is far more likely in tightly tuned controllers where the user attempted to increase response too much.

When deciding on a PID control scheme, it is important to initially review all elements of the process. Sticking valves, undersized pumps or delays in reaction times associated with chemical addition can have a dramatic effect on the stability of the control loop. When controlling a chemical mix or reaction, the sensor should be placed in a location that ensures proper mixing or reaction time has occurred.

The easiest processes to control with closed-loop schemes are generally linear, and symmetrical, in nature. For example, controlling level in tank where the opening of valve for a fixed period of time corresponds linearly to the amount that flows into a tank. Chemical control processes can be more problematic when the nature of the setpoint value is nonlinear relative to the input of chemical added. For example, D.O. control of a process may appear linear only in a certain range of operation and become highly exponential at the extreme ranges of the measuring scale. In addition, if a chemical process is not symmetrical, that means it responds differentially to the addition and subtraction of chemical. It is important in these applications to study steady-state impact as well as step-change impact to process changes. In other words, once the process has apparently been tuned under normal operating conditions, the user should attempt to force a dramatic change to the input to study how the output reacts. If this is difficult to do with the actual process input (the recommended method), the user can place the control in manual at an extreme control point such as 5% or 95%, and release it in manual. The recovery should not be overly oscillatory. If so, the loop needs to be de-tuned to deal with that condition (reduce "P" and/or "I").

SYSTEM MAINTENANCE

General

The Q45D/60 Dissolved Oxygen system generally provides unattended operation over long periods of time. With proper care, the system should continue to provide measurements indefinitely. For reliable operation, maintenance on the system must be done on a regular schedule. Keep in mind that preventive maintenance on a regular schedule is much less troublesome than emergency maintenance that always seems to come at the wrong time.

Analyzer Maintenance

No unusual maintenance of the analyzer is required if installed according to the guidelines of this operating manual. If the enclosure door is frequently opened and closed, it would be wise to periodically inspect the enclosure sealing gasket for breaks or tears.

Sensor Maintenance

Sensor maintenance is required for accurate measurements. The primary requirement is simply to keep the sensor membrane clean. The membrane is a polymer material that is resistant to anything that is encountered in water streams. However, deposits or biological growth can form on the surface of the membrane, and these deposits reduce the sensitivity to oxygen. Normally, these coatings can be removed by simply wiping the membrane with a soft cloth or paper towel.

Should a coating form on the membrane that does not wipe off, it is best to change the membrane. Chemical cleaning may work as well, but a new membrane is a more reliable solution. To change a membrane, follow the *"Sensor Assembly" on page 19*. Do not reuse the electrolyte from the sensor when changing a membrane. Always refill with fresh electrolyte. The electrolyte is stable and does not have a limited shelf life.

Even if no buildup is apparent on the membrane, it should be changed on a regular schedule. The recommended membrane change interval is every 6…12 months depending on application.

The actual membrane life is often in excess of one year, but periodic preventive maintenance simply avoids having to do service on an emergency basis.

While the sensor is disassembled for membrane changing, examine the condition of the O-rings on both ends of the electrolyte canister. If the O-rings show any signs of damage, replace them with new ones from the spare parts kit. It is good practice to change these O-rings once a year, regardless of their condition.

Lead Anode Replacement

Galvanic D.O. sensors consume the lead electrode during normal operation. As oxygen is measured, lead is converted to lead oxide, and after a period of time, the lead is expended. The lead electrode in our D.O. sensor cartridge can be easily replaced (part number 04-0003). Replacement should be done automatically every 12 months.

The lead electrode is the thick lead wire wrapped around the sensor body. It is connected through a stainless steel post with a nut and star washer. To change the lead electrode, remove the nut and washer and unwrap the old lead. Loop the end of a new lead electrode around the post and replace the nut and washer. Tighten the nut firmly but do not over tighten as damage to the sensing module can result. Wrap the remainder of the lead around the sensor body. There is no need to secure the other end of the lead.

Pressure Compensator Rebuild

On the side of the electrolyte chamber is a pressure compensator gland assembly. See *Figure 14 on page 21* for an exploded view of this assembly. Normally, this assembly does not require service, but it is possible that the pressure gland inside this assembly might be punctured if excessive pressure is applied. Rebuilding the gland is relatively easy using the parts supplied with the sensor.

