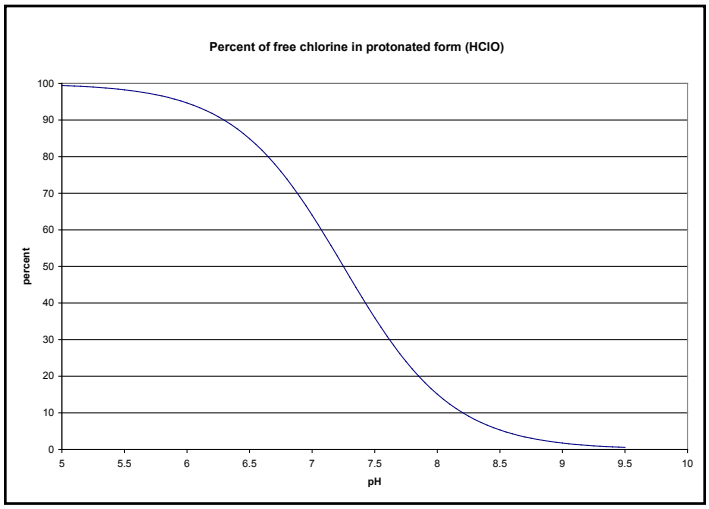
Free Chlorine Amperometric 4-20mA Sensors

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, pH compensation is required above pH 6.5.
pH compensation for the sensors current (mA) reading is:

Real mA = (measured mA – 4)/ compensation factor + 4
compensation factor (2ppm ONLY) = $-0.13*pH^2 + 1.6718*pH - 4.1567$

compensation factor (5ppm & 10ppm) =
$-0.0214*pH^4 + 0.7011*pH^3 - 8.4556*pH^2 + 44.209*pH - 83.573$

2.1 Chemical Interferences

The sensors should not be used in water containing surfactants, organic chlorine or stabilizers such as cyanuric acid, chlorine dioxide, ozone or bromine.

2.2 Flow

To acheive reproducible measurements, the free chlorine (FCL) 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)

Parts covered by this product data sheet include:
FCL410, FC72, FCLA-4015, FCLA-4016

Form: InstrFCL4 [Rev: 2011-06-27]

Section 3.0
Sensor Preparation

3.0 Free Chlorine Sensor Assembly

The Free Chlorine Sensor is shipped with the membrane cap pre-installed and covered with a cap with water inside to keep the membrane wet. Make sure to keep sensor cap, anode and cathode, away from oily or greasy materials. Contact with oil or grease will result in inaccurate measurements. The sensor is also supplied with a three ounce bottle of refill solution, a syringe, and needle tip.

NOTE: If Sensor will be stored dry out of the flow cell, shake body downward into a sink to remove the fill solution. Take the membrane cap and immerse it 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. See Section 5.0 for sensor installation into flow cell).

Section 4.0
Flow Cell/Flow Sensor Installation

4.0 Flow Cell

To obtain accurate Free Chlorine readings, the Sensor must be installed into the Flow Cell to prevent air bubble formation on the membrane, 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 FM001provides flow control from 0.1 to 1.0 GPM (0.5 to 4.0 LPM) with 6% 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

