Free Chlorine Amperometric 4-20mA Sensors

Product Instructions

Section 1.0
Theory of Operation

1.0 Free Chlorine Defined

Free Chlorine or "freely active chlorine" is defined as the sum of molecular chlorine (Cl_2), hypochlorous acid (HOCl) and hypochlorite ions (OCl^-). Molecular chlorine occurs at pH values <pH4. Hypochlorus acid and hypochlorite ions are in pH dependent equilibrium with one another as shown in FIG 1. The graph shows the percentage of hypochlorous acid on the left of the curve. Hypochlorous acid is a much stronger disinfecting agent (oxidizer) as compared to hypochlorite ions.

1.1 Sensor Operating Principle

Only hypochlorous acid (HOCl) diffuses through the membrane between the cathode and sample solution. At the applied potential, only hyphochlorous acid is electrochemically reduced. HOCl is reduced to chloride ion at the gold cathode. At the same time, the silver anode is oxidized to form silver chloride (AgCl). When the concentration of HOCl at the cathode is dramatically decreased by electrochemical reduction, hypochlorite ion will be transformed into hypochlorous acid, and to some extent, by proton transfer. The release of electrons at the cathode and acceptance at the anode creates a current flow, which under constant conditions, is proportional to the free chlorine concentration in the medium outside the sensor. The resulting low current output is then conditioned to 4-20mA current by the sensor's onboard electronic circuitry.

Section 2.0
Factors Influencing the Sensor

2.0 pH

Free Chlorine (FCL) exists as hypochlorous acid and hypochlorite anion (FIG 1). The acid-base dissociation of FCL has a pKa of approximately 7.5. The FCL sensor responds to hypochlorous acid and hypochlorite anion with different sensitivity. In combination, an increase in pH reduces the measured FCL and decrease in pH increases the measured FCL. For the most accurate free chlorine measurement, keep system pH at <6.5.

2.1 Chemical Interferences

The sensor should not be used in water containing surfactants. Monochloramine and ozone are interferences.

2.2 Flow

To acheive reproducible measurements, the (CLD) chlorine dioxide sensors require a specified constant flow rate. To avoid complications (such as bubbles), it is best to operate the sensors at a flow rate of 0.2 - 0.6 gpm if using flow cell FC72 or FC70 (old version). Use of a flowmeter is recommended (FM001- See Section 4.1)

2.2 Pressure

Pressure is relieved via a small vent hole covered with a silicone sleeve (FIG1). DO NOT REMOVE THE SLEEVE, even when refilling the sensor.

FIG. 1

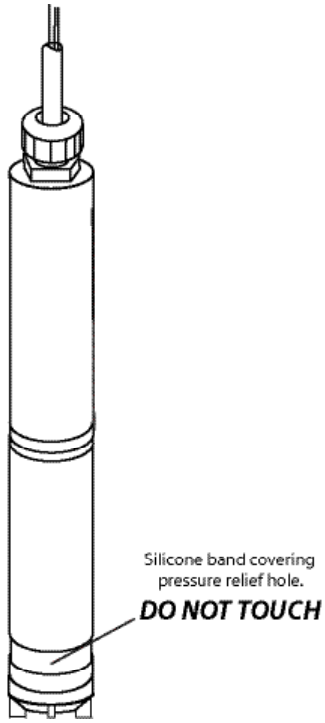


FIG. 1a

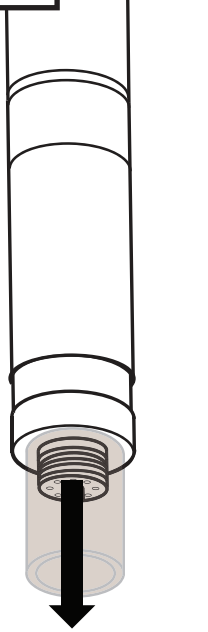
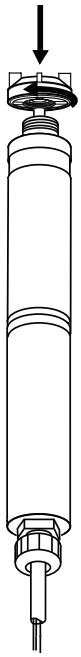


FIG. 1b



Parts covered by this product data sheet include:
FCL502, FCL505, FCL510, FC72, FCLA-5015, FCLA-5016, FCLA-5017, FCLA-5018