You need either a torque wrench (preferred) or a wide bladed screwdriver to remove the retaining nut. Unscrew the nut and set it aside. Then carefully remove the old gasket and membrane. A small tweezers is useful in handling the replacement parts.

Carefully place a new membrane (clear material) into the gland recess. Place a white gasket on top of the clear membrane. Replace the retaining nut, tightening it just enough to make sure the white gasket material compresses for a good seal. To test the integrity, put a new membrane on the bottom of the chamber and fill the chamber with water. Look for any liquid leaks coming from the gland area. If you note leakage, tighten the nut a bit more.

TROUBLESHOOTING

General

The information included in this section is intended to be used in an attempt to quickly resolve an operational problem with the system. During any troubleshooting process, it saves the most time if the operator can first determine if the problem is related to the analyzer, sensor or some external source. Therefore, this section is organized from the approach of excluding any likely external sources, isolating the analyzer and finally isolating the sensor. If these procedures still do not resolve the operational problems, any results the operator may have noted here are very helpful when discussing the problem with the Technical Support group.

External Sources of Problems

To begin this process, review the connections of the system to all external connections.

1. Verify the analyzer is earth grounded. For all configurations of the analyzer, an earth ground connection MUST be present for the shielding systems in the electronics to be active. Grounded conduit provides no earth connection to the plastic enclosure, so an earth ground wiring connection must be made at the power input terminal strip. Use the special "shield terminal" stub on the power supply board for optimum sensor cable shield grounding.
2. Verify the proper power input is present (16…35V DC).
3. Verify the loads on any 4…20 mA outputs do not exceed the limits in the Instrument Specifications (500 Ohms each for analyzer). During troubleshooting, it is helpful to disconnect all these outputs and place wire-shorts across the terminals in the instrument to isolate the system and evaluate any problems which may be coming down the analog output connections.
4. Do not run sensor cables or analog output wiring in the same conduits as power wiring. If low voltage signal cables must come near power wiring, cross them at 90° to minimize coupling.
5. If rigid conduit has been run directly to the Q45D enclosure, check for signs that moisture has followed conduit into the enclosure.
6. Check for ground loops. Although the membrane sensor is electrically isolated from the process water, high frequency sources of electrical noise may still cause erratic behavior in extreme conditions. If readings are very erratic after wiring has been checked, check for a possible AC ground loop by temporarily placing the sensor into a bucket of water. The reading should be initially stable and then fall very slowly in a smooth fashion as the powered sensor depletes oxygen in the static sample directly at the sensor face.
7. Carefully examine any junction box connections for loose wiring or bad wire stripping. If possible, connect the sensor directly to the analyzer for testing.
8. Check sensor membrane for fouling. Look closely for signs of grease or oil which may be present. Replace membrane and electrolyte, allow to stabilize and re-check. The procedure in *"Sensor Assembly" on page 19*, must be followed when replacing the membrane.

Analyzer Tests

1. Disconnect power and completely disconnect all output wiring coming from the analyzer. Remove sensor wiring, relay wiring and analog output wiring. Re-apply power to the analyzer. Verify proper voltage (115 or 230V AC) is present on the incoming power strip of the analyzer, and that the analyzer power label matches the proper voltage value.
2. If analyzer does not appear to power up (no display), remove power and check removable fuse for continuity with a digital voltmeter (DVM).
3. Using a DVM, check the voltage across the BLUE and WHITE wires coming from the power supply board in the base of the enclosure. FIRST, disconnect any wiring going to Iout#1. Then, verify voltage across these wires is about 16…18V DC when still connected to the terminal strip on the front half of the enclosure. If the BLUE and WHITE wires are not connected to the terminal strip on the front half of the enclosure, the voltage across them should measure about 29V DC.
4. If analyzer does power up with a display, use the *Simulate* feature to check operation of the analog outputs (and relays contacts with a DVM).
5. Check sensor power circuits. With a DVM, verify between –4.5…–5.5V DC from sensor connection terminals WHITE (+) to BLACK (–). Then verify between +4.5…+5.5V DC from GREEN (+) to BLACK (–).
6. Check TC drive circuit. Place a wire-short between the RED and BLACK sensor terminals. With a DVM, measure the voltage between the BLACK (–) and BROWN (+) sensor terminals to verify that the TC drive circuit is producing about –4.6…–5.5V DC open-circuit. Remove DVM completely and connect a 1000 Ohms resistor across the BLACK to BROWN terminals. The temperature reading on the front LCD should display approximately 0° C and the dissolved oxygen reading should display approximately 0 ppm.

