

**871FT Series
Toroidal Flow-Through Conductivity Sensors**

Installation, Calibration, and Troubleshooting



FLANGED INDUSTRIAL VERSION



TRI-CLAMP SANITARY VERSION

(NPT INDUSTRIAL VERSION NOT SHOWN)

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1. Introduction

The 871FT Toroidal Flow-Through Conductivity Sensors are a family of in-line, noninvasive, sensors that measure conductivity of virtually any conductive liquid. These sensors are available in many common line sizes and materials of construction to accommodate a wide range of sanitary and industrial applications. The sanitary virgin PEEK version uses Tri-Clamp® Flange mounting (Figure 1) and materials to comply with 3A and FDA standards. Industrial versions use ANSI Class 150 flanges (Figure 2), ANSI Class 300 flanges or NPT (Figure 3) mounting.

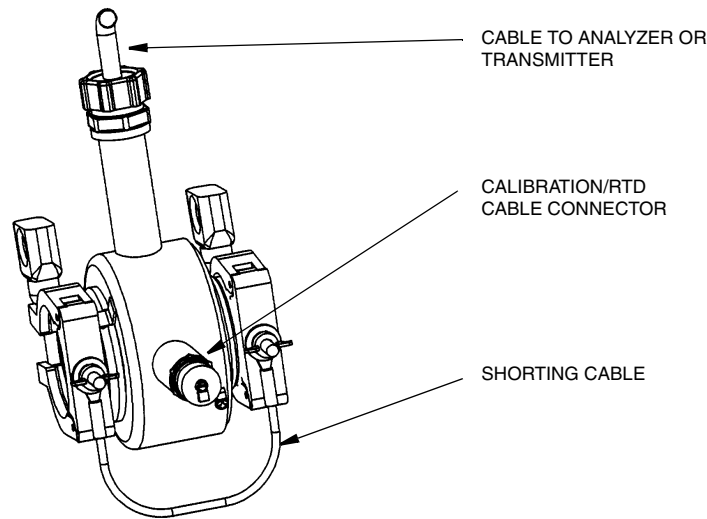


Figure 1. 871FT Conductivity Sensor – Sanitary Version

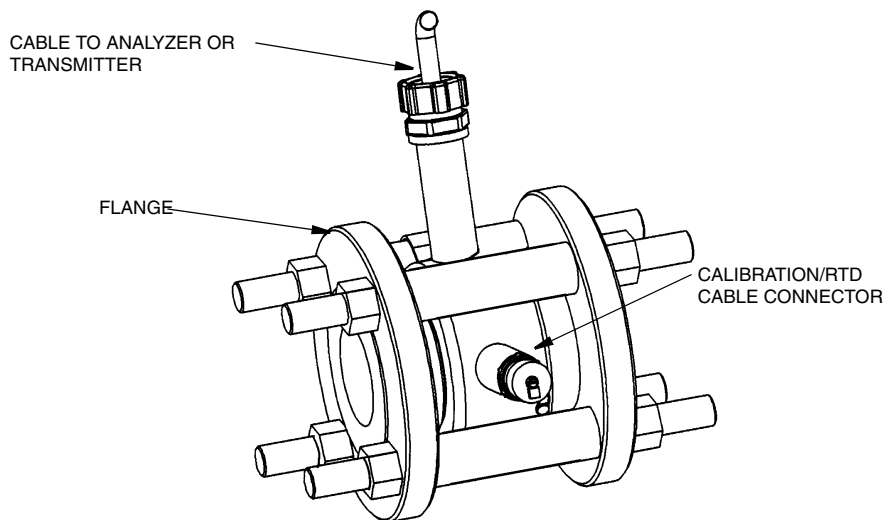


Figure 2. 871FT Conductivity Sensor – Industrial Version (Flanged)