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SECTION 3.0
Sensor Preparation

3.0 Free Chlorine Sensor Assembly

Your Free Chlorine Sensor is shipped with a protective tube covering the cathode. Remove the tube per FIG. 1A. It is also shipped with 2 mebrane cap assemblies, 1 replacement pressure relief band, 3 sheets of polishing paper and 2 bottles of electrolyte. First, fill the sensor with electrolyte using the provided needle and syringe (FIG. 8). Next attached the membrane cap assembly (FIG. 1B). Next install sensor into flow cell per SECTION 5. 0. **NOTE:** ***If sensor will be stored out of flow cell, the internal fill solution should be removed. Take the membrane cap and immerse in a cup of tap water until ready to reuse. See Section 10. Replace cap and electrolyte before installing into flow cell (See section 10 for cap and electrolyte change and see section 5 for sensor installation into flow cell).***

SECTION 4.0
Flow Cell/Flow Meter Installation

4.0 Flow Cell

To obtain accurate Free Chlorine readings, the Sensor must be installed into the Flow Cell to prevent air bubbles formation on the membrane while maintaining proper spacing between the sensor and the installation wall, and laminar flow across the membrane. *Make sure sensor and flow cell are oriented vertically or no more than 45 degrees below vertical* (SEE FIG 2B).

4.0a Using two 1/4" NPT Tube fittings, connect the FC72 Flow Cell into your system, noting the inlet (bottom) and outlet (side) orientation (SEE FIG 2).
4.0b Install clamp with rubber backing as shown in FIG 2A.
4.0c Drill 3/8" diameter hole on the panel.
4.0d Insert bolt as shown in FIG 2A.
4.0e On back of panel attach lock washer and nut to secure clamp and flow cell to panel.

Ensure flow cell is mounted at 45 deg or higher above horizontal as shown in FIG 2B.

4.1 Flow Meter

To control flow to the flow cell, a flow meter is recommended. Sensorex supplies model FM001 for this purpose. The FM001 provides flow control from 0.1 to 1.0 GPM (0.5 to 4.0 LPM) with 94% accuracy.

4.1.1 Install the flow meter and flow cell as shown in FIG 2C. Follow the diagram so that the incoming water is attached to the bottom of the flow meter (where flow adjustment knob is located).

FIG. 2

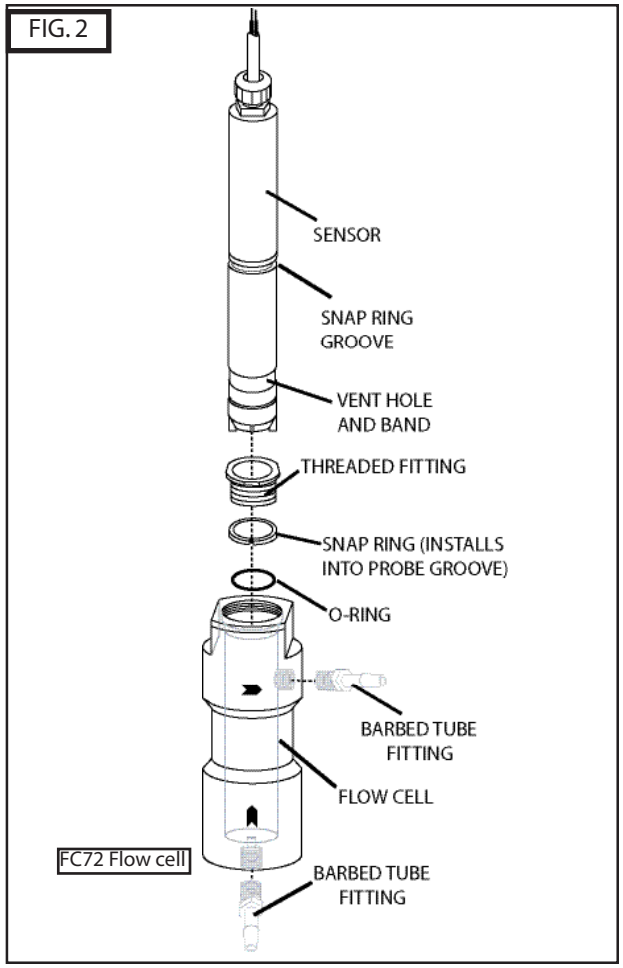
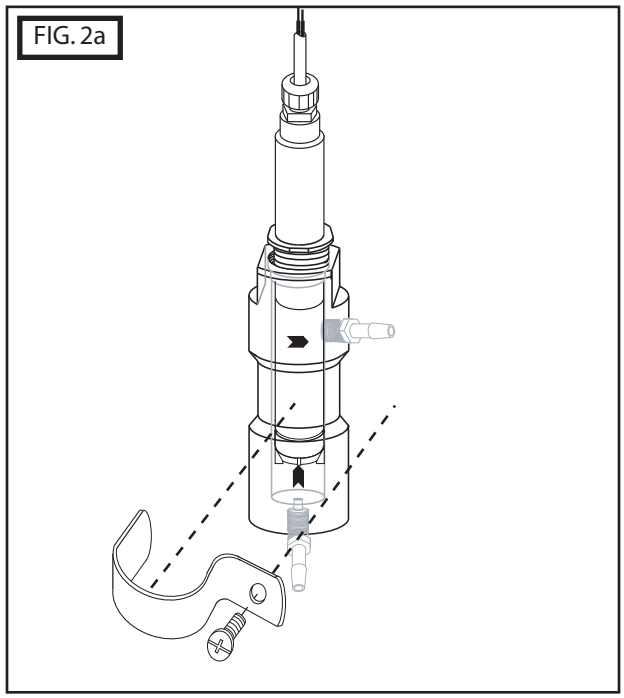


