

Water Quality Monitor

Model Q45C4 2-Wire 4-Electrode Conductivity Transmitter



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INTRODUCTION

General

The Model Q45C4 conductivity monitor/analyzer provides an extremely versatile measurement system for monitoring and control of conductivity over the range of 1 $\mu\text{S}/\text{cm}$...2.000 Siemens/cm.

Q45C4 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.

In all configurations, the Q45C4 displays conductivity on the main display, total dissolved solids (TDS), sensor temperature and output loop current on the secondary line of the custom display.

WARNING

NOT FOLLOWING OPERATING INSTRUCTIONS MAY IMPAIR SAFETY.

NOTE: Due to the high degree of flexibility of the Q45 system options, it is important to note areas of the operating manual that detail these optional features.

Features

- Standard Q45C4 transmitters are fully isolated, loop-powered instruments for 2-wire DC applications.
- High accuracy, high sensitivity system, measures from 1...2,000,000 μS through 7 internal automatic ranges. User display ranges include 2000 μS , 2.000 mS, 20.00 mS, 200.0 mS, 2000 mS or 2.000 S.
- *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 transmitter.
- Configurable for TDS display and signal output on one analog output.
- Large, high contrast, custom LCD display with LED back light provides excellent readability in any light conditions. The secondary line of display uses 5 \times 7 dot matrix characters for clear message display. Two of four measured parameters may be on the display simultaneously.
- 4-Electrode measurement system. Two of the electrodes are used to establish the sensor drive potential, while the other two sense the flow of current between the drive electrodes and maintain proper drive potential. Sensor diagnostics monitor electrode coating/fouling, sensor leaks and RTD condition. 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 1-point 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 Pt1000 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.
- PEEK electrode insulator, custom rear PEEK sealing nut and triple O-ring rear seal (Viton and EPR) allow complete submersion of the sensor.
- Custom double-shielded, cross-linked cable with PE jacket for excellent chemical resistance.
- Pt1000 RTD. The temperature element used in Badger Meter sensors is highly accurate and provides a highly linear output.



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.

Q45C4 System Specifications

Displayed Parameters	Main input, 0 μ S...2S (2,000,000 μ S) Sensor temperature, -10.0...210.0° C (23...410° F) Loop current, 4.00...20.00 mA Sensor slope Model number and software version PID Controller Status Timer Status
Main Parameter Ranges	Automatic or manual selection of one of the following display ranges: 0...2000 μ S 0.0...2.000 mS 0.00...20.00 mS 0.0...200.0 mS 0...2000 mS 0.000...2.000 S
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 \times 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) Storage, -30...70° C (-22 ...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 (CSA and UL standards - both approved by CSA), 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	Fully isolated 4-electrode sensor design for direct measurement. 1 in. NPT process connection.
Measuring Range	0.000...2.000 S/cm
Wetted Materials	Titanium, PEEK, Viton, EPR (316SS when sensor is submersion mounted)
Temperature Compensation	Pt1000 RTD
Sensor Cable	6 Conductor plus 2 shields
Temperature Pressure Range	The choice of sensor material/mounting option and the hardware used to mount the sensor determines the temperature and pressure ratings. Please consult the factory for relevant temperature and pressure rating information.
Maximum Flow Rate	10 ft (3 m) per second
Max. Sensor-Analyzer Distance	60 ft (18.2 m)
Power	16...35V DC (2-wire device)
Enclosure	NEMA 4X, polycarbonate, stainless steel hardware, weatherproof and corrosion resistant HWD: 4.40 in. (111.76 mm) \times 4.40 in. (111.76 mm) \times 3.50 in. (88.90 mm)
Mounting Options	Wall or pipe mount bracket standard. Bracket suitable for either 1.50 in. or 2 in. I.D. U-bolts for pipe mounting.
Conduit Openings	Two Pg9 openings with gland seals, one 1 in. NPT opening with plug
DC Cable Type	Belden twisted-pair, shielded, 22 gauge or larger
Insertion Loss	16V DC

Q45C4 Performance Specifications

Accuracy	0.5% of user range, or better ($\pm 2 \mu\text{S}$)
Repeatability	0.2% of user range, or better ($\pm 2 \mu\text{S}$)
Sensitivity	0.05% of user ranges ($\pm 2 \mu\text{S}$)
Stability	0.2% of user range per 24 hours, non-cumulative
Warm-Up Time	7 seconds to rated performance
Supply Voltage Effects	DC version only, $\pm 0.05\%$ of user range
Instrument Response Time	6 seconds to 90% of step input at lowest setting
Temperature Drift	Span or zero, 0.04% of span/ $^{\circ}\text{C}$

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 standard cable length of the conductivity sensor is 20 ft. For sensor cables longer than 20 ft, use the optional junction box (07-0100) and sensor interconnect cable (31-0057).

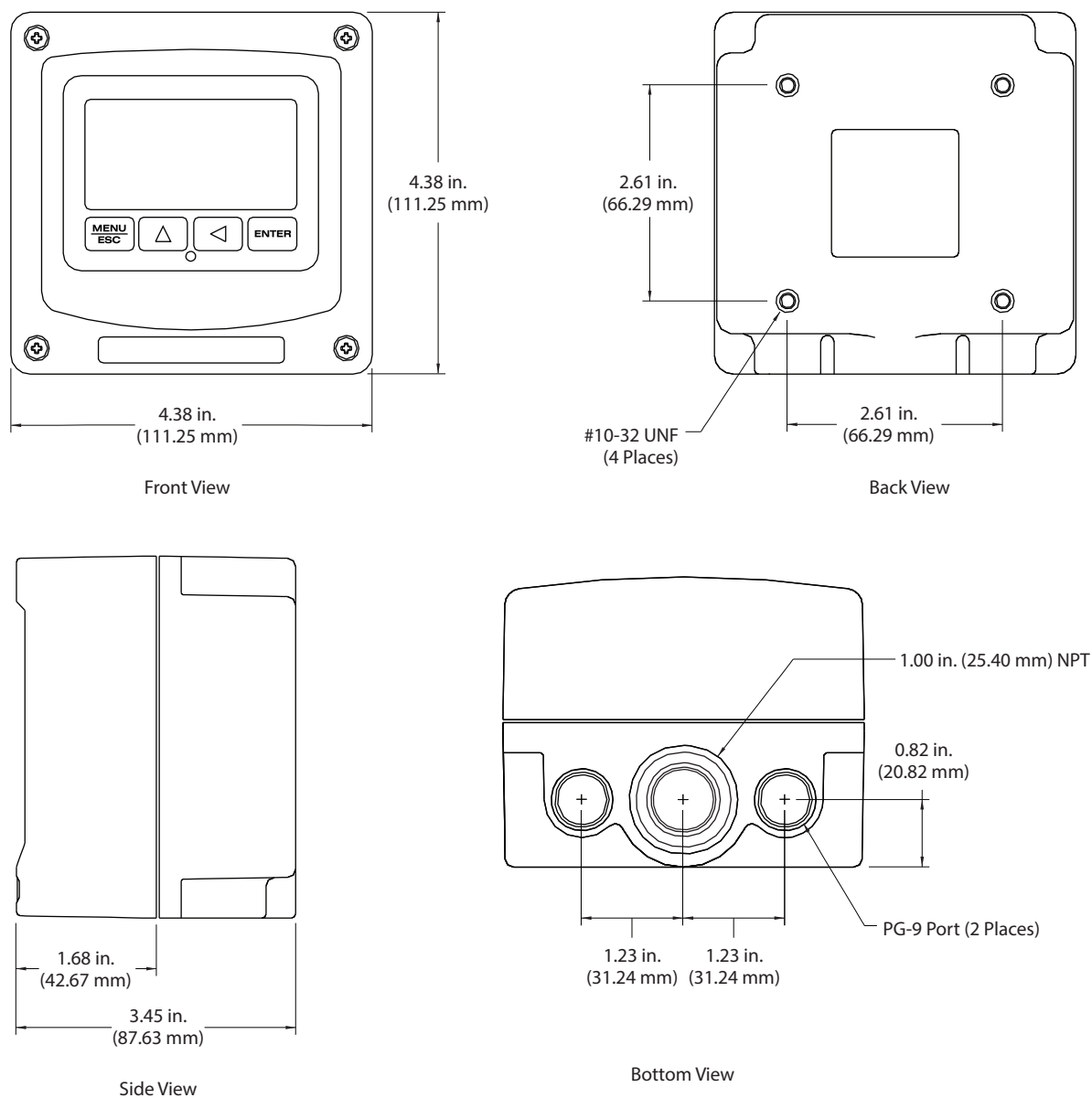


Figure 1: Q45 Enclosure dimensions

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 in. or 2 in. 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 in. pipe U-bolt (2 in. I.D. clearance) is available from Badger Meter in type 304 stainless steel under part number (47-0005).