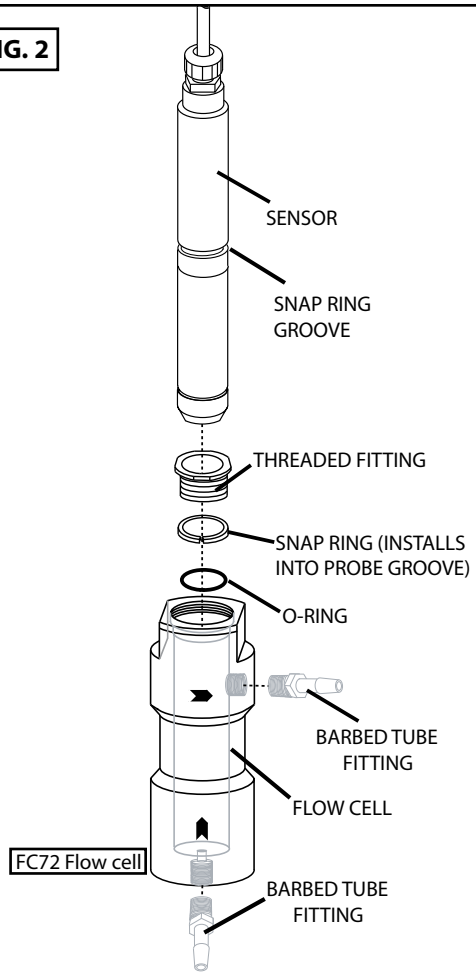
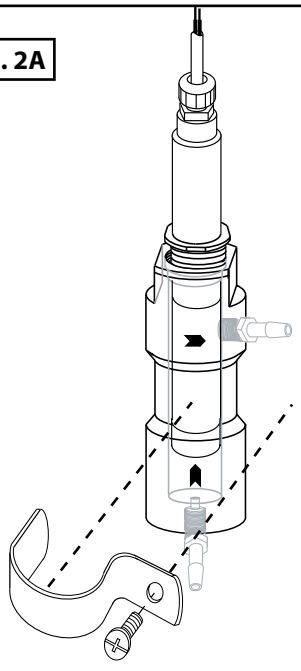


FIG. 2A



Form: InstrFCL4 [Rev: 2011-06-27]

Section 5.0
Sensor Installation

5.0 Sensor Installation into Flow Cell

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

Section 6.0
Electrical Installation

6.0 Electrical Installation

The sensor produces an approximate output of 4 mA in air and 20mA at the top range of free chlorine output (0-2ppm, 0-5ppm, 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 three wires: red (+) , black (-) and clear (shield). Twist together or solder black and clear if instrument does not have separate ground. If a separate ground is available such as for PLC's connect clear (shield) to it. 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.

Section 7.0
Sensor Conditioning

7.0 Sensor Conditioning:

The sensor requires conditioning prior to generating stable values.

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

FIG. 2B

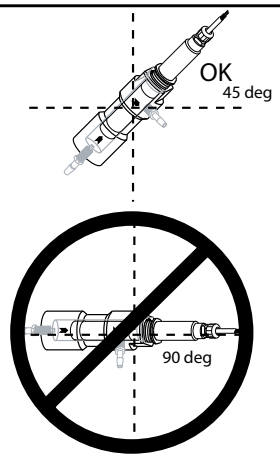


FIG. 2C

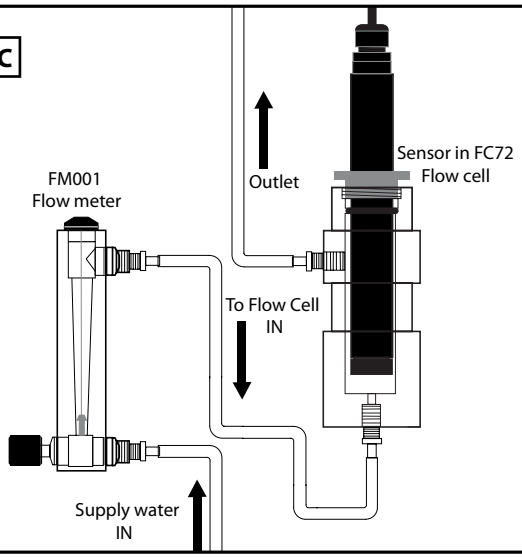
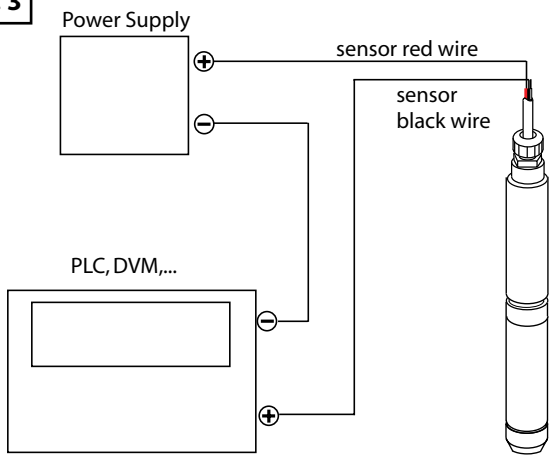