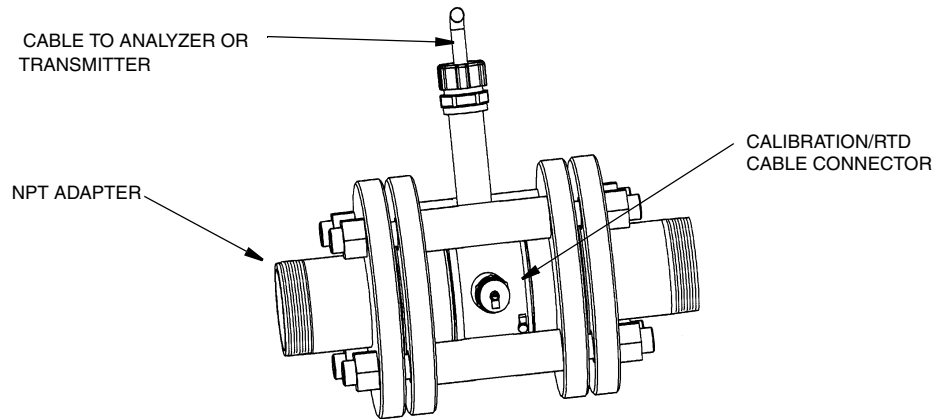


Figure 3. 871FT Conductivity Sensor – Industrial Version (NPT)

Principle of Operation

As illustrated in Figure 4, an 871FT sensor consists of inductive toroids mounted on an electrically nonconductive (insulator) section coaxial with the piping system. The primary toroids induce an electric current in the process fluid as it passes through the insulator. The voltage created, which varies with process fluid conductivity, is detected by a secondary toroid and converted to a conductivity measurement. Because of the smooth bore, the 871FT sensor provides a totally noninvasive measurement of conductivity and significantly reduces the influence of coatings and deposits on conductivity measurement.

An RTD is available to measure process temperature. This measurement is used for automatic temperature compensation of the conductivity measurement. The RTD also provides an indication of process temperature at the analyzer instrument.

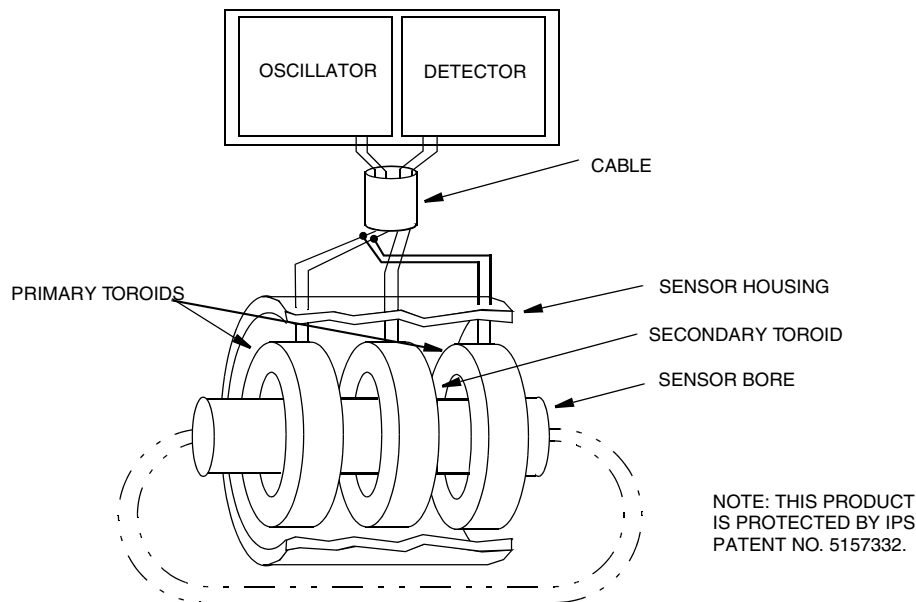


Figure 4. Principle of Operation

Reference Documents

Document	Description
DP 611-150	Dimensional Print – 871FT Flow-Through Conductivity Sensors with ANSI Class 150 Flanged End Connections
DP 611-151	Dimensional Print – 871FT Flow-Through Conductivity Sensors with Industrial-Rated NPT Threaded End Connections
DP 611-152	Dimensional Print – 871FT Flow-Through Conductivity Sensors with Sanitary End Connections
DP 611-153	Dimensional Print – 871FT Flow-Through Conductivity Sensors with ANSI Class 300 Flanged End Connections
MI 611-150	Master Instruction – 871EC Electrodeless Conductivity Sensors and Accessories
MI 611-167	Master Instruction – 873EC Series Electrochemical Analyzers
MI 611-193	Master Instruction – 873AEC Series Electrochemical Analyzers
MI 611-212	Master Instruction – 870ITEC Intelligent Electrochemical Transmitters
MI 611-220	Master Instruction – System Calibration Examples
MI 611-224	Master Instruction – 875EC Intelligent Electrochemical Analyzer
PL 611-017	Parts List – 871FT Flow-Through Conductivity Sensors
TI 612-005	Electrodeless Conductivity, Toroidal Magnets and the Procedure of Degaussing