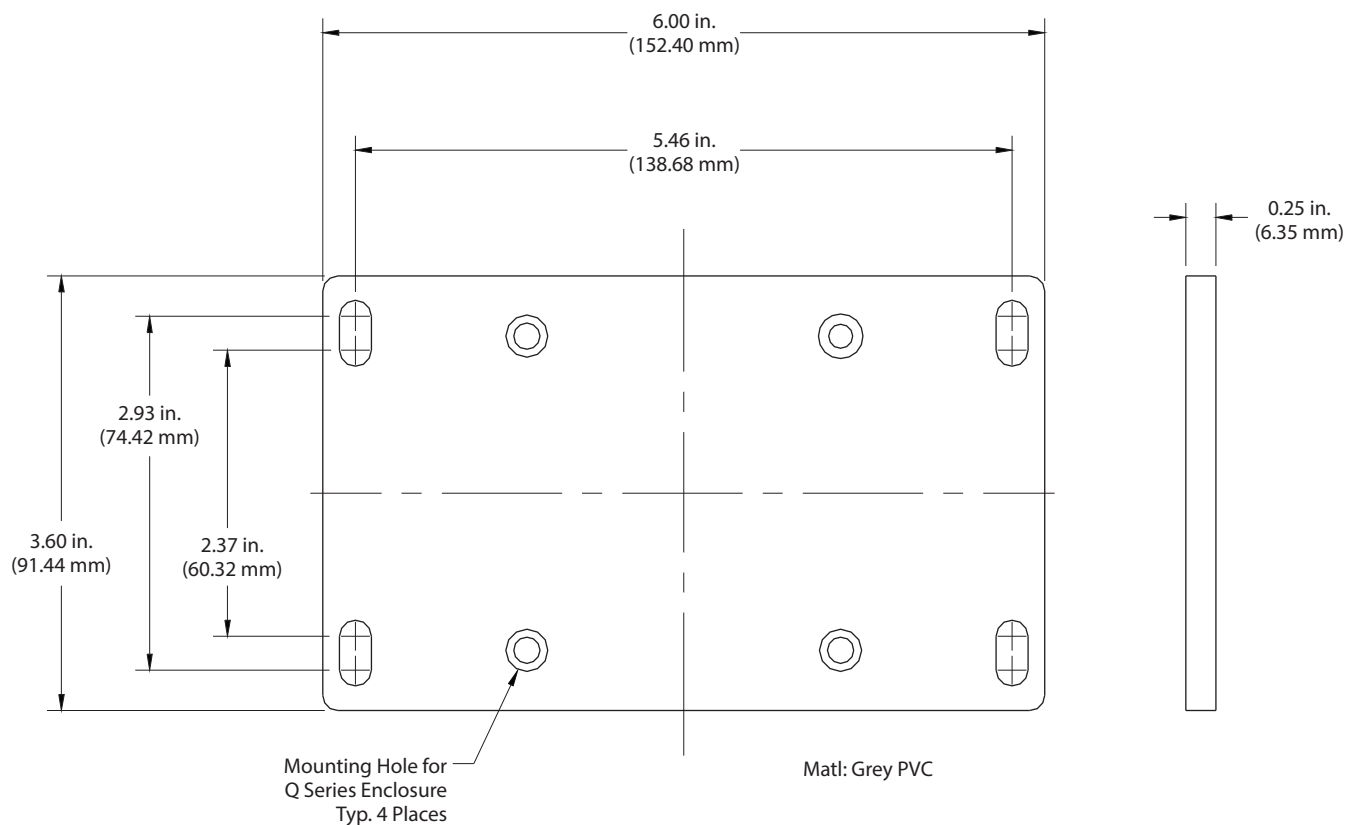


Figure 2: Wall or pipe mount bracket

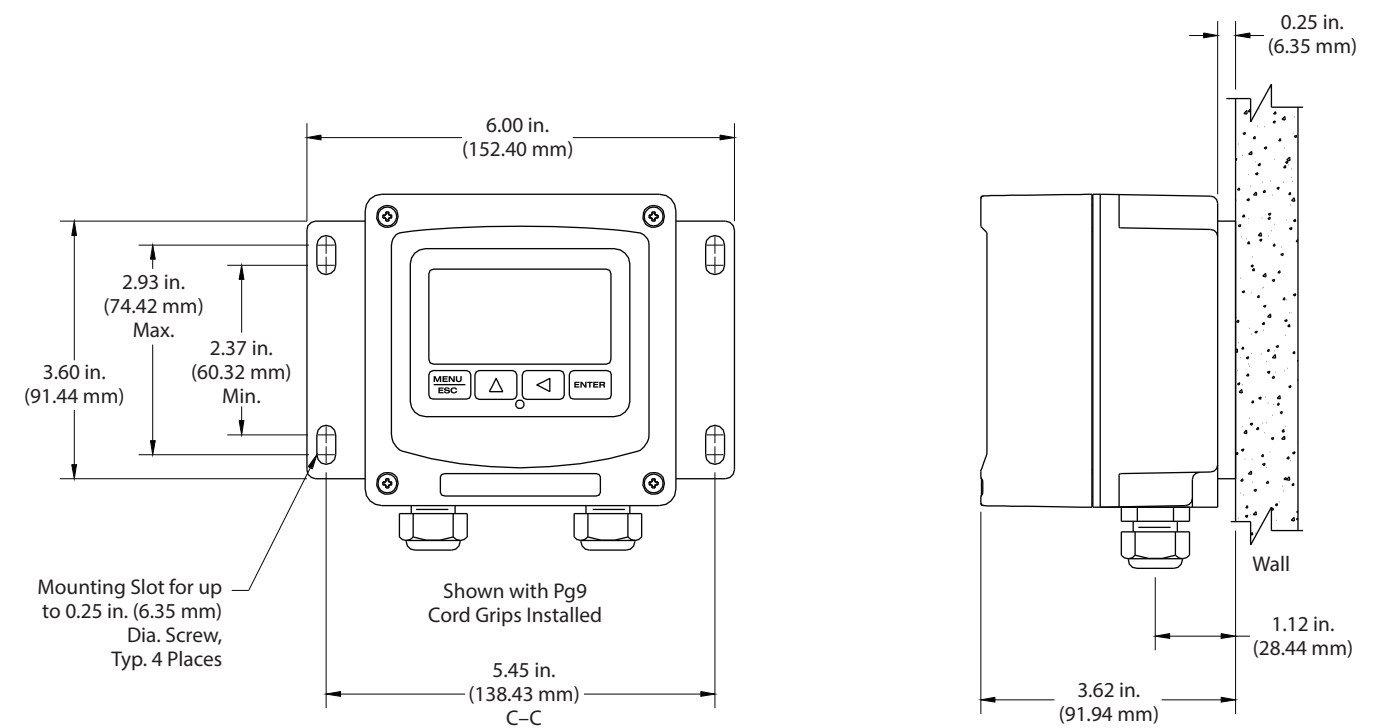
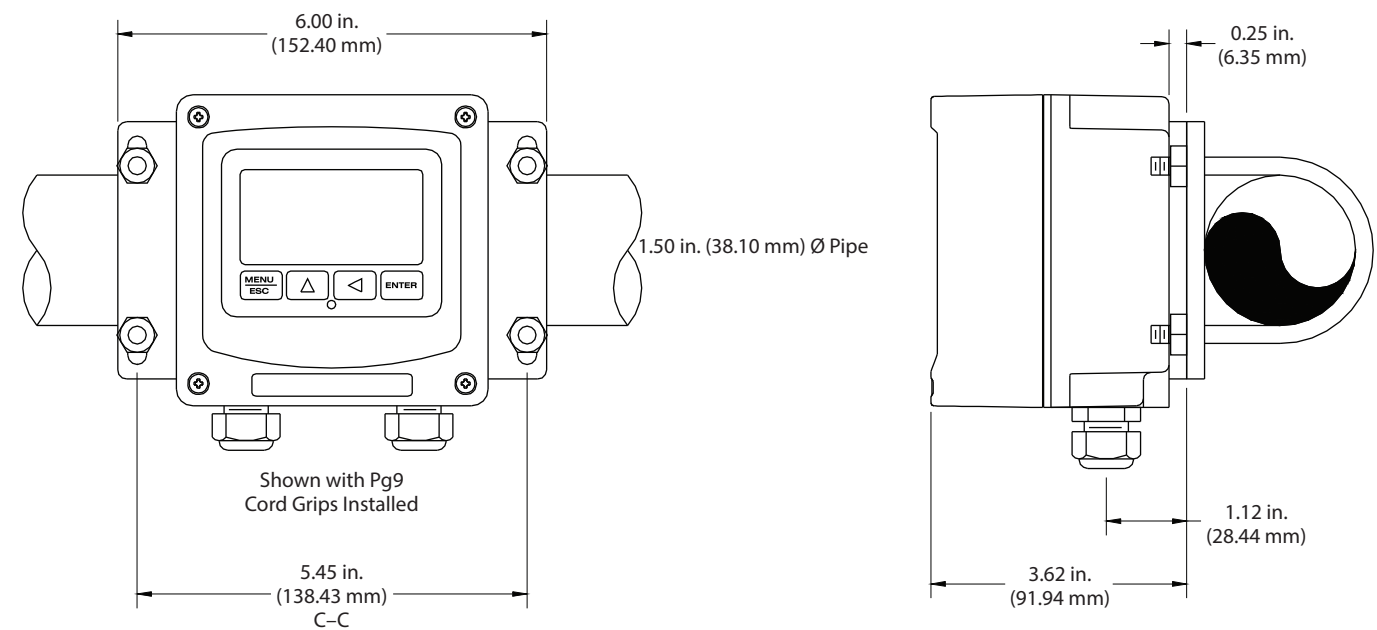


Figure 3: Wall mounting diagram



NOTE: Mounting plate hole spacing can support up to 2 in. (50.80 mm) Ø pipe max.

Figure 4: Pipe mounting diagram

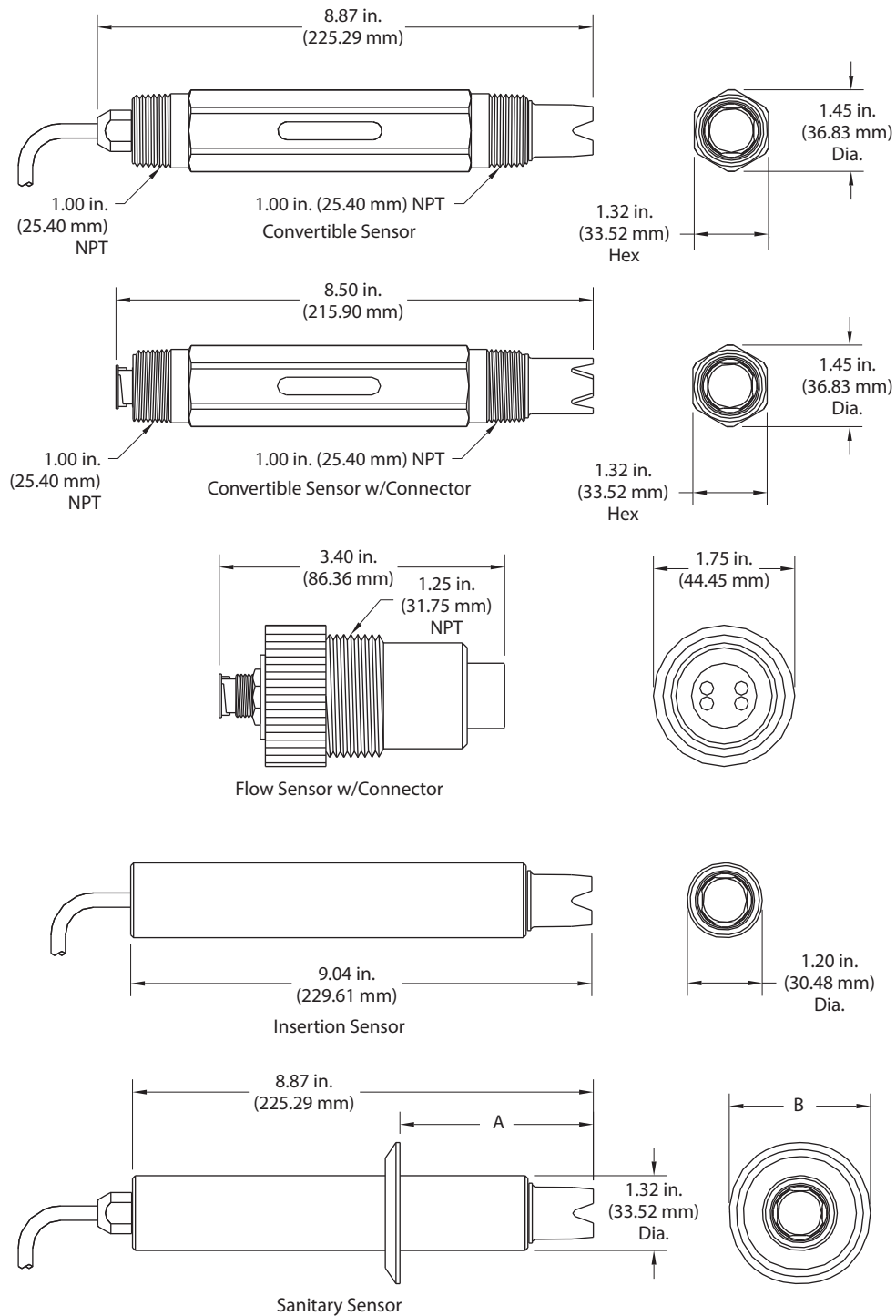
SENSOR/FLOWCELL MOUNTING

General

The Q25C4 Conductivity Sensor is designed for industrial and municipal process applications. Mounting options include flow-through, submersion, insertion (special hardware required) or sanitary mount depending on the type of sensor purchased. The sensor-to-analyzer distance must not exceed 60 ft (18.2 m).

Calibrate the sensor before placing it into the process. See *“Calibration” on page 34* of this manual for detailed calibration instructions.

The sensor comes with a removable guard that surrounds the electrode face, except for flow type sensors. This guard minimizes interference effects in tight locations where the sensor face is close to surrounding objects. If it is removed, take care to leave at least 1 in.³ of space in front of the electrodes. If the guard is to be used, the sensor must be calibrated with it in place, since the guard affects the sensor cell constant.



Sensor Size	A	B
1-1/2 in.	2.75 in. (70.00 mm)	1.98 in. (50.40 mm)
2 in.	3.50 in. (88.90 mm)	2.50 in. (63.50 mm)

Figure 5: Q25C4 Sensor dimensions

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 that can be used ahead of this flowcell on the incoming sample line. The flow control is part number (55-0048). 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.