FIG. 3



Form: InstrFCL4 [Rev: 2011-06-27]

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 0-10 ppm). Any span/range calibration can be done at your PLC or other 4-20mA input device. The zero point calibration is not necessary since the zero setting is very stable. Periodic calibration (about once per week) is recommended. This is useful in tracking sensor failures as well. This calibration should also be done at the PLC or other 4-20mA input device.

8.1 Span/Slope Calibration:

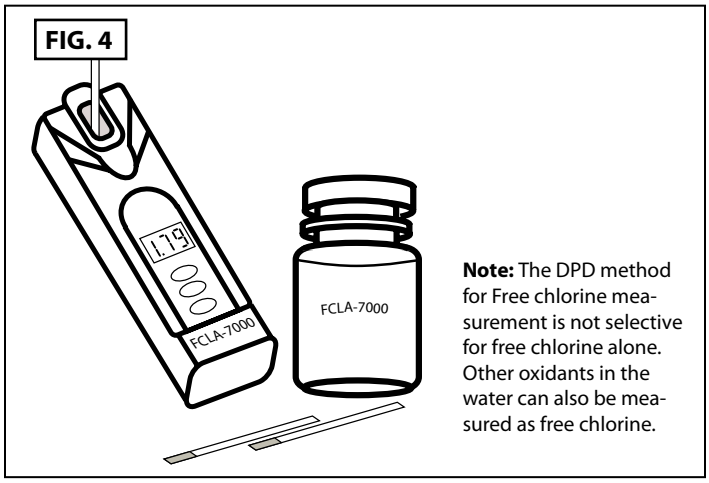
1. Determine the free chlorine content using a diethyl-p-phenylenediamine (DPD) colorimeter test kit (SEE FIG 4), not included with Free Chlorine sensor and flow cell.
2. Measure Free Chlorine content with sensor. Make sure that calibration flow rate and pH matches flow rate when measuring sample since probe output is flow rate and pH dependent. Make sure pH is within 5.5-8.0 range.
3. Adjust span/slope at PLC/4-20mA device.
4. Repeat this slope calibration one day after sensor is initially installed.
5. Repeat the slope calibration monthly.

Section 9.0
Sensor Storage

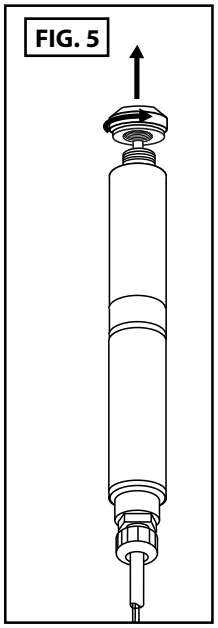
9.0 Storage

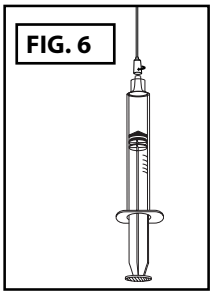
Store sensor at 5^{O}C- 50^{O}C *only* and maximum humidity of 90% (non-condensing).