Electrical Safety Specifications

Table 1. Electrical Safety Specifications

Testing Laboratory, Type of Protection, and Area Classification	Application Conditions	Electrical Safety Design Code
ATEX intrinsically safe for II 1 GD EEx ia IIC, Zone 0.	Temperature Class T4 - T6. T110°C - T260°C. Connect per MI 611-208.	CS-E/AAA
ATEX Type n energy limited for II 3 GD EEx nL IIC, Zone 2.	Temperature Class T4 - T6. T110°C - T235°C. Connect per MI 611-208.	CS-E/ANN
CSA intrinsically safe for Class I, Division 1, Groups A, B, C, and D; Class II, Division 1, Groups E, F, and G; Class III, Division 1.	Connect to certified 870ITEC per MI 611-206. Temperature Class T6.	CS-E/CAA
CSA Class I, Division 2, Groups A, B, C, and D; Class II, Division 2, Groups F and G; Class III, Division 2.	Connect to certified 870ITEC Transmitter or 873EC, 873AEC, or 875EC Analyzer per MI 611-206. Temperature Class T6.	CS-E/CNZ
FM intrinsically safe for Class I, Division 1, Groups A, B, C, and D; Class II, Division 1, Groups E, F, and G; Class III, Division 1.	Connect to approved 870ITEC per MI 611-206. Temperature Class T6.	CS-E/FAA
FM nonincendive Class I, Division 2, Groups A, B, C, and D; Class II, Division 2, Groups F and G; Class III, Division 2.	Connect to approved 870ITEC Transmitter or 873EC, 873AEC, or 875EC Analyzer per MI 611-206. Temperature Class T6.	CS-E/FNZ

— NOTE —

These sensors have been designed to meet the electrical safety descriptions noted in the table above. For detailed information or status of testing laboratory approvals and certifications, contact Invensys.

Sanitary Certifications

Models 871FT-1 and 871FT-2 sensors with Tri-Clamp end Connections and Virgin PEEK Insulator material are FDA compliant for food use and comply with 3A standard 74.

Pressure Equipment Directive (PED) Compliance

With the exception of the model codes listed in Table 2, the 871FT Sensors are in compliance with the Pressure Equipment Directive 97/23/EC as Sound Engineering Practice (SEP). For those models listed in Table 2, please contact Invensys.

Table 2. Exceptions to PED Compliance

Model Code	Description
871FT-1J1A1 871FT-2J1A1	4 inch Sanitary Type with Virgin PEEK Insulator Material and Tri-Clamp Flange End Connections.
871FT-3H.D4 871FT-4H.D4	3-inch Industrial Type with Glass Filled PEEK Insulator Material and ANSI Class 300 End Connections
871FT-3J.D3 871FT-4J.D3	4-inch Industrial Type with Glass Filled PEEK Insulator Material and ANSI Class 150 End Connections
871FT-3J.D4 871FT-4J.D4	4-inch Industrial Type with Glass Filled PEEK Insulator Material and ANSI Class 300 End Connections