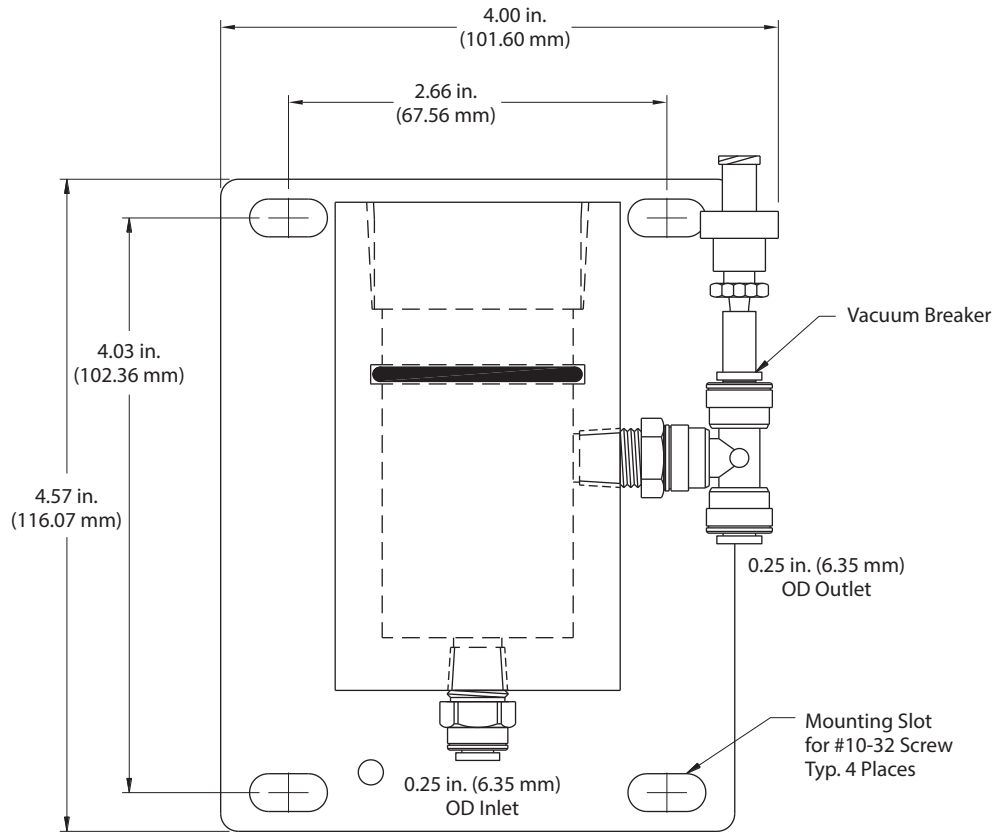


Figure 6: Sealed flowcell details

Flow Tee Mounting

Convertible sensors may be used in a 1 in. flow tee as shown in [Figure 7](#). The flow tee is a modified pipe fitting that accommodates the pipe thread on the front of the sensor. Sample must flow directly against the face of the sensor. The sensor may be mounted horizontally provided that the outlet flow is pointed up to avoid “air locking” in the tee.

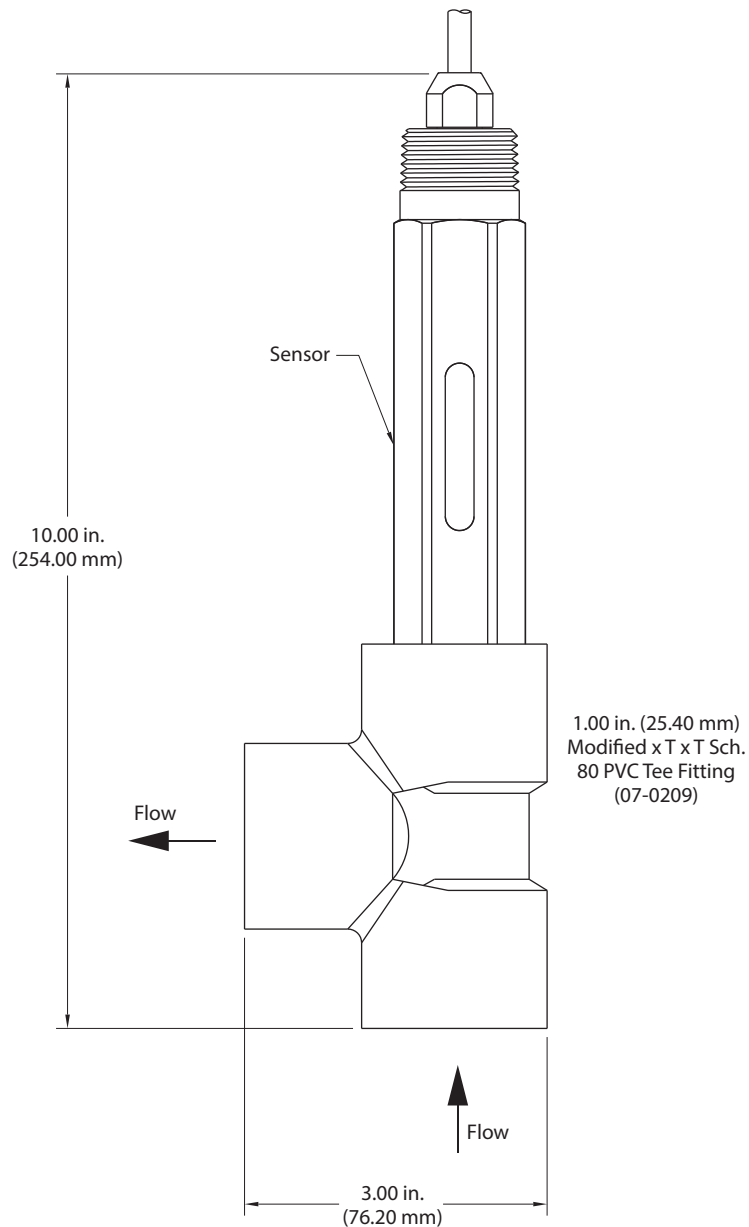


Figure 7: Flow through tee mount

Union Mounting

For mounting the sensor in larger pipe and allowing for easy sensor removal, a 1-1/2 in. or 2 in. union mount adapter system is available. This arrangement allows connection of the sensor to pipe sizes up to 2 in. (using adapters if necessary) while allowing easy removal without twisting sensor wires. Contact Badger Meter for part numbers and prices for union mount assemblies and associated pipe tees.