Display Messages

The Q45 Series instruments provide a number of diagnostic messages which indicate problems during normal operation and calibration. These messages appear as prompts on the secondary line of the display or as items on the *Fault List*.

The following messages appear as prompts:

Message	Description	Possible Correction
Max is 200	Entry failed, maximum user value allowed is 200.	Reduce value to ≤ 200.
Min is 20	Entry failed, minimum value allowed is 20.	Increase value to ≥ 20.
Cal Unstable	Calibration problem, data too unstable to calibrate. Icons do not stop flashing if data is too unstable. User can bypass by pressing **ENTER**.	Clean sensor, get fresh cal solutions, allow temperature and conductivity readings to fully stabilize, do not handle sensor or cable during calibration.
Out of Range	Input value is outside selected range of the specific list item being configured.	Check manual for limits of the function to be configured.
Locked!	Transmitter security setting is locked.	Enter security code to allow modifications to settings.
Unlocked!	Transmitter security has just been unlocked.	Displayed just after security code has been entered.
Offset High	The sensor zero offset point is out of the acceptable range of –40…+40 mV.	Check wiring connections to sensor. Allow sensor to operate powered a minimum of 12 hours prior to first zero cal.
Sensor High	The raw signal from the sensor is too high and out of instrument range.	Check wiring connections to sensor.
Sensor Low	The raw signal from the sensor is too low.	Check wiring connections to sensor.
D.O. High	The oxygen reading is greater than the maximum of the user-selected range.	The oxygen reading is over operating limits. Set measuring range to the next highest level.
Temp High	The temperature reading is > 55° C.	The temperature reading is over operating limits. Check wiring and expected temp level. Perform RTD test as described in sensor manual. Recalibrate sensor temperature element, if necessary.
Temp Low	The temperature reading is < -10° C.	Same as "Temp High" above.
TC Error	TC may be open or shorted.	Check sensor wiring and perform RTD test as described in sensor manual. Check j-box connections.
D.O. Cal Fail	Failure of oxygen calibration. *FAIL* icon does not extinguish until successful calibration has been performed, or 30 minutes passes with no keys being pressed.	Clean sensor, redo zero and span calibration. If still failure, sensor slope may be less than 20% or greater than 500%. Perform sensor tests as described in *"Sensor Tests" on page 42*. Replace sensor if still failure.
TC Cal Fail	Failure of temperature calibration. *FAIL* icon does not extinguish until successful calibration has been performed, or 30 minutes passes with no keys being pressed.	Clean sensor, check cal solution temperature and repeat sensor temp calibration. TC calibration function only allows adjustments of ± 6° C. Replace sensor if still failure, perform sensor tests as described in *"Sensor Tests" on page 42*. Replace sensor if still failure.
EEPROM Fail	Internal nonvolatile memory failure.	System failure, consult factory.
Chcksum Fail	Internal software storage error.	System failure, consult factory.
Display Fail	Internal display driver fail.	System failure, consult factory.
Range Cal Fail	Failure of factory temperature calibration.	Consult factory.

Sensor Tests

1. Check the membrane condition. A membrane that is not stretched smoothly across the tip of the sensor causes unstable measurements. If necessary, change membrane and electrolyte.
2. Dissolved oxygen sensors can be tested with a DVM to determine if a major sensor problem exists. Follow the steps below to verify sensor integrity:
    a. Prior to disconnecting the sensor, measure the sensor output voltage at the analyzer terminal strip with a DVM while the sensor is hanging in air. If the sensor has been connected to a powered analyzer for at least 12 hours, the nominal output of the sensor is about 400mV DC when measured in air at 25° C (100% saturation) from BLACK (–) to RED (+) on the analyzer terminal strips. This value is affected by temperature, pressure and age of the sensor so it is possible to see a typical value that ranges from perhaps +200mV DC…+800mV DC under a wide range of conditions in air.
    b. Disconnect the five sensor wires from the oxygen monitor. Those wires are color coded red, white, blue, green, brown and black.