Flow-Through Conductivity Sensor Identification

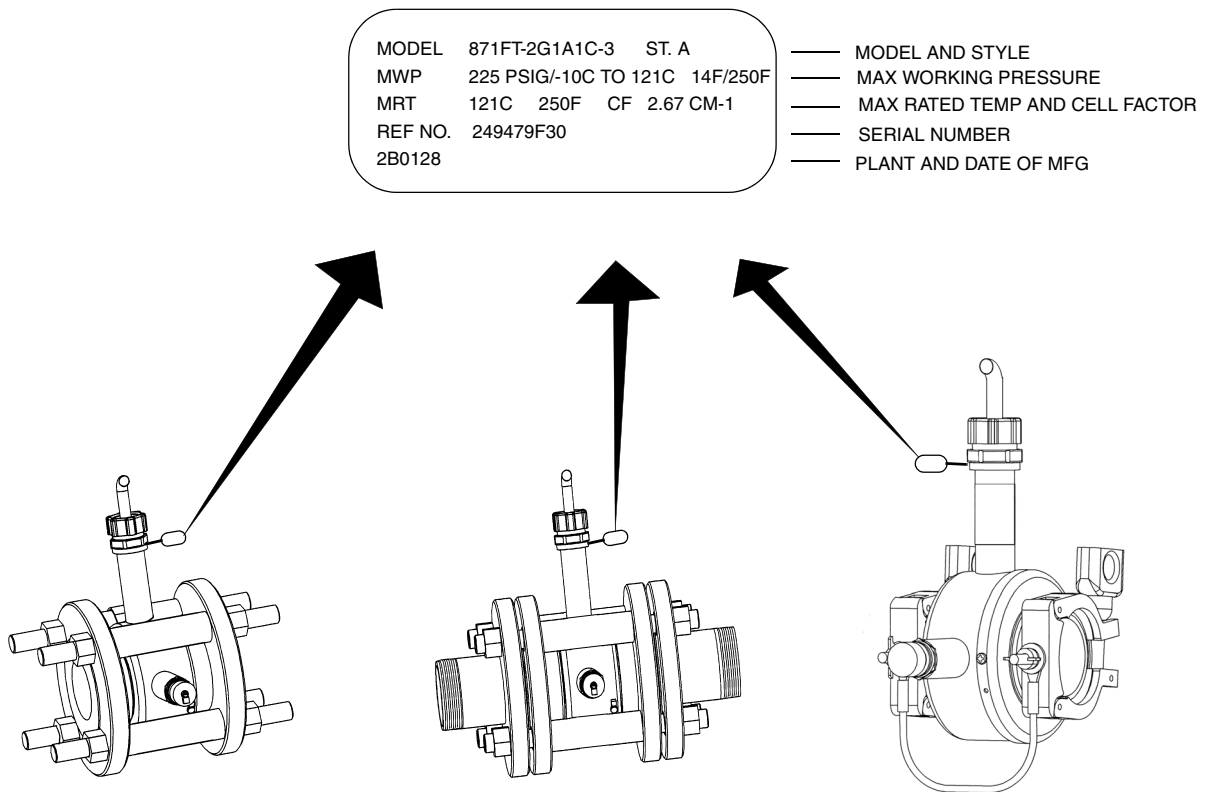


Figure 5. 871FT Toroidal Flow-Through Conductivity Sensor Data Label

Standard Specifications

Table 3. Standard Specifications

Item	Description
Ambient Temperature	
Normal Operating Condition Limits:	-10 and +50°C (14 and 120°F)
Process Temperature	Listed for various situations below
Wetted Parts	
Sanitary Versions:	Virgin PEEK (PolyEtherEtherKetone) or PolyChloroTriFluorEthylene Insulators (PCTFE)
Industrial Versions:	KYNAR (PolyVinylideneDiFluoride [PVDF]), PCTFE, or Glass Filled “PEEK” Insulators and 316 Stainless Steel, Hastelloy C-276 [®] or Carpenter 20-CB3 End Connections. Industrial versions have EPDM O-rings, with Viton or Chemraz optional.

Table 3. Standard Specifications (Continued)

Item	Description
Cable Standard: Optional:	6 m (20 ft) PVC Jacketed Cable terminated in numbered tinned spadeless leads or spade lugs. This cable should be selected for use in conduit wiring applications. 6 m (20 ft) Teflon [®] Jacketed Cable terminated in numbered tinned spadeless or spade lugs. This cable provides RFI/EMI shielding and therefore does not normally require a conduit.
Maximum Recommended Cable Length^(a):	30 m (100 ft).
Nominal Line Sizes	Available line sizes in Sanitary and Industrial Sensors are determined by industry standard mounting sizes for sanitary tubing with Tri-Clamp flanges or IPS Schedule 40 pipe dimensions with ANSI Class 150 or 300 flanges, respectively. NPT terminated models use Industrial Sensors with Flange/NPT adapters and have corresponding bore dimensions. These dimensions are shown in Table 4. Also shown in Table 4 are the part numbers for the Flange/NPT adapters that convert Flanged Industrial Sensors to NPT end fittings.
Temperature and Pressure Limits (Also see Appendix A)	
Sanitary Sensors with Tri-Clamp Type Fittings:^(b)	
Virgin PEEK: 1/2, 3/4, and 2 in 1, 1 1/2, and 3 in 4 in PCTFE:	225 psi, -10 to +121°C (14 to 250°F) ^(c) 150 psi, -10 to +121°C (14 to 250°F) ^(c) 100 psi, -10 to +121°C (14 to 250°F) ^(c) 60 psi, -10 to +60°C (14 to 140°F) linearly derated to 10 psi at 121°C (250°F) ^(d)
Industrial Sensors with ANSI Class 150 Flanges or NPT Mounting:	
Glass Filled PEEK: PVDF: PCTFE:	275 psi, -10 to +60°C (14 to 140°F) linearly derated to 190 psi at 210°C (411°F) 100 psi, -10 to +60°C (14 to 140°F) linearly derated to 60 psi at 121°C (250°F) 100 psi, -10 to +60°C (14 to 140°F) linearly derated to 10 psi at 121°C (250°F)
Industrial Sensors with ANSI Class 300 Stainless Steel Flanges:	
Glass Filled PEEK: 1/2, 1, 1 1/2, 2, 3, 4 in	400 psi, -10 to +210°C (14 to 411°F)
Industrial Sensors with ANSI Class 300 Hastelloy C276 Flanges:	
PVDF: 1/2 in	365 psi, -10 to +66°C (14 to 150°F) linearly derated to 60 psi at 121°C (250°F)