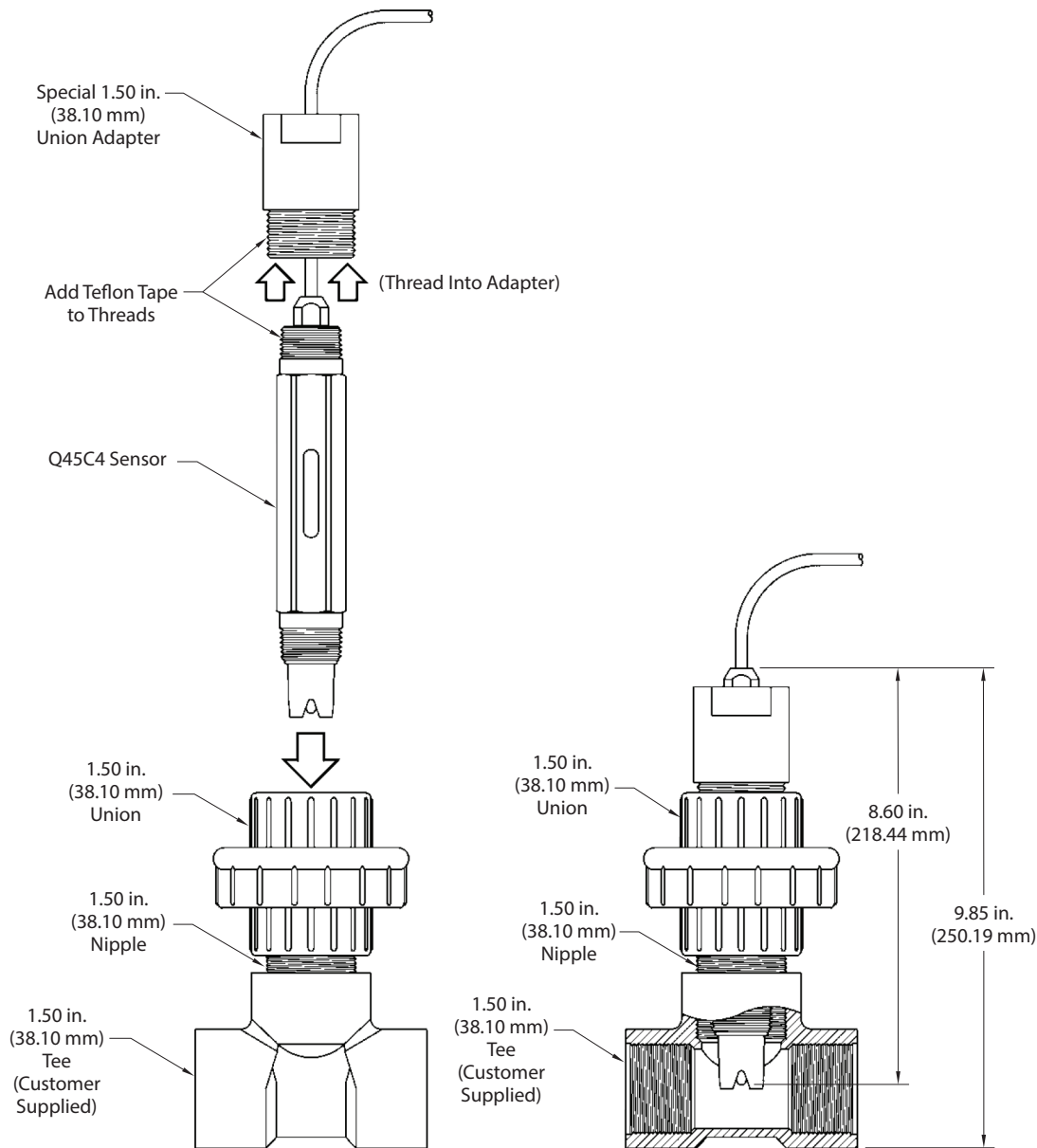


Figure 8: 1.50 in. Union mount

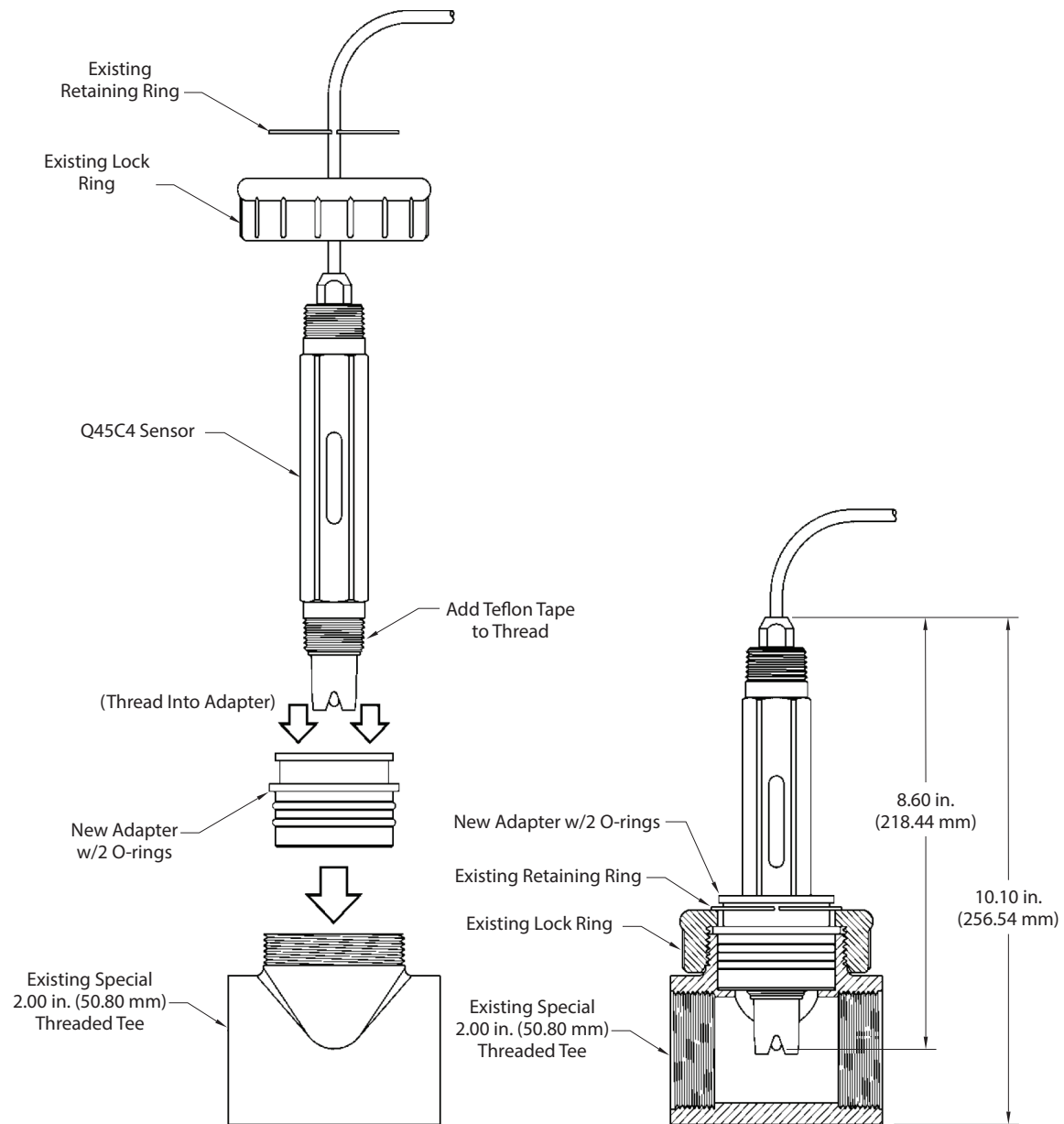


Figure 9: 2 in. union mount

Submersion Mounting

When using this conductivity sensor for submersion applications, mount the sensor to the end of a 1 in. mounting pipe using a 1 in. coupling. Badger Meter's (00-0628) mounting assembly shown in [Figure 10](#) is available for submersible applications. This assembly is designed to mount to standard handrails and facilitates insertion and removal of the sensor.

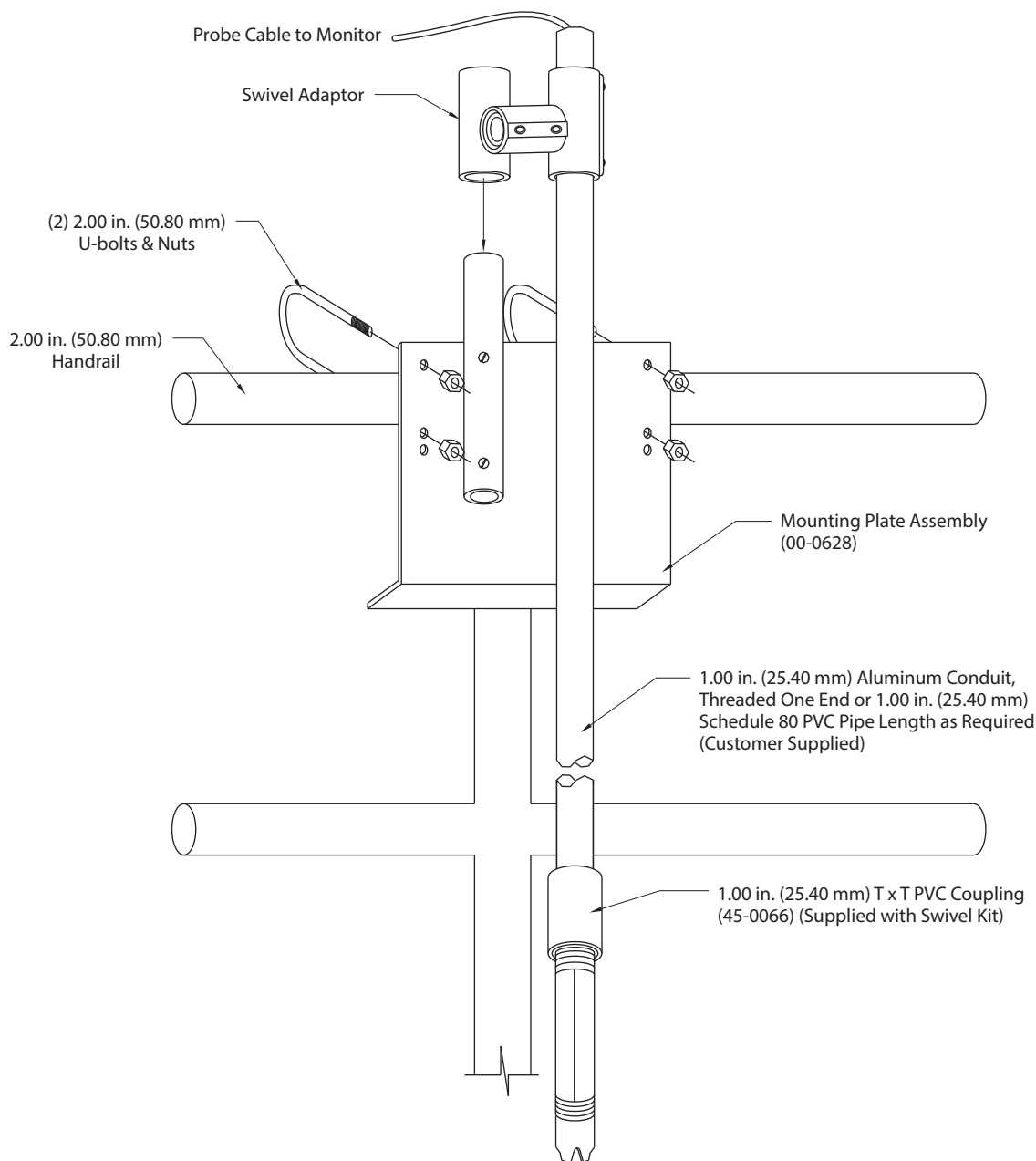


Figure 10: Sensor submersion mount

Insertion Mounting

Special insertion mounting hardware is available for applications requiring the removal of the sensor from a process line or tank without shutting off the sample flow in the line. [Figure 11](#) and [Figure 12 on page 19](#) show typical insertion assemblies. Separate manuals are available for the installation and operation of these assemblies.