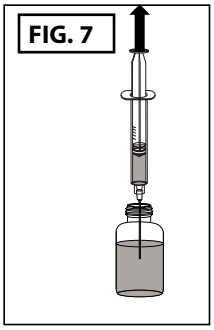
1. Short Term Storage (1 week or less): Store in Flow Cell with water to prevent the probe from drying out.
2. Intermediate Term (1 week to 1 month): Store in cap, bottle, or beaker with water to keep membrane wet.
3. Long Term (1 month or longer): Remove Membrane Cap and store completely immersed in DI water or tap water if DI water is not available. Turn sensor upright and shake it to remove fill solution from inside the sensor.
4. Electrolyte bottle shelf-life = 1 year from date of manufacturer (See expiration date on bottle).

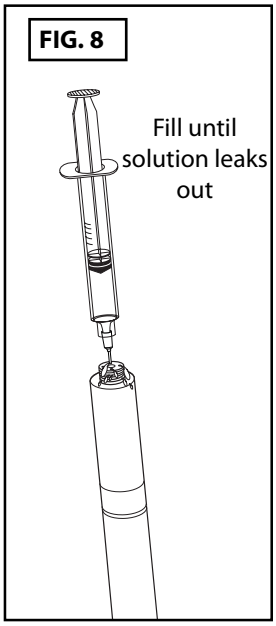


Note: The DPD method for Free chlorine measurement is not selective for free chlorine alone. Other oxidants in the water can also be measured as free chlorine.









Form: InstrFCL4 [Rev: 2011-06-27]

Section 10.0
Sensor Maintenance/Reconditioning

10.0 Electrolyte Solution Replacement

Drain and refill the sensor approximately every two months.

10.1 Membrane Cap Replacement

If membrane replacement is required, a new cap with pre-installed membrane must be used. Order FCLA-4016 or FCL4026 replacement membrane cap and FCLA-4015 refill solution. To change membrane cap (do the following over a sink or washbasin):

1. Turn sensor upside down with cap facing upward.
2. Rotate cap counter-clockwise to remove (SEE FIG 5).
3. Attached supplied needle to syringe and remove fill solution as shown in FIG 6 and FIG 7.
4. Fill sensor body with electrolyte using needle and syringe of refill solution (SEE FIG 8).
5. Install a new membrane cap by threading cap onto sensor, rotating cap clockwise (opposite of FIG 5).

10.2 Membrane Cap/Sensor Cleaning

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

Section 11.0
Sensor Troubleshooting

11.0 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

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* DPD Test	1) Run in time too short	1) See Sec 7.0 -CONDITIONING
	2) Membrane cap damage	2) Replace cap - See Sec 10.0
	3) Interference from contaminants	3) See SPECIFICATIONS Sec 12
	4) DPD chemicals bad	4) Use new DPD kit
	5) pH value < pH 5.5	5) Increase pH (5.5-8.5) See SPECIFICATIONS Sec 12
	6)Temperatue increased since cal	6) 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 10.0
	6) pH > pH 8.5	6)Lower pH (5.5-8.5) See SPECIFICATIONS
	7) No electrolyte in cap	7) Add new electrolyte, run in sensor and re-calibrate
	8) Temperature decreased since cal	8) Increase temp to match cal
	9) Organic chlorination agents present in water	9) Use chlorinating agents per DIN 19643
Sensor output is 4mA (0 ppm)	1) Only bound chlorine present NO FREE CHLORINE	1) Check for Chloramine with appropriate DPD test. Replace water/ Rechlorinate.
	2) Run in time too short	2) See Sec 7.0 -CONDITIONING
	3) Chlorine content below limit	3) Add 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

Form: InstrFCL4 [Rev: 2011-06-27]

Section 12.0
Sensor Specifications

12.0 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+/- 0.2mA in air (zero) 20mA +/- 0.2mA 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