       NOTE: The brown wire may be replaced with an orange wire in some cables.
    c. Remove the front sensor "cartridge" for the sensor body by unscrewing the cartridge at the large "knurl" in a counterclockwise manner. Inspect the gold RCA jack for signs of moisture or other foulants. Clean and thoroughly dry both connectors if necessary. Re-assemble when complete.
    d. Connect the DVM between the brown and black wires. These are the RTD leads and you should find a resistance value that depends on the temperature. The table below lists the resistance values for various temperatures:

PT100 RTD Table

Temperature	Resistance
0° C	1000 Ω
5° C	1019 Ω
10° C	1039 Ω
15° C	1058 Ω
20° C	1078 Ω
25° C	1097 Ω
30° C	1117 Ω
35° C	1136 Ω
40° C	1155 Ω
45° C	1175 Ω
50° C	1194 Ω

If you suspect that water has gotten into a cable connection on a flow type sensor or into the plug connection of a submersible sensor, disconnect the cable and allow the parts of the sensor to sit in a warm place for 24 hours. If water in the connector is the problem, it should dry out sufficiently to allow normal sensor operation.

Barometric Pressure Conversion

Inches of Mercury (inHg)	Millimeters of Mercury (mmHg)	Feet Above Sea Level
22.00	558.8	+8790
22.50	571.5	+8053
23.00	584.2	+7347
23.50	596.9	+6671
24.00	609.6	+6023
24.50	622.3	+5402
25.00	635.0	+4806
25.50	647.7	+4233
26.00	660.4	+3682
26.50	673.1	+3156
27.00	685.5	+2653
27.50	698.5	+2150
28.00	711.2	+1675
28.50	723.9	+1217
29.00	736.6	+776
29.50	749.3	+349
30.00	762.0	–64
30.50	774.7	–463
31.00	784.4	–759

Water Saturated Concentration of O_2

Temperature		PPM	Temperature		PPM
°F	°C		°F	°C	
32	0.0	14.6	74	23.3	8.5
34	1.1	14.1	76	24.4	8.3
36	2.2	13.7	78	25.6	8.2
38	3.3	13.3	80	26.7	8.0
40	4.4	12.9	82	27.8	7.8
42	5.6	12.6	84	28.9	7.7
44	6.7	12.2	86	30.0	7.5
46	7.8	11.9	88	31.1	7.4
48	8.9	11.6	90	32.2	7.3
50	10.0	11.3	92	33.3	7.1
52	11.1	11.0	94	34.4	7.0
54	12.2	10.7	96	35.6	6.9
56	13.3	10.4	98	36.7	6.8
58	14.2	10.2	100	37.8	6.6
60	15.6	9.9	102	38.9	6.5
62	16.7	9.7	104	40.0	6.4
64	17.8	9.5	106	41.1	6.3
66	18.9	9.3	108	42.2	6.2
68	20.0	9.1	110	43.3	6.1
70	21.1	8.9	112	44.4	6.0
72	22.2	8.7	114	45.6	5.9

SPARE PARTS

Part No.	Description
Spare Electronics	
03-0337	Front Lid electronics assembly
*	Q45D Loop-Powered Transmitter, 2-Wire
Spare Sensors	
07-0078	Flow Type D.O. sensor
07-0095	Oxygen sensor, submersion type with 30 ft cable
Spare Sensor Components	
02-0007	Submersion sensing module, (for #07-0095)
02-0014	Submersion element body, (for #02-0007)
02-0113	Submersion holder, 30 ft cable (for #07-0095)
02-0224	Flow Type Sensor Element (for #07-0078)
03-0358	Electrolyte chamber with pressure gland
48-0001	Membrane holder, type 316 stainless steel
45-0010	Membrane holder, noryl
04-0003**	Lead Electrode
05-0001**	5-mil Membranes, pkg. of 10
05-0011**	2-mil Membranes, pkg. of 10
05-0014	Spare Parts Kit, screw and O-ring (Submersible Sensor)
05-0015	Spare Parts Kit, screw and O-ring (Flow Sensor)
05-0088	Pressure gland rebuild kit
09-0007**	Dissolved oxygen electrolyte, 4 oz (120 cc)
Spare Flowcells	
00-1522	Sealed Flowcell Assy
Misc Components	
07-0100	Junction box
31-0001	Interconnect cable for junction box to monitor wiring
42-0014	Flowcell O-ring
05-0101	Sealed flowcell vacuum breaker

***** Consult factory for item number of electronic assembly.

****** Instrument is supplied with sufficient spare parts for 12 months of operation. For 2 year spare parts inventory, 1 each of the items marked with a double asterisk (**) is required.

Lock/Unlock Code: 1454

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