FIG. 2a



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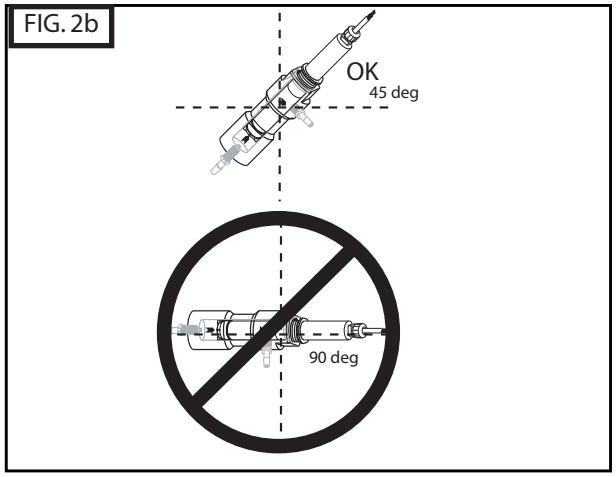
SECTION 5.0
Sensor Installation

5.0 Sensor Installation into Flow Cell

a) First install threaded fitting onto sensor body (remove fitting if pre-installed in flow cell)
b) Install snap-ring into groove on sensor body
c) Next, slide o-ring onto body of sensor until it reaches bottom of threaded fitting.
d) Thread sensor assembly into top of flow cell as shown in FIG 2.
e) Turn on flow and verify the flow through the Flow Cell is at least 0.2 gpm (45 liters/hour and no more than 0.6gpm (135 liters/hour).

FIG. 2b



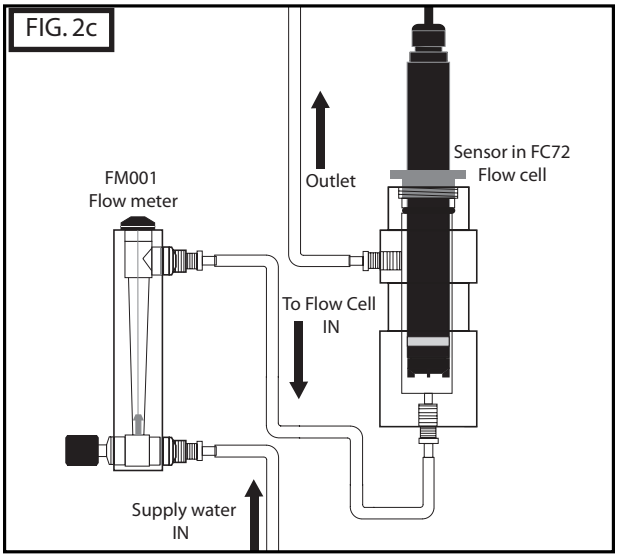
SECTION 6.0
Electrical Installation

6.0 Electrical Installation

The sensor produces an approximate output of 4 mA in air and 20 mA at the top range of chlorine dioxide output (0-2ppm, 0-5ppm and 0-10ppm).