Table 3. Standard Specifications (Continued)

Item	Description
------	-------------

- (a) Maximum recommended overall length.
- (b) Tri-Clamp wing nut tightened to 25 lb•in (2.8 N•m) torque.
- (c) Applications to 140°C (284°F) - contact IPS.
- (d) Pressure of 15.3 psi at 250°F can be used for a short period of time (2 hours) for hot water or steam sterilization. For longer periods, contact IPS.

Table 4. Standard Bore Dimensions for Sanitary and Industrial Sensors and Part Numbers of Flange/NPT Adapters

Line Size (in)	Sanitary Bore (in)	Industrial Bore (in)	Flange/NPT Adapter Part Number (Industrial)
1/2	0.375	0.622	N/A
3/4	0.625	N/A	N/A
1	0.870	1.049	BS807GR (316 ss) BS807HB (Hastelloy C) BS807GW (C20-Cb3)
1-1/2	1.370	1.610	BS807GS (316 ss) BS807HC (Hastelloy C) BS807GX (C20-Cb3)
2	1.870	2.067	BS807GT (316 ss) BS807HD (Hastelloy C) BS807GY (C20-Cb3)
3	2.870	3.068	N/A
4	3.830	4.026	N/A

Temperature Compensation

Solution temperature measurement is obtained by using nonintegral RTD Probe Assemblies available in both sanitary and industrial versions with 100 Ω or 1000 Ω RTDs. Typical installations are shown in Figures 6 and 7.