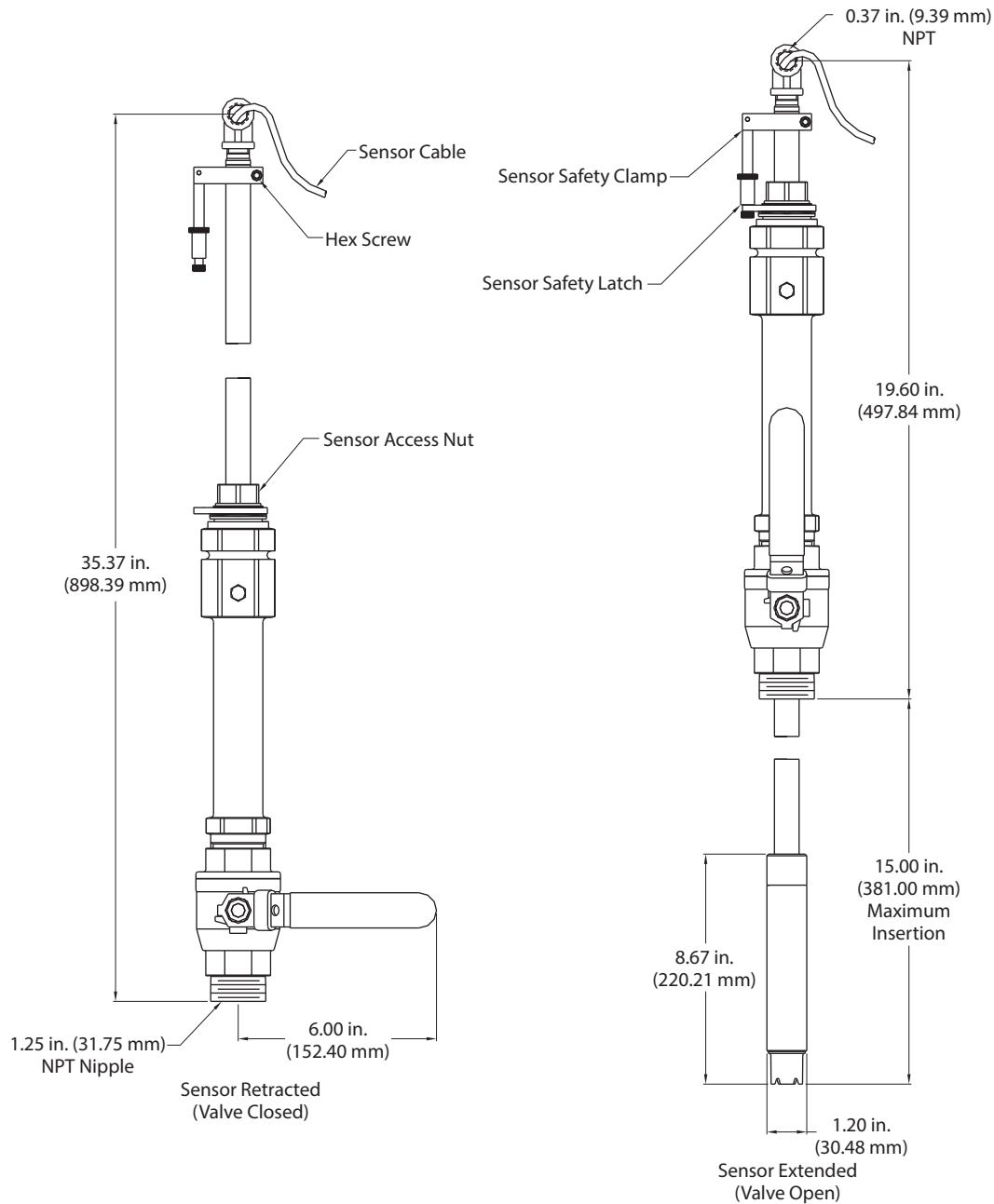


Figure 11: Stainless steel sensor insertion mount

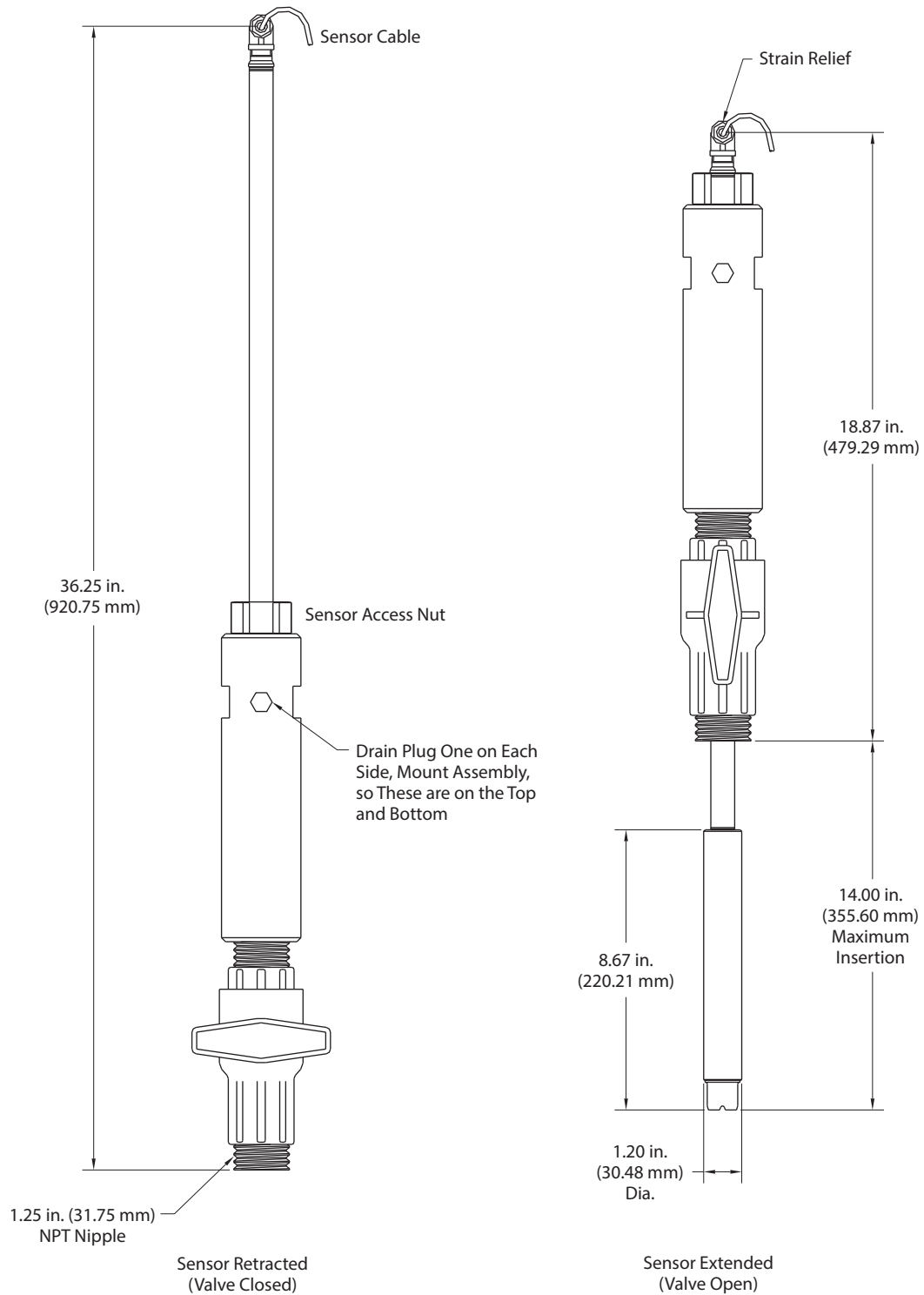


Figure 12: CPVC sensor insertion mount

ELECTRICAL INSTALLATION

General

The Q45 is powered in one of 3 ways, depending on the version purchased. The 2-wire version is a 16...35V DC powered transmitter. The battery powered unit is supplied with AA 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. See [Figure 13 on page 21](#).
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 13 on page 21](#) 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.

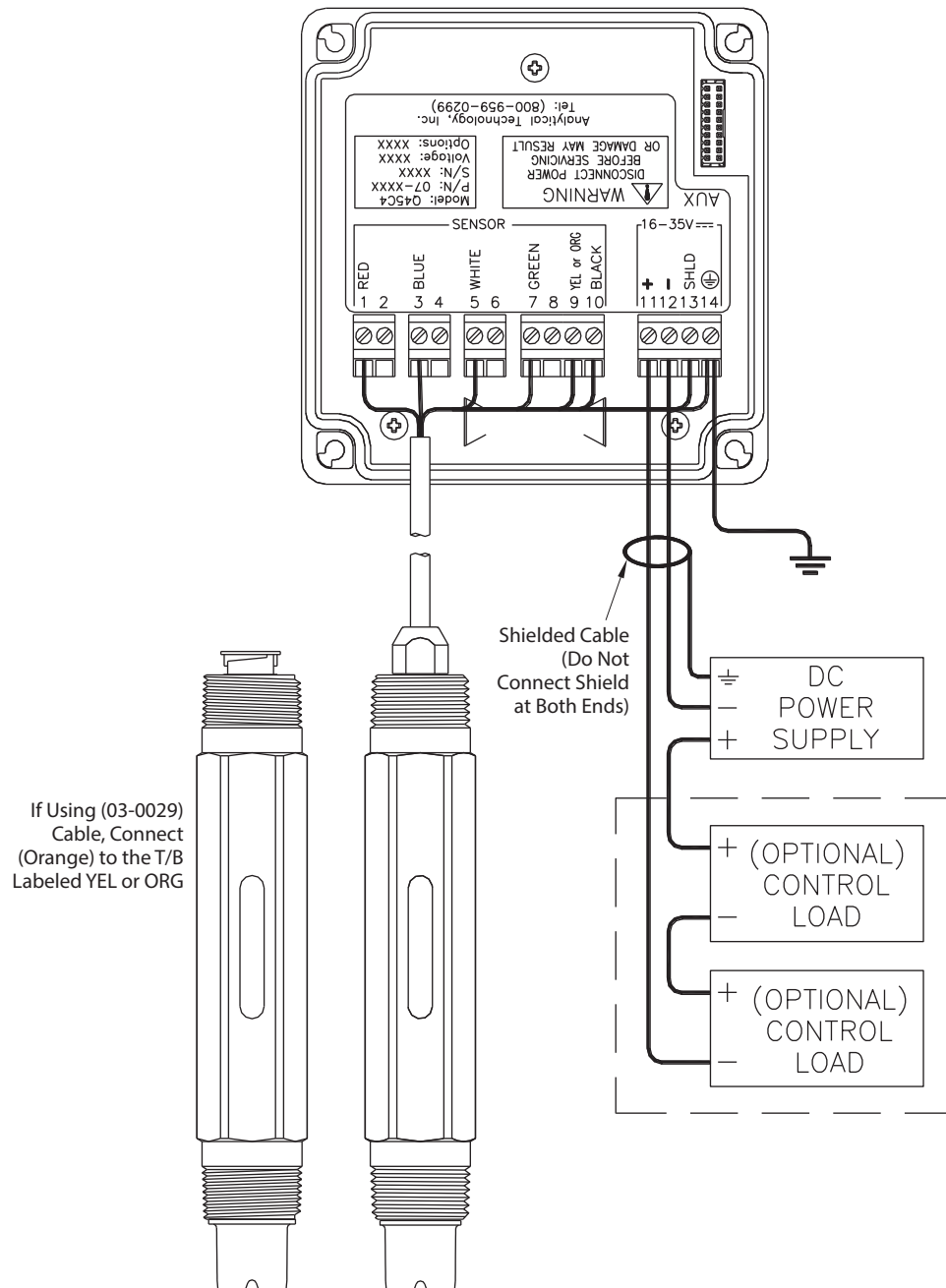


Figure 13: Loop-power connection

NOTE: Voltage between Terminals 11...12 MUST be between 16...35V DC.

NOTE: Earth ground into Terminal 14 is STRONGLY recommended. This connection can greatly improve stability in electrically-noisy environments.

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 of 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:

$$\frac{(\text{Power Supply Voltage} - 16)}{0.02} = R_{\text{MAX}}$$

For example, if the power supply voltage is 24V DC, first subtract 16V DC, and then divide the remainder by 0.02.

$8/0.02 = 400$; 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 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.

NOTE: When installing conductivity monitors and sensors, we recommend keeping the sensor cable as short as is practical. This minimizes potential noise problems.

Standard convertible sensors, insertion sensors and sanitary sensors have cable permanently attached to the sensor. This cable contains double shielded conductors to minimize noise problems in heavy industrial environments. Convertible sensors with connectors and flow type sensors use a slightly different cable assembly with only a single shield. This assembly is sufficient for many applications where EMI/RFI problems are not severe. [Figure 14](#) and [Figure 15](#) show the two different cable assembly terminations.

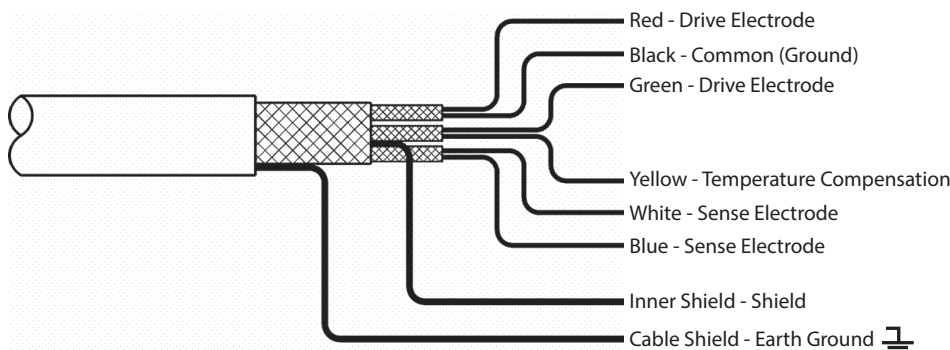


Figure 14: Standard double shielded cable

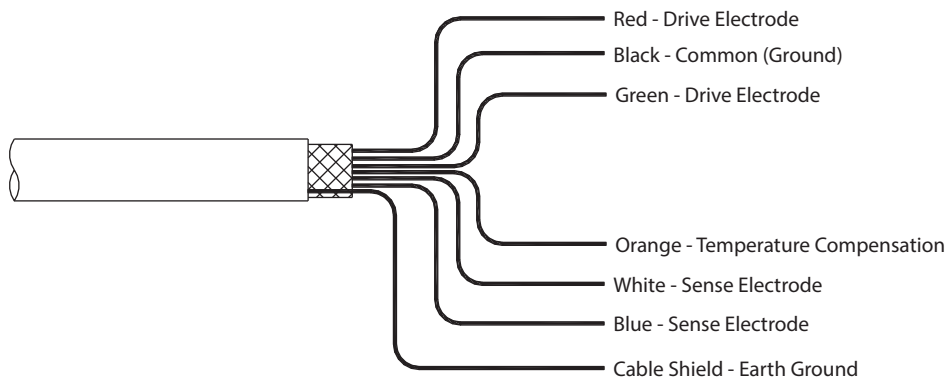


Figure 15: Detachable single shielded cable

⚠ DANGER

DO NOT CONNECT SENSOR CABLE TO POWER LINES. SERIOUS INJURY MAY RESULT.

Take care to route sensor cable away from AC power lines, adjustable frequency drives, motors or other noisy electrical signal lines. Do not run signal lines in the same conduit as AC power lines. Run signal cable in dedicated metal conduit if possible. For optimum electrical noise protection, run an earth ground wire to the ground terminal in the transmitter.

CAUTION:

ONLY BADGER METER'S CUSTOM 6-WIRE SHIELDED INTERCONNECT CABLE SHOULD BE USED WHEN CONNECTING THE MODEL Q25C4 SENSOR TO THE ANALYZER. THIS HIGH-PERFORMANCE, DOUBLE SHIELDED, POLYETHYLENE JACKETED CABLE IS SPECIALLY DESIGNED TO PROVIDE THE PROPER SIGNAL SHIELDING FOR THE SENSOR USED IN THIS SYSTEM. SUBSTITUTED CABLES MAY CAUSE PROBLEMS WITH SYSTEM PERFORMANCE.