NOTE: The supply voltage to the Sensor must be 12-24 V DC with minimum of 250 mA. Maximum load is 1 Watt. The sensor has 2 wires, red (+), black (-). Attach the red wire to the power supply positive terminal (+) and the black wire to the PLC or DVM positive (+) terminal. Connect a wire (customer supplied) from the power suppy negative (-) and the PLC or DVM (-). See FIG 3. The Sensor will require several minutes to stabilize after power is supplied to it.

FIG. 2c



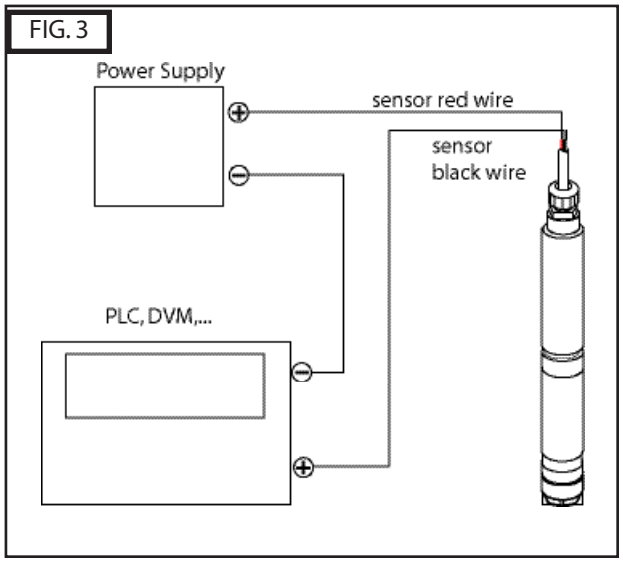
SECTION 7.0
Sensor Conditioning

7.0 Sensor Conditioning

The sensor requires conditioning prior to generating stable values.

a) For new Sensors, connect the sensor to power and allow to run overnight (at least 12 hours) before calibration.
b) If the Sensor will be un-powered for two hours or more, run for two hours prior to use.
c) If the Sensor's flow will be off for one hour or less, run the sensor for at least one hour prior to recalibration.
d) After membrane/electrolyte replacement, allow the Sensor to run powered overnight (at least 12 hours before calibration.

FIG. 3



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Section 8.0
Calibration

NOTE: Sensors are supplied factory calibrated with a 4-20mA signal output corresponding to their specific range (0-2, 0-5 OR 0-10ppm). Any span/range calibration can be done at your PLC or other 4-20mA input device. Fine span calibration can be done at the sensor if required. The zero-point calibration is not necessary since the zero setting is very stable. Check calibration about once per week. No need to calibrate if it has not changed much. This is useful in tracking sensor failures as well. This calibration should also be done at the PLC or other 4-20mA input device.

8.0 Span/Slope Calibration

a) Determine the chlorine dioxide content using a diethyl-p-phenylenediamine (DPD) colorimeter test kit (SEE FIG 4) not included with the and flow cell.
b) Measure free chlorine content with sensor. Make sure that calibration flow rate matches flow rate when measuring sample since probe output is flow rate dependent. Make sure pH is within 4.0-11 range.
c) Adjust span/slope at PLC/4-20mA device.
d) Repeat this slope calibration one day after sensor is initially installed.
e) Repeat the slope calibration monthly.

Section 9.0
Sensor Storage

9.0 Storage

Store sensor at 5^{O} C - 50^{O} C *only* and maximum humidity of 95% non-condensing.

a) *Short Term Storage* (one week or less): Store in Flow cell with water to prevent the probe from drying out.
b) *Intermediate Term* (one week to one month): Store in cap, bottle, or beaker with water to keep membrane wet.
c) *Long Term* (one month or longer): Remove Membrane Cap and store cap completely immersed in tap water. Remove fill solution and pour down drain.

Note: Electrolyte shelf life is one year from date of mfg (see bottle).