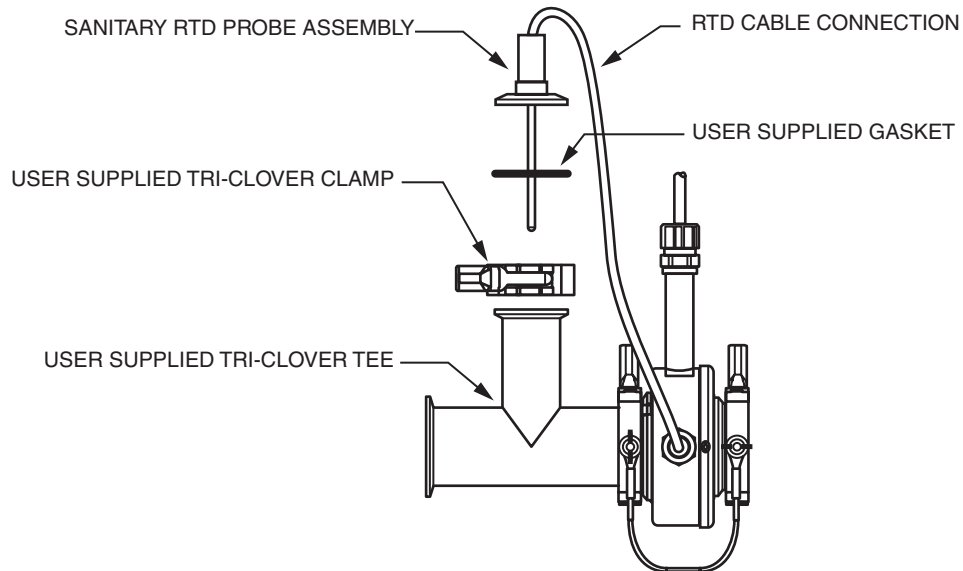


Figure 6. Temperature Compensation Assembly With Sanitary Sensor

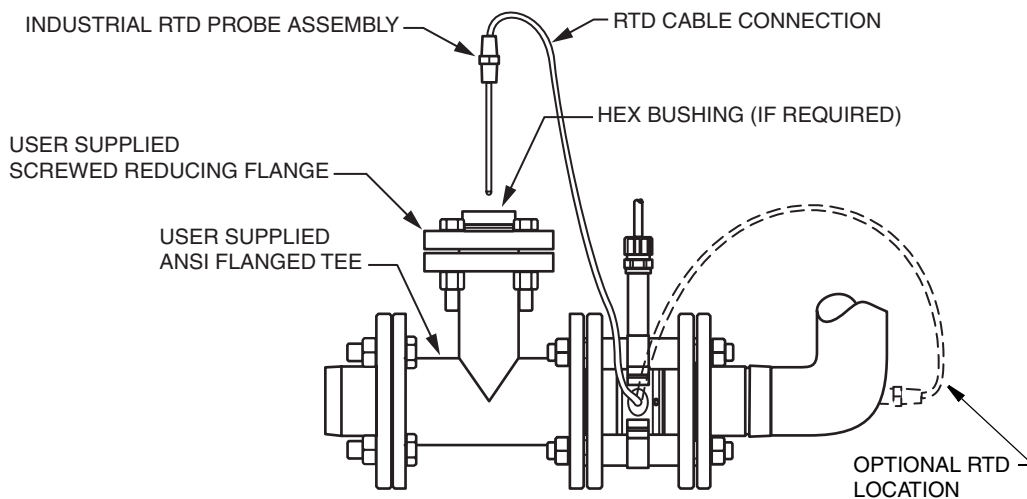


Figure 7. Temperature Compensation Assembly With Industrial Sensor

Sanitary RTD Probe Assemblies are available in 316L Stainless Steel with 3/4-, 2-, and 4-inch Tri-Clover flanges for use with user-supplied sanitary tees. Industrial RTD Probe Assemblies are available in 316 Stainless Steel, Carpenter 20-Cb3, and Hastelloy-C276. These probes all use a 1/2-inch pipe nipple for mounting in a user-supplied flanged process tee using a reducing screwed flange. Industrial RTD sensors can also be mounted directly into the process line (for example, at an elbow). Avoid excess flow against the sheath if mounted vertically. Avoid accumulation of

fouling material. Tables 5 and 6, list Foxboro part numbers for these probes plus potential source and vendor part numbers for the associated hardware items required for each type and line size of sensor.

Table 5. Parts List for Addition of Temperature Measurement to Sanitary Sensor

Size	RTD Ohms	RTD Assembly	Tri-Clover Tee* Part No.	Tri-Clover Clamp* Part No.
1/2 inch	100 1000	BS807VR BS807VS	1/2 inch Full Tee 7MP-1/2-316L	13MHHS 3/4-S
3/4 inch	100 1000	BS807VR BS807VS	3/4 inch Full Tee 7MP-3/4-316L	13MHHS 3/4-S
1 inch	100 1000	BS807VR BS807VS	Reducing Tee 1 in to 1/2 in 7RMP-1x1/2-316L	13MHHS 3/4-S
1-1/2 inch	100 1000	BS807VR BS807VS	Reducing Tee 1-1/2 in to 1/2 in 7RMP-1-1/2x1/2-316L	13MHHS 3/4-S
2 inch	100 1000	BS807VT BS807VU	2 inch Full Tee 7MP-2-316L	13MHHS 2-S
3 inch	100 1000	BS807VT BS807VU	Reducing Tee 3 in to 2 in 7RMP-3x2-316L	13MHHS 2-S
4 inch	100 1000	BS807VV BS807VW	4 in Full Tee 7MP-4-316L	13MHHS 4-S

*Typical Vendor Source: Tri-Clover, Inc., 9201 Wilmot Road, Kenosha WI 52141-1413

Table 6. Parts List for Addition of Temperature Measurement to Industrial Sensors

Size	Material	RTD Ohms	RTD Assembly	Commercial Tee*	Reducing Screwed Flange*	Hex Bushing*
1/2 inch	316	100	BS807WR	---	---	---
		100	BS807WS			
	Hast C276	100	BS807WP			
		100	BS807WQ			
1-inch	316	100	BS807WR	1-in ANSI 300 lb Flanged	1-in ANSI 300 lb x 1/2 NPT	Not Required
		100** 1000	BS811EU BS807WS			
	C20-Cb3	100	BS807WT	1-in ANSI 150 lb Flanged	1-in ANSI 150 lb x 1/2 NPT	Not Required
		1000	BS807WU			
Hast-C276	100	BS807WP				
	1000	BS807WQ				