Direct Sensor Connection

Sensor connections are made in accordance with [Figure 16](#). The sensor cable can be routed into the enclosure through one of 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 depending on the installation type.

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 16](#). The standard 20 ft 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.

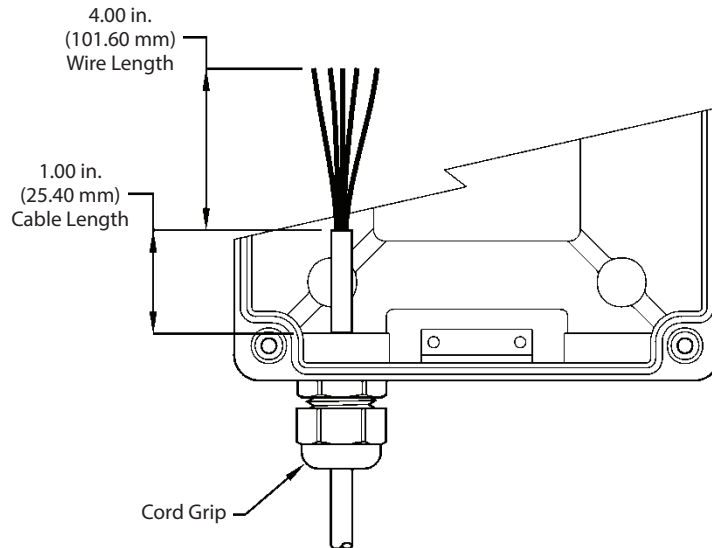
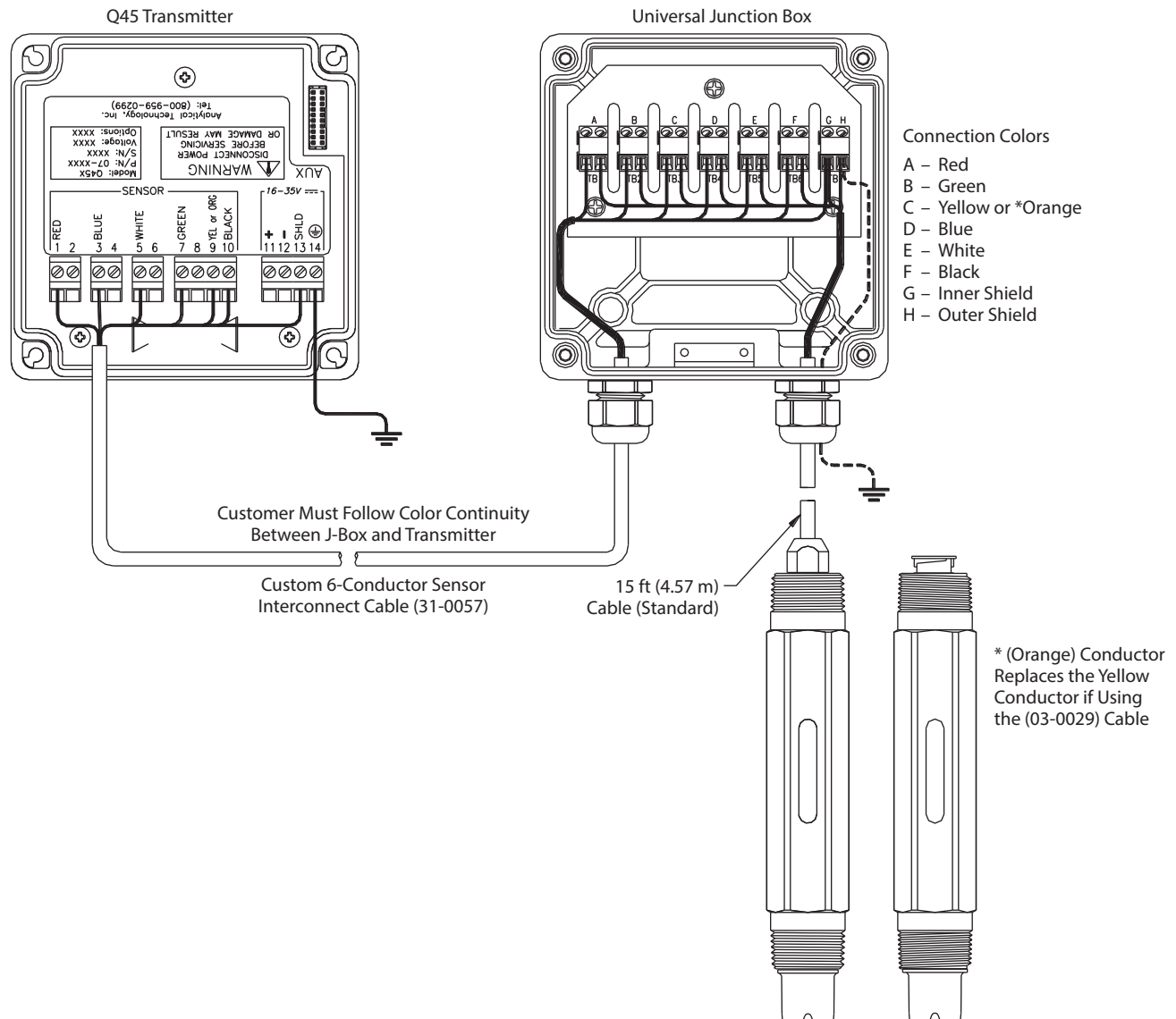


Figure 16: Sensor cable preparation

Junction Box Connection

For installations where the sensor is to be located more than 30 ft from the monitor (max. 60 ft), a junction box must be used. The junction box is shown in [Figure 17](#) for junction box wiring diagram.



NOTE: If the sensor cable (03-0029) is used, use the (yellow) conductor in the interconnect cable to mate with the (orange) conductor in the sensor cable, when connecting the junction box to the transmitter.

Figure 17: Junction box interconnect wiring

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 (for example, no internal jumpers or pots).

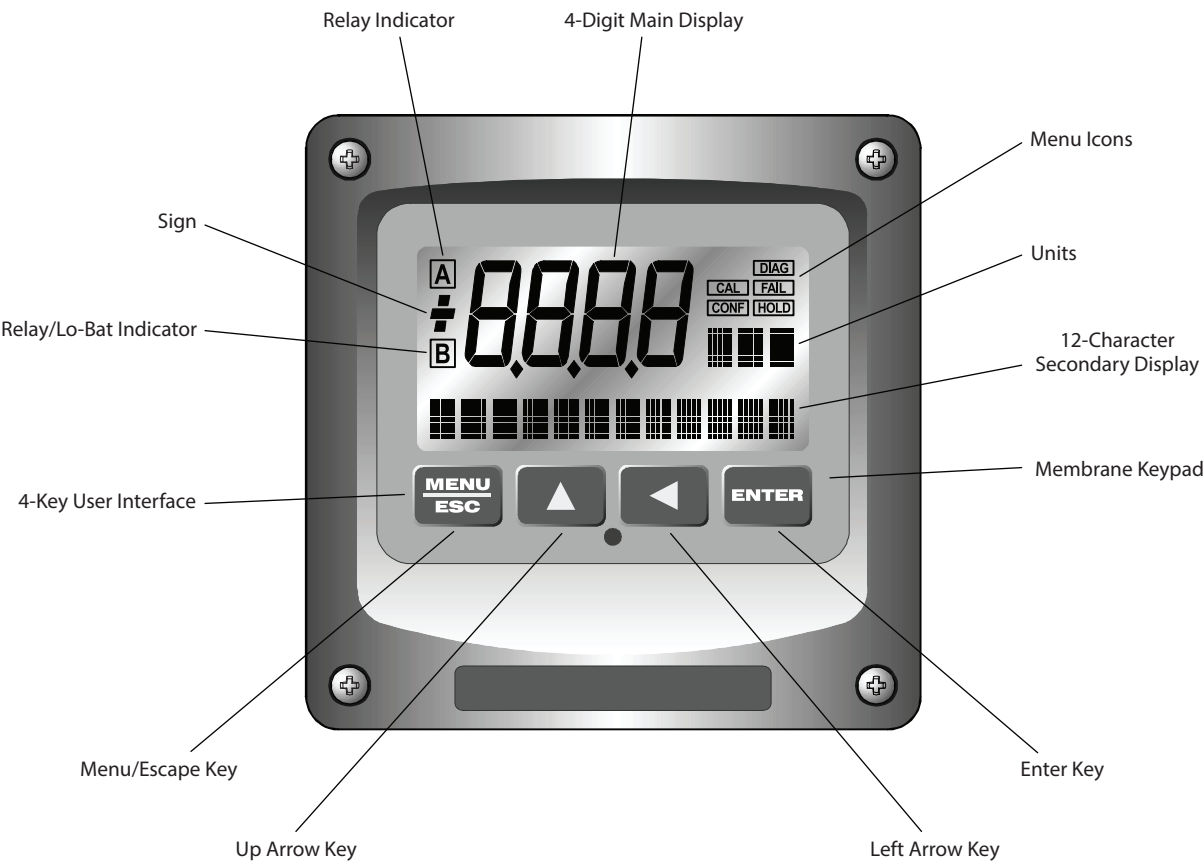


Figure 18: User interface

Keys

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

MENU/ESC	To 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 ESC 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)	To scroll through individual list or display items and to change number values.
LEFT (arrow)	To move the cursor from right to left during changes to a number value.
ENTER	To select a menu section or list item for change and to store any change.

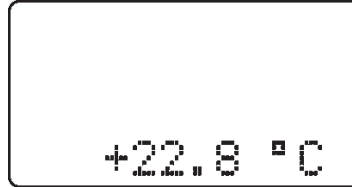
Display

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 43](#).



Icon Area The icon area contains display icons that assist the user in set-up 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 dramatically. 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 that 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 Q45C4 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 19 on page 29](#) 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 conductivity generally requires more than one piece of information to be entered. Most 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 which 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.

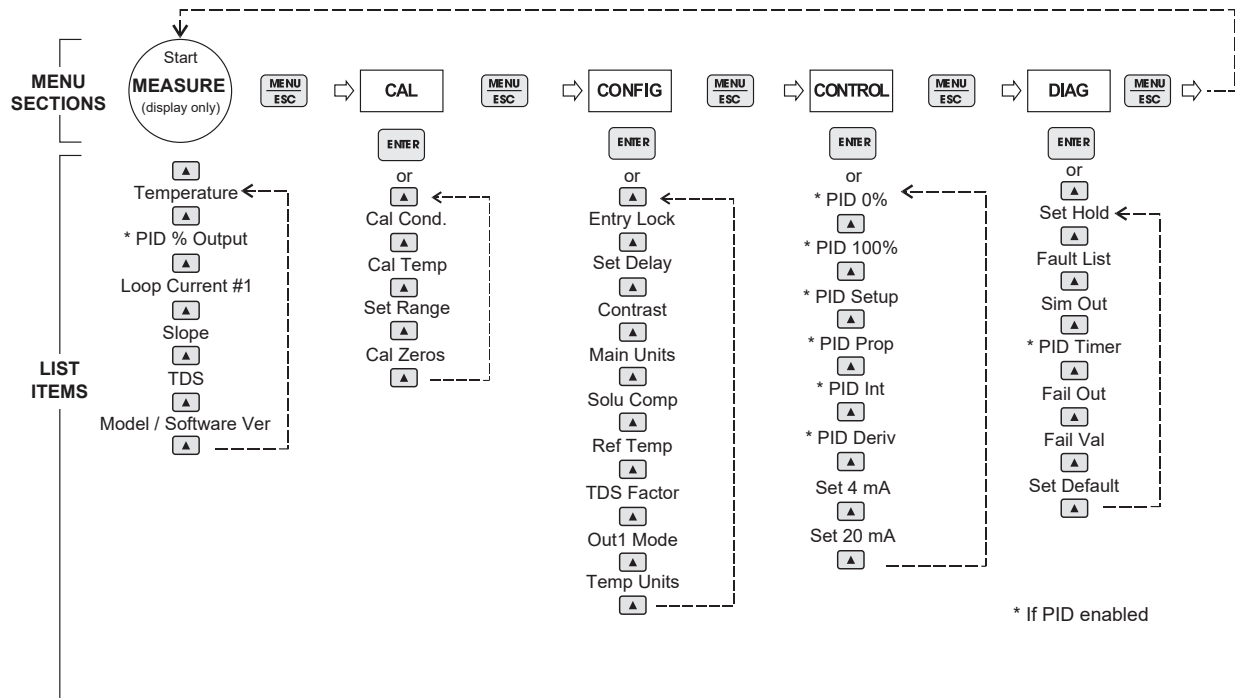


Figure 19: Software map

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.
100% 20.00 mA	<i>PID Status</i> 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.
Cell Const	This function allows the user to directly enter the factory measured cell constant for the Q25C4 sensor. When this feature is used, calibration with reference solutions is unnecessary. See “Calibration” on page 34 for more details.
TDS = 200 ppm	Total Dissolved Solids (TDS). Displays TDS of process.
Q45C2 v4.00	Transmitter software version number.