Section 10.0
Sensor Maintenance/Reconditioning

10.0 Membrane Cap Replacement

If membrane replacement is required, a new cap with preinstalled membrane must be used. One cap and refill solution is shipped with each sensor. Additional caps are ordered as FCLA-5016, and refill solution as FCLA-5015.
To change membrane cap:

a) Turn sensor upside down with cap facing upward.
b) Rotate cap counter-clockwise to remove (SEE FIG 5).
c) Place needle tip on syringe as shown in FIG 6
d) Remove solution from bottle with needle and syringe as shown in FIG 7
c) Fill sensor body with electrolyte using needle and bottle of refill solution (SEE FIG 8).
d) Install new membrane cap by threading cap onto sensor rotating cap clockwise (Opposite of FIG 5).

FIG. 4

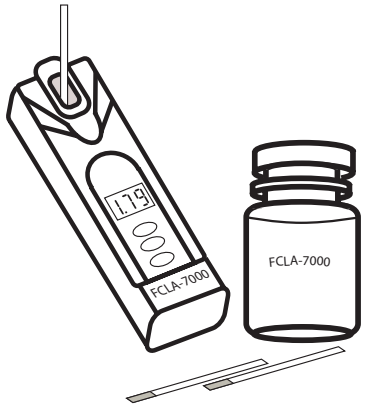


FIG. 5

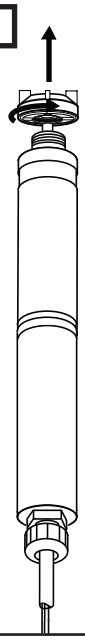


FIG. 6

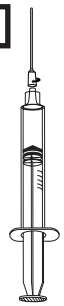


FIG. 7

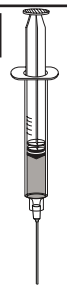
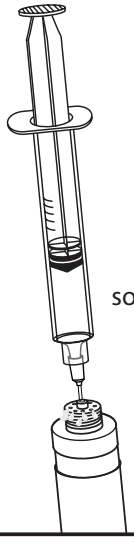


FIG. 8



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SECTION 11
Sensor Maintenance/Reconditioning

11.0 Electrolyte Solution Replacement

Drain old refill solution and pour down drain. Refill the sensor approximately every two months.

11.1 Membrane Replacement

If membrane replacement is required **(change at least every 6 months**), a new cap with preinstalled membrane must be used. One cap and fill solution is shipped with each sensor. Additional caps are ordered as FCLA-5016, and refill solution as FCLA-5015. To change membrane cap :

a) Turn sensor upside down with cap facing upward.
b) Rotate cap counter-clockwise to remove (SEE FIG 5).
c) Attached supplied needle to syringe and remove fill solution as shown in FIG 6 & FIG 7. ***Electrolyte is safe and can be poured down the drain.***
d) Fill sensor body with electrolyte using needle and syringe of refill solution (SEE FIG 8).
e) Install a new membrane cap by threading cap onto sensor rotating cap clockwise (FIG 1B).

11.2 Membrane Cap/Sensor Cleaning

Rinse cap with water only. If cap does not clean, replace with new one.

11.3 Cathode Polishing

If the sensor cannot calibrate, then the gold cathode could be coated. Follow instruction in cathode polishing addendum to this instruction manual. Then fill the sensor and replace membrane cap assmbly and attempt calibration again.

SECTION 12
Sensor Troubleshooting

12.0 Calibration Problems

A. Sensor output *higher* than DPD test
1. Run in time too short
2. Membrane cap damaged
3. Interference from water contaminants (see Specifications, "Cross Sensitivity")
4. Cable short circuit or damage
5. pH value less than pH 5.5

B. Sensor output *lower* than DPD test
1. Run in time too short
2. Deposits on Membrane cap
3. Flow rate too low
4. Air bubbles on membrane
5. Surfactants in water
6. pH value more than pH 8.5
7. No electrolyte in sensor chamber
8. Cathode coated

C. Sensor ouput is 4mA (zero ppm)
1. Run in time too short
2. Only bound chlorine present
3. Chlorine content below detection limit
4. Sensor not wired correctly (See SECTION 6.0 of this manual)
5. Defective sensor