Table 6. Parts List for Addition of Temperature Measurement to Industrial Sensors (Continued)

Size	Material	RTD Ohms	RTD Assembly	Commercial Tee*	Reducing Screwed Flange*	Hex Bushing*
1-1/2 inch	316	100 100** 1000	BS807WB BS811EV BS807WC	1-1/2 in ANSI 300 lb Flanged	1-1/2 ANSI 300 lb x 1-1/4 NPT	1-1/4 x 1/2 NPT
	316	100 1000	BS807VX BS807VY	1-1/2-in ANSI 150 lb Flanged	1-1/2-in ANSI 150 lb x 1/2 NPT	Not Required
	C20 -Cb3	100 1000	BS807WF BS807WG			
	Hast-C276	100 1000	BS807VH BS807VJ			
2-inch	316	100 100** 1000	BS807WB BS811EV BS807WC	2 in ANSI 300 lb Flanged	2 ANSI 300 lb x 1-1/4 NPT	1-1/4 x 1/2 NPT
	316	100 1000	BS807VX BS807VY	2-in ANSI 150 lb Flanged	2-in ANSI 150 lb x 1-1/4 NPT	1-1/4 x 1/2 NPT
	C20-Cb3	100 1000	BS807WF BS807WG			
	Hast-C276	100 1000	BS807VH BS807VJ			
3-inch	316	100 100** 1000	BS808EG BS811EW BS808EH	3 in ANSI 300 lb Flanged	3 ANSI 300 lb x 1-1/4 NPT	1-1/4 x 1/2 NPT
	316	100 1000	BS807WB BS807WC	3-in ANSI 150 lb Flanged	3-in ANSI 150 lb x 1-1/4 NPT	1-1/4 x 1/2 NPT
	C20-Cb3	100 1000	BS807WK BS807WL			
	Hast-C276	100 1000	BS807VM BS807VN			
4-inch	316	100 100** 1000	BS808EG BS811EW BS808EH	4 in ANSI 300 lb Flanged	4 ANSI 300 lb x 1-1/4 NPT	1-1/4 x 1/2 NPT
	316	100 1000	BS807WB BS807WC	4-in ANSI 150 lb Flanged	4-in ANSI 150 lb x 1-1/4 NPT	1-1/4 x 1/2 NPT
	C20-Cb3	100 1000	BS807WK BS807WL			
	Hast-C276	100 1000	BS807VM BS807VN			

*Typical Vendor Source: All Stainless, Inc., 75 Research Road, Hingham MA 02043

**Per MIL-T-24388C (SH)

The 100 and 1000 Ω Platinum RTDs have temperature functions per DIN 43760 or IEC 751-1983. The 100 Ω MIL SPEC RTD is per MIL-T-24388C (SH). This function, at various temperatures, is shown in Table 7.

Table 7. Temperature vs. RTD Resistance

Temperature		100 Ohm RTD	100 Ohm RTD (MIL SPEC)	1000 Ohm RTD
$^{\circ}\text{C}$	$^{\circ}\text{F}$	Ohms	Ohms	Ohms
-5	+20	98.04	98.01	980.4
0	32	100.00	100.00	1000.0
10	50	103.90	103.98	1039.0
20	68	107.79	107.94	1077.9
25	77	109.73	109.92	1097.3
30	86	111.67	111.89	1116.7
40	104	115.54	115.83	1155.4
50	122	119.40	119.77	1194.0
60	140	123.24	123.69	1232.4
70	158	127.07	127.60	1270.7
80	176	130.89	131.49	1308.9
90	194	134.70	135.37	1347.0
100	212	138.50	139.24	1385.0
105	225	140.39	141.17	1403.9
110	230	142.28	143.10	1422.8
120	248	146.06	146.95	1460.6
130	266	149.82	150.79	1498.2
140	284	153.58	154.61	1535.8
150	302	157.32	158.42	1573.2
160	320	161.04	162.22	1610.4
170	338	164.76	166.01	1674.6
180	356	168.47	169.79	1684.7
190	374	172.16	173.42	1721.6
200	392	175.84	177.23	1758.4
210	410	179.51	181.05	1795.1

Temperature compensation sensor elements (RTDs) are shown in Figure 8. Cable lengths are 2 ft (0.6 m) long for sanitary sensors and 3 ft (0.9 m) for industrial sensors. Patch Cables are available for RTD assemblies. Cable BS809UN is 10 ft (3 m) long. Cable BS809UP is for special lengths per sales order. RTD sheath length (Figure 8) and protrusion into the pipe (Figure 9) is shown in Table 8.