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 five items in this list: *Cal Cond*, *Cell Temp*, *Cal Const*, *Set Range* and *Cal Zeros*.

- | | |
|-------------------|---|
| Cal Cond | The conductivity calibration function allows the user to adjust the transmitter offset and span reading to match reference buffers, or to adjust the sensor offset to match the sample reading. See “Calibration” on page 34 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 $\pm 5^\circ\text{C}$. 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 34 for more details. |
| Cell Const | This function allows the user to directly enter the factory measured cell constant for the Q25C4 sensor. When this feature is used, calibration with reference solutions is not necessary. See “Calibration” on page 34 for more details. |
| Set Range | This function allows the user to set the display range of the transmitter for a specific application. Once set, all output functions use this display range to establish configuration settings. Press ENTER to initiate <i>User Entry</i> mode; the value flashes. Use the arrow keys to modify the range for the desired range and then press ENTER . |
| Cal Zeros | This function calibrates all range zero-points to the specific sensor being used. This function is only required to be performed once at initial startup or when the sensor has been replaced. See “Calibration” on page 34 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 <i>Entry Lock</i> 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 <i>User Entry</i> mode and the first digit flashes. Use arrow keys to modify value. See page 45 for the Q45C4 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 conductivity 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 <i>User Entry</i> mode; 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 | <p>This function sets the contrast level for the display. The custom display is designed with a wide temperature range, Super-Twist Nematic (STN) fluid.</p> <p>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 <i>User Entry</i> 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.</p> |
| Main Units | This function allows the user to change the measurement in the primary display area. The user may select between conductivity, sensor temperature or output current. Using this function, the user may choose to put temperature in the main display area and conductivity on the secondary, lower line of the display. Press ENTER to initiate <i>User Entry</i> mode, and the entire value flashes. Use the UP arrow key to modify the desired display value. Press ENTER to store the new value. |

Select TC	<p>This function allows the user to select either a Pt1000 or Pt100 platinum RTD temperature element. The Pt1000 element is the standard element in all high performance Q25 sensors; it is the recommended temperature sensing element for all measurements. The Pt100 selection is provided as an alternative for use with existing combination-style sensors. Press ENTER to initiate <i>User Entry</i> mode, and the entire value flashes. Use the UP arrow key to modify the desired value. Press ENTER to store the new value.</p>
Temp Mode	<p>This function sets the temperature compensation algorithm for the instrument. The following choices are available: <i>Lin</i>, <i>1 Tbl</i> and <i>2 Tbl</i>.</p> <ul style="list-style-type: none"> • Lin: Linear temperature compensation method. This is the most common method and is recommended for most aqueous solutions. The slope for this method is set in the <i>Linear Comp</i> section. • 1 Tbl: Ammonia compensation method. This method is specific only to ammonia measurement. • 2 Tbl: Natural Water compensation method. This setting is limited to the temperature range of 0...35° C. <p>NOTE: Do not set the <i>Temp</i> mode to a value other than Lin unless the instrument is specifically intended to measure one of the compounds listed above.</p> <p>NOTE: If <i>Temp</i> mode is set to 1 Tbl or 2 Tbl, the settings for <i>Linear Comp</i> and <i>Ref Temp</i> does not appear in the <i>Software</i> menu.</p> <p>This selection is critical for control of the internal diagnostics and compensation factors. Press ENTER to initiate <i>User Entry</i> mode, and the entire value flashes. Use the UP arrow key to modify the desired value.</p>
Solu Comp	<p>This function sets the correction slope value for the linear temperature compensation method and is used when the <i>Temp Mode</i> is set to Lin. Linear compensation is the method recommended for most aqueous solutions, and the value is typically 2.00%/°C (25° C reference temperature) for neutral water. This is the factory default and it provides the best compensation for most aqueous solutions. Other typical ranges include:</p> <p>Acids: 1.0...1.6%/°C Bases: 1.8...2.0%/°C Salts: 2.2...3.0%/°C</p> <p>NOTE: If the temperature units are changed between °C and °F (see "<i>Temp Units</i>"), the default setting for this output changes between 2.00%/°C...1.11%/°F accordingly.</p> <p>Other compensation slopes for uncommon solutions may be found in chemical handbooks (such as the CRC). Press ENTER to initiate <i>User Entry</i> mode, and the entire value flashes. Use the arrow keys to modify the desired value; entry range is 0.000%/°C (no compensation)...4.000%/°C. Press ENTER to store the new value.</p>
Ref Temp	<p>The reference temperature function sets the basis point for the linear temperature compensation methods. In most cases this setting should be left at the default of 25.0° C.</p> <p>Press ENTER to initiate <i>User Entry</i> mode, and the entire value flashes. Use the arrow keys to modify the desired value; range is 0.0...50.0° C. Press ENTER to update and store the new value. This setting appears in the <i>Software</i> menu only if "<i>Temp Mode</i>" is set to Lin.</p>
TDS Factor	<p>This function sets the linear relationship of the TDS (total dissolved solids) reading to the conductivity measurement. The actual units for the slope are in mg/L/μS. The default value is 00.49 mg/L/μS.</p> <p>Press ENTER to initiate <i>User Entry</i> mode, and the entire value flashes. Use the arrow keys to modify the desired value; range is 00.00...99.99 mg/L/μS. Press ENTER to update and store the new value.</p>
Out 1 Mode	<p>This assigns the 4...20 mA output #1 to either μS (by selecting 1) or for PID output (by selecting 2).</p>
Temp Units	<p>This function sets the display units for temperature measurement. Press ENTER to initiate <i>User Entry</i> 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.</p>

CONTROL

Set 4 mA

Set 20 mA

[Iout1=Cond]

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. Typically set 4 and 20 mA are used for conductivity.

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*, and 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*, and 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]

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.

CALIBRATION

Overview and Methods

Calibration of the Q45C4 is required to accurately match the sensor characteristics to the monitor/analyzer. Since the output of the conductivity sensor does not degrade over time, it is typically only required that the sensor be calibrated at initial installation and then cleaned periodically to maintain proper system accuracy.

It is important for the user to establish a periodic cleaning and calibration-check schedule for sensor maintenance to maintain high system accuracy. Since the conductivity of a solution is greatly affected by temperature, proper settings for thermal compensation are critical for accurate operation. Before calibrating the instrument for the very first time, it is important to select the proper operating parameters in the *Configuration* menus for temperature compensation methods. Also at initial installation, a temperature calibration must be performed before conductivity can be calibrated.

When using conductivity calibration standards for a wet calibration, take care not to inadvertently contaminate the reference solution; always thoroughly clean the sensor, rinsing off in tap water and then finish rinsing in pure or de-ionized water.

NOTE: Calibration solutions less than 200 μ S or greater than 100 mS can be very unstable. Moving the sensor back and forth between different value conductivity reference solutions can quickly contaminate the solutions and render them inaccurate.

1-Point Calibration Explained

The 1-point calibration method is generally known as the “grab sample” calibration method. In the 1-point calibration method, the sensor may be removed from the application and placed into a reference solution. It may also be left in the measurement process and calibrated by reference. The 1-point calibration adjusts the sensor slope to match the exact calibration point. Readings beyond that point are then extrapolated from the determined slope of the calibration line. Since the sensor slope does not degrade over time, frequent re-calibration is unnecessary. Calibration accuracy can be optimized by calibrating with a reference solution which is close to the values typically measured.

Zero Cal Calibration Explained

The sensor offset must be set for the system only on initial sensor installation or when the cable length has been altered. The Zero Cal method establishes all of the sensor offset points for the instrument's 6 ranges of operation.

Performing a Sensor Zero Calibration

The sensor offset **MUST** be set for the system on initial sensor installation, or when the cable length has been altered. However, it can easily be adjusted at any time by re-calibrating the sensor in air. The sensor zero-calibration generally has little effect in measurements above about 50 mS, but it can have a significant effect in measurements below about 1 mS. If the sensor zero cal is to be performed, it must be done **BEFORE** the 1-point reference calibration.

To begin the sensor zero cal, verify that the sensor is connected, clean and dry. It should be placed in the air with the electrodes at least 1 ft away from any nearby objects. Holding it is not recommended – place on table or just hang.

Procedure

1. Remove sensor from process and clean thoroughly. Dry sensor and position on table or hang in air (in air is best.) If on table, let end of sensor hang over the edge of table.
2. Scroll to the *CAL* menu section using the **MENU** key and press **ENTER** or the **UP** arrow key. Scroll to the menu *Zero Cal*.
3. Press the **ENTER** key. The screen prompts the user to position the sensor in air.
4. Press the **ENTER** key. The screen automatically scrolls through all ranges and establish and store the proper zero points.

Performing a 1-Point Calibration

This calibration method is intended to be used as an online calibration method or a wet-cal with reference solutions. During calibration, the system displays the current conductivity reading, and the user can manually enter a reference value from a reference solution bottle or a comparative reference instrument.

For wet calibrations, the user may use pre-made calibration references (also available from Badger Meter) or a NaCl solution may be made using pure, dried NaCl crystals and one liter of high purity, de-ionized, CO₂-free water as mixed in the table shown in [“NaCl Reference Solution for Calibration \(25° C\)”](#). All table data is at 25° C, therefore, the sensor must be at this temperature to calibrate properly using the table data. If another reference calibration solution is being used, be sure to note temperature of reference solution before calibration. Since the sensor must ideally be at the specified temperature, wet calibrations can be difficult to perform accurately.

NaCl Reference Solution for Calibration (25° C)

$\mu\text{S/cm}$	NaCl (gm)
100	0.05
200	0.10
500	0.25
1000	0.50
2000	1.01
3000	1.53
4000	2.06
5000	2.61
8000	4.34
10000	5.56
20000	11.59

During the 1-point calibration, the system automatically picks the correct range for the calibration reference if the Q45C4 is in the AUTO range (see [“1-Point Calibration Explained” on page 34](#)). If the Q45C4 is in a normal display mode, the user must be careful to calibrate with a solution that falls into the manual range selected. If the calibration solution is outside the manual range, an error results.