D. Sensor output *unstable*
1. Air bubbles on membrane
2. Membrane damage
3. Pressure fluctuation in sample line

TROUBLESHOOTING CHART

Symptom	Possible Cause	Solution/Remedy
The sensor cannot be calibrated- ouput is *HIGHER than*	1) Run in time too short	1) See Sec 7.0 -CONDITIONING
	2) Membrane cap damaged	2) Replace cap - See Sec 11.0
	3) Interference from contaminants	3) See SPECIFICATIONS
	4) DPD chemicals bad	4) Use new DPD kit
	5)Temperatue increased since cal	5) Match calibration temp.
The sensor cannot be calibrated- output is *LOWER than* DPD Test	1) Run in time too short	1) See Sec 7.0 -CONDITIONING
	2) Deposits on membrane cap	2) Remove deposits or replace cap if cleaning ineffective.
	3) Flow rate too low	3) increase flow - See SPECIFICATIONS
	4) Air bubbles on membrane	4) Remove and re-install sensor to remove bubbles.
	5) Surfactants in water	5) Remove surfactants and replace cap. See SEC 11.0
	6) No electrolyte in cap	6) Add new electrolyte, run in sensor and re-calibrate
	8) Temperature decreased since cal	8) Increase temp to match cal
	9) Cathode coated	9) Polish cathode per Sensorex instructions. This should only be done if electrolyte refill and membrane cap change have not improved sensor performance.
Sensor output is 4mA (0ppm)	1) NO Free chlorine present	1) Check system.
	2) Run in time too short	2) See Sec 7.0 -CONDITIONING
	3) Free chlorine concentration low	3) Add free chlorine and repeat calibration
	4) No electrolyte in cap	4) Refill electrolyte
	5) Sensor electrical connection wrong	5) See SECTION 6.0
Unstable output from sensor	1) Air bubbles on sensor membrane	1) Tap to remove bubbles
	2) Membrane damaged	2) Replace membrane, run in sensor and recalibrate.
	3) Non-sensor problem	3) check PLC or I/O device

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SECTION 13
Sensor Specification

13.0 Operating Specifications

Follow all operating specifications, especially for pH and flow rate as noted in the specification tables below.

TECHNICAL SPECIFICATIONS

SENSOR	
Dimensions:	8.2"L x 1" dia
Body Material:	Black PVC
Membrane Material:	PVDF (FCL405, FCL410), proprietary(FCL402)
O-ring material:	Viton®
Cathode:	Gold
Anode:	Silver chloride (AgCl)
Cable:	2 -conductor shielded, 10ft (3mtr) tinned wire leads
FLOW CELL	
Dimensions:	5.60"H x 2.25"DIA
Material:	Acrylic
Connections:	1/4" NPT inlet and outlet

OPERATING SPECIFICATIONS

Operating Temperature Range:	0-45 degC
Maximum Operating Pressure:	1 bar/14.7 psi/1atm
Flow Rate Minimum:	0.2 gpm (0.75Lpm)
Flow Rate Maximum:	0.6 ppm (2.25Lpm)
pH Range:	5.5-8.5
Output Signal:	4.0+/- 0.4mA in air (zero) 21mA +/- 0.5mA at high range (2, 5 or 10ppm)
Power Requirement:	12-24 VDC, *250* mA minimum
Cross-Sensitivity:	ClO2, ozone, bromine, iodine
Chemical Compatibility:	up to 50% ethanol/water or up to 50% glycerol/water