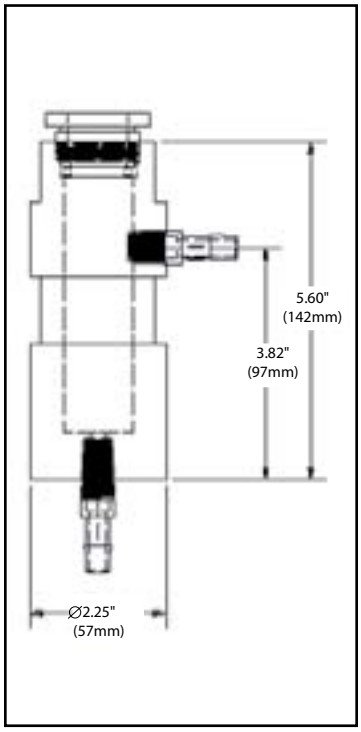
MAINTENANCE/REPLACEMENT PARTS

FC72	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-4015	Free Chlorine sensor fill solution, 30mL, 1 each
FCLA-4016	FCL Replacement premembraned cap (for use with models FCL405 & FCL410 ONLY), 1 each, BLACK PVC
FCLA-4026	FCL Replacement premembraned cap (for use with model FCL402, FCL402D, FCL405D, FCL410D ONLY), 1 each, GREY PVC.

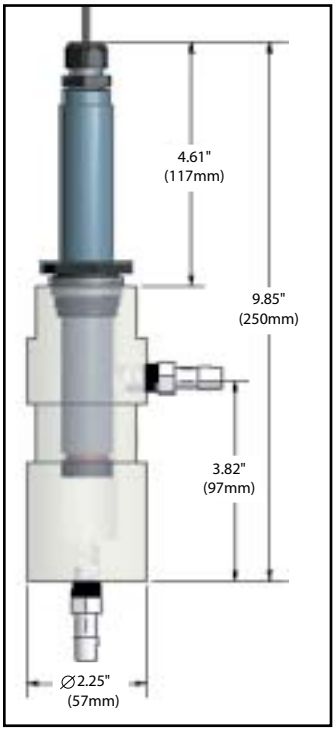
ACCESSORIES

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)
FCLA-7000	Exact-Micro 7+ colorimeter and 1000 test strips for free chlorine DPD testing

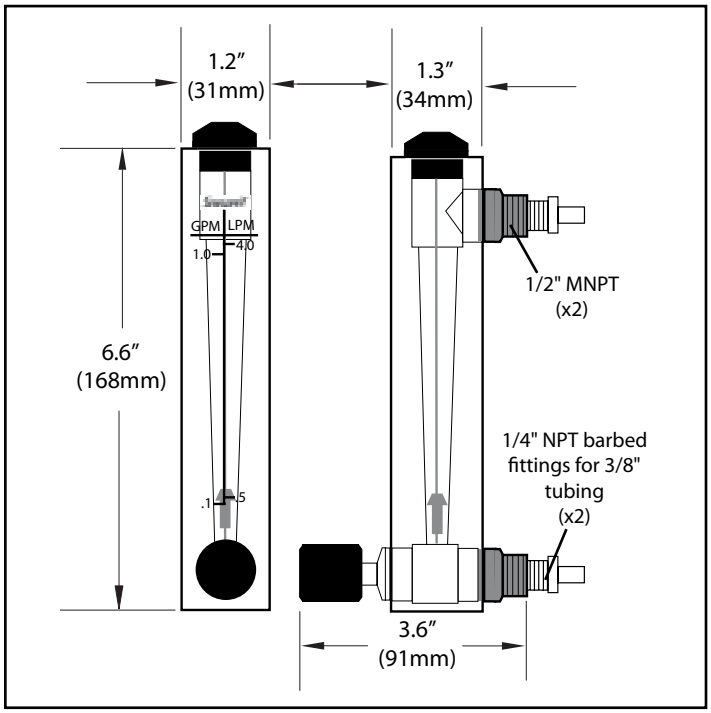
FC72 FLOW CELL DIMENSIONS



SENSOR AND FLOW CELL INSTALLATION DIMENSIONS



FM001 - FLOW METER INSTALLATION



Form: InstrFCL4 [Rev: 2011-06-27]