Procedure

1. If a zero calibration on the sensor is also to be performed, that must be done **FIRST**. The zero calibration process can have an impact on the result of the 1-point calibration. So if a zero cal is required, do that procedure and return here.
2. Determine whether the calibration is done online or with the sensor removed and placed into a reference solution. If the sensor is removed from the application, rinse and clean.
3. If the sensor has been removed and placed into a solution, allow the sensor to temperature equilibrate with the solution as much as possible. With the sensor coming from an application that 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.
4. Scroll to the *CAL* menu section using the **MENU** key and press **ENTER** or the **UP** arrow key. Scroll until *Cal Cond* is displayed. Press **ENTER**.
5. The screen prompts the user to place the sensor into the reference solution (ideally this has already been done to achieve temperature equilibrium.) Once sensor is ready, press **ENTER**.
6. The system now begins acquiring data for the calibration value. As data is gathered, the units for conductivity 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.
7. The screen displays the last measured conductivity value and a message displays prompting the user for the reference value. The user must then modify the screen value with the arrow keys and press **ENTER**. The system then performs the proper checks.
8. If accepted, the screen displays the message "PASS" with the slope value, then it returns to the main measurement display. If the calibration fails, a message indicating the cause of the failure displays and the *FAIL* icon turns on.

Temperature Calibration

The temperature input is factory calibrated for the highest accuracy. Temperature calibration is not recommended; however, it is provided for applications in which very long cable lengths are needed. For example, at 50 ft, readings may be off $\pm 0.2^{\circ}\text{C}$.

The temperature calibration sequence is essentially a 1-point offset calibration that allows adjustments of approximately $\pm 5^{\circ}\text{C}$.

The sensor temperature may be calibrated on line, 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* (see [“Control” on page 33](#)) feature prior to calibration to lock out any output fluctuations.

Procedure

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 sensors 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 message “Adjust temp value then 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 $\pm 5^{\circ}\text{C}$ from the factory calibrated temperature are allowed. Press **ENTER**.
5. The calibration data gathering process begins. The message “Wait” flashes as data is accumulated and analyzed. The $^{\circ}\text{C}$ or $^{\circ}\text{F}$ symbol may flash periodically if the reading is too unstable.
6. 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 which may be simply 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 (for example, valves and proper chemicals) 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, 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).

PID Equation

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

Where:

output = controller output

P = proportional gain

I = integral gain

D = derivative gain

t = time

e(t) = controller error (e=measured variable – setpoint)

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 or 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” on page 33](#), 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, it's 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 *P*s and low *I*s appear to operate the same as combinations of low *P*s and high *I*s, there is a difference in rate of recovery and stability. Because of the way the algorithm is structured, large *P*s can have a larger impact to 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 Q45H 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) do not 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 38](#) 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 PID Output* function allows the user to take manual control of the PID control signal. 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 or you may decrease the output by pressing the **LEFT** arrow. 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.

Close-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, pH 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

System Checks

1. If the "FAIL" icon is flashing on the display, check the *Fault List* to determine the cause of the failure. To access the *Fault List*, press the **MENU/ESC** key until the *DIAG* menu appears. Then press the **UP** arrow key until the *Fault List* appears. Press the **ENTER** key to access the *Fault List*, and the highest priority fault message displays. For a list of all messages and possible causes/solutions, see "*Display Messages*" on page 43.
2. In **ALL** environments, connect an earth ground jumper to earth terminal connection on transmitter.
3. Perform a 1-point calibration prior to sensor installation.
4. Check sensor cable color to terminal strip markings.
5. For highly unstable behavior, remove sensor from the process and measure the process solution in a plastic beaker. If the reading now stabilizes, place wire in beaker solution and actual process solution to determine if a ground loop exists.
6. If the instrument 4...20 mA output is connected into other control systems, disconnect output loop from system load and run through a handheld DMM to monitor current. Verify that the system operates correctly in this mode first.

Instrument Checks

1. Remove sensor completely and connect 1100 Ohms from the yellow-to-black sensor input leads. Make sure the unit is configured for a Pt1000 thermal element and that the temperature is not in *Manual Locked* mode. The temperature reading should display approximately 25° C and the conductivity reading should display approximately 0.0 µS.
2. With a DMM, measure the DC voltage from the white sensor lead connection to the black sensor lead connection. With the positive DMM lead on the white wire, the meter should read between -4.5...-5.5V DC.
3. For the line powered version, verify the proper line voltage power. With power disconnected, verify continuity across the line fuse.
4. For the DC transmitter variation, verify that power supply has required voltage based on size of resistance in current loop. Large resistive loads can reduce available power for transmitter.

NOTE: See sensor manual for specific sensor tests to be performed.

Cleaning the Sensor

Keep the sensor as clean as possible for optimum measurement accuracy. Frequency of cleaning depends upon the process solution.

Wipe the measuring end of the sensor with a fine abrasive cloth (ScotchBrite or equivalent). Then rinse with clean water (distilled or de-ionized if possible). This should remove most contaminate buildup.

If necessary, soak the sensor for several minutes in a mild soap solution. Use a small, extra-soft bristle brush (such as a mushroom brush) to thoroughly clean the electrode surfaces. If surface deposits are not completely removed after performing this step, a dilute acid may be used to dissolve the deposits. Soak for a few minutes, and then rinse the sensor thoroughly with clean water (distilled or de-ionized if possible).

NOTE: DO NOT soak the sensor in dilute acid solution for more than 5 minutes.

WARNING

ACIDS ARE HAZARDOUS. ALWAYS WEAR EYE AND SKIN PROTECTION WHEN HANDLING. FOLLOW ALL MATERIAL SAFETY DATA SHEET RECOMMENDATIONS. A HAZARDOUS CHEMICAL REACTION CAN BE CREATED WHEN CERTAIN ACIDS COME IN CONTACT WITH PROCESS CHEMICALS. MAKE THIS DETERMINATION BEFORE CLEANING WITH ANY ACID, REGARDLESS OF CONCENTRATION. DO NOT USE HYDROCHLORIC ACID ON ANY STAINLESS STEEL PORTION OF THE SENSOR.

After cleaning the sensor, check measurement and re-calibrate the sensor.

Troubleshooting

The first step in resolving any measurement problem is to determine whether the trouble lies in the sensor or the transmitter. Since measurement problems can often be traced to foulants coating the electrodes, cleaning the sensor using the method outlined in *"Cleaning the Sensor" on page 41* should always be the first step in any troubleshooting. If the sensor cannot be calibrated after cleaning, perform the following test. A multimeter is needed.

- 1. Disconnect the sensor from the transmitter or junction box.
- 2. Using a multimeter, verify continuity between electrodes indicated below and the corresponding wire colors in the cable (red, blue, green and white only).

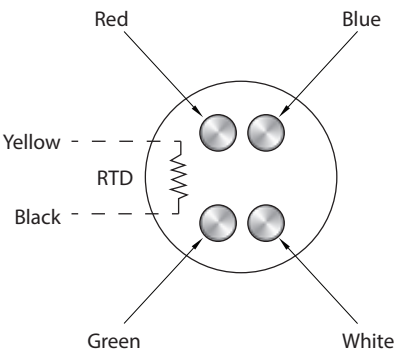


Figure 20: Sensor face

- 3. Verify that the sensor’s temperature element (Pt1000 RTD) is functioning properly by measuring the resistance between the sensor’s yellow and black wires. The nominal resistance value at 25° C is 1097 Ohms. Use the following table as a guide to the approximate resistance value:

°C	RTD
20	1078 Ω
25	1097 Ω
30	1117 Ω
35	1136 Ω

Display Messages

The Q45 Series instruments provide a number of diagnostic messages that 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 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.	Clean sensor, get fresh cal solutions, allow temperature and conductivity readings to fully stabilize, do not handle sensor or cable during calibration.
Slope HIGH	Sensor slope from calibration is greater than 110%.	Get fresh cal solutions, allow temperature and conductivity readings to fully stabilize, check for correct buffer values.
Slope LOW	Sensor slope from calibration is less than 80%.	Clean sensor, get fresh cal solutions, allow temperature and conductivity readings to fully stabilize, check for correct buffer values.
Offset HIGH	Sensor offset from calibration is less than -90 mV or greater than $+90$ mV.	Clean or replace saltbridge, replace reference cell solution, clean sensor, get fresh cal solutions, allow temperature and conductivity readings to fully stabilize, check for correct buffer values.
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.
TC-F25 lock!	The TC selection is in F25 mode, locked at 25°C .	Calibration and TC adjustment cannot be performed while the TC is in F25 mode. To allow access to TC calibrations, change TC mode from F25 (fixed 25) to SENS (sensor).

The following messages appear as items on the *Fault List*:

Message	Description	Possible Correction
Sensor High	The raw signal from the sensor is too high.	Check wiring connections to sensor.
Sensor Low	The raw signal from the sensor is too low.	Check wiring connections to sensor.
Cond Too High	The conductivity reading is > 2000 mS.	The conductivity reading is over operating limits.
Temp High	The temperature reading is > 210° 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.	The temperature reading is under operating limits. Check wiring and expected temp level. Perform RTD test as described in sensor manual. Recalibrate sensor temperature element if necessary.
TC Error	TC may be open or shorted.	Check sensor wiring and perform RTD test as described in sensor manual.
Clean Sensor	Foulants on sensor have reached the level that they cannot be adjusted out.	Clean the sensor thoroughly.
Cond Cal Fail	Failure of conductivity calibration.	Clean sensor, get fresh cal solutions and redo calibration. If still failure, sensor slope may be less than 50%. Perform sensor tests as described in sensor manual. Replace sensor if still failure.
TC Cal Fail	Failure of temperature calibration.	Clean sensor, check cal solution temperature and repeat sensor temp calibration. TC calibration function only allows adjustments of $\pm 6^{\circ}$ C. If still failure, perform sensor tests as described in sensor manual. Replace sensor if still failure. NOTE: TC offset may also be adjusted using the <i>Cal TC Factor</i> function (See " Calibration Menu [CAL] " on page 31) which involves no calibration reference solutions.
EEProm Fail	Internal non-volatile memory failure.	System failure, consult factory.
Checksum 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.

SPARE PARTS

Part No.	Description
Spare Electronics	
*	Transmitter Assy, 2 Wire
03-0335	Q45C4 Front Lid Assy
Spare Sensors	
00-1526	Flow Type, Noryl Body with Connector
07-0055	Convertible, PEEK Body, 15 ft
07-0067	Convertible, PEEK Body, 30 ft
07-0090	Convertible, PEEK Body with Connector
07-0083	Insertion, 316 SS Body, 15 ft
07-0098	Sanitary Style, 1-1/2 in., 316 SS Body, 15 ft
07-0068	Sanitary Style, 2 in., 316 SS Body, 15 ft
07-0243	Insertion, 316 SS Body, 30 ft
07-0424	Sanitary Style, 1-1/2 in., 316 SS Body, 30 ft
07-0425	Sanitary Style, 2 in., 316 SS Body, 30 ft
Spare Flowcells	
00-1522	Sealed Flowcell Assy
05-0110	Sealed Flowcell Vacuum Breaker
07-0209	1 in. Flow Tee
Spare Sensor Components	
09-0046	Conductivity Standard – 84 microSiemens, 500 mL
09-0047	Conductivity Standard – 447 microSiemens, 500 mL
09-0048	Conductivity Standard – 1,500 microSiemens, 500 mL
09-0049	Conductivity Standard – 8,974 microSiemens, 500 mL
09-0050	Conductivity Standard – 80,000 microSiemens, 500 mL
Miscellaneous Components	
07-0100	Junction Box
03-0029	Sensor Cable with Connector, 25 ft
31-0057	Sensor Interconnect Cable

* Please consult factory for electronic assembly part number.

Lock/Unlock Code: 1453

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