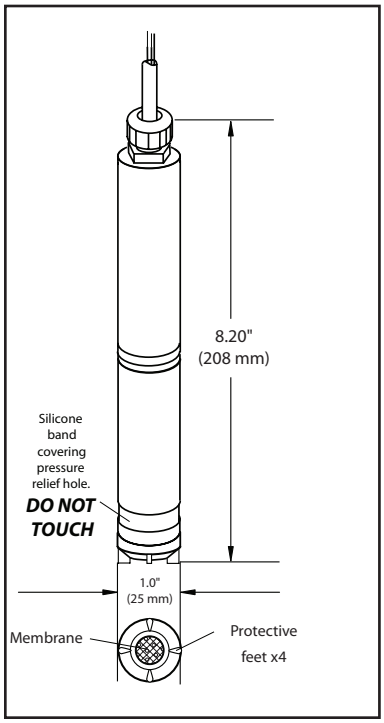
MAINTENANCE/REPLACEMENT PARTS

FCLA-5015	Free Chlorine sensor fill solution, 30mL, 2 each
FCLA-5016	Free Chlorine Replacement premembraned cap, 1 each + pressure relief band, 1 each
FCLA-5017	Polishing squares for gold cathode, 3 each
FCLA-5018	Complete maintenance kit, FCL5 Series includes: 2 each 30mL bottles of electrolyte, 1 membrane cap assembly, 1 pressure relief band, 3 polishing squares for gold cathode

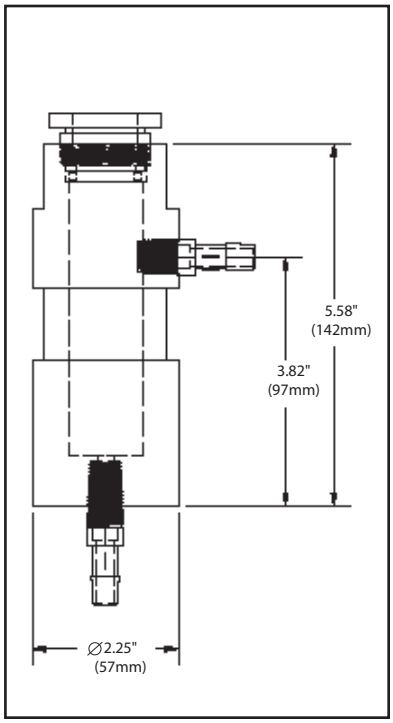
ACCESSORIES

FM001	Flow Meter, 0.1 to 1.0 gpm (0.5 to 4.0 Lpm)1/2 inch MNPT & 1/4 inch FNPT inlet and outlet, includes: 2 each 1/4" barbed tube fittings(3/8" tube)
FC72C	Flow Cell, 1/4 inch FNPT inlet and outlet, includes: 2 each 1/4" barbed tube (3/8" tube) fittings, clamp, threaded flow cell installation fitting
FCLA-7000	Free Chlorine /Chlorine Dioxide Colorimeter-eXact 7+, requires CLDA-7001 strips

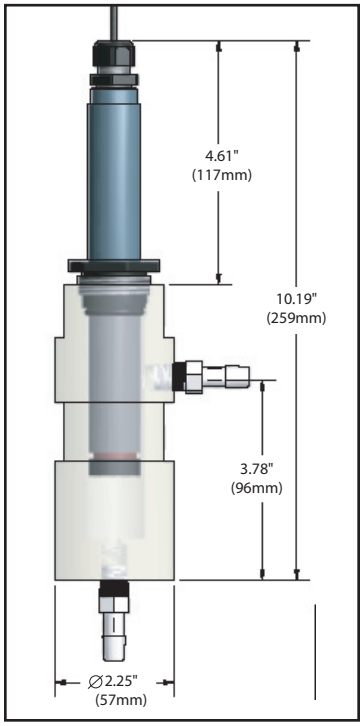
SENSOR DIMENSIONS



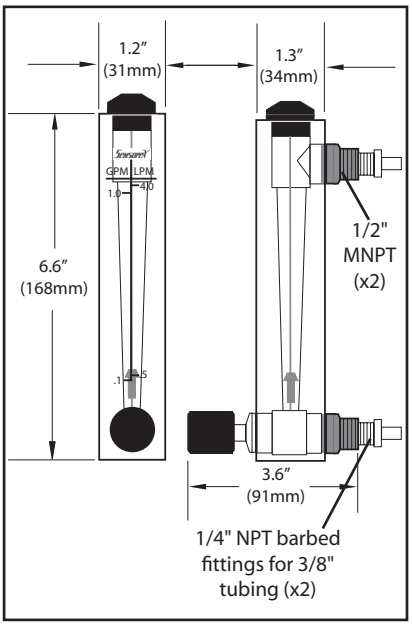
FC72 FLOW CELL DIMENSIONS



SENSOR AND FLOW CELL INSTALLATION DIMENSIONS



FM001 - FLOW METER DIMENSIONS



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