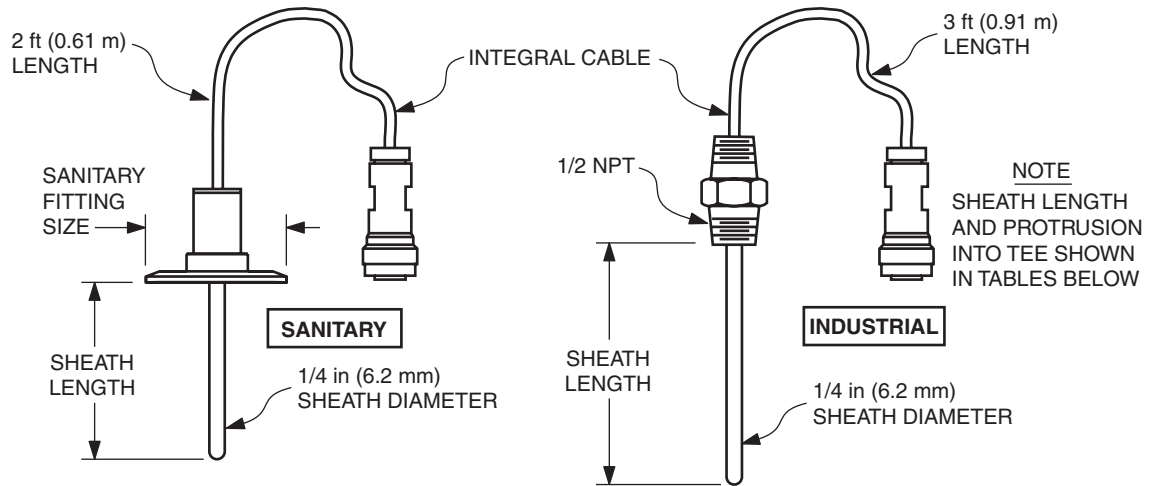


Figure 8. Temperature Compensation Sensor Elements (RTDs)

Table 8. RTD Sheath Length and Protrusion

Sensor Type	Size	Sheath Length	Protrusion ^(a)	Sanitary Fitting Size
Sanitary	1/2, 3/4, 1, 1 1/2 in	2.5 in	0.13 in	0.98 in
	2 in	3.25 in	0.25 in	2.5 in
	3 in	3.25 in	0.19 in	2.5 in
	4 in	4.5 in	center of pipe	4.7 in
Industrial Class 150	1/2 and 1 in	3.38 in	0.56 in	
	1 1/2	3.38 in	0.56 in	
	2 in	3.38 in	0.19 in	
	3 in	5.44 in	0.65 in	
	4 in	5.44 in	0.25 in	
Industrial Class 300	1/2 and 1 in	3.38 in		
	1 1/2 and 2 in	5.44 in		
	3 and 4 in	6.62 in		

(a) The amount of protrusion into the pipe may vary with gasket thickness.

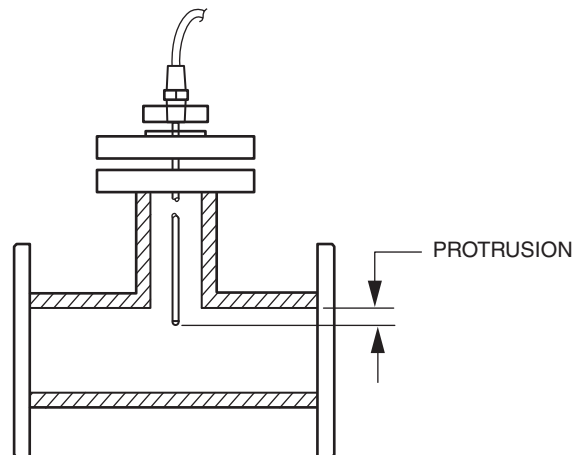


Figure 9. Protrusion Into Pipe

Sensor Weights

Table 9 lists approximate gross weights for various sizes of sensors.

Table 9. Approximate Sensor Weights

Nominal Size Per Model Code	Weight (lb)			
	Sanitary	ANSI Class 150	ANSI Class 300	NPT
C = 1/2	2.5	11	15	14
D = 3/4	2.5	N/A	N/A	N/A
E = 1	7.5	10	14	18.5
F = 1-1/2	7.0	12	15	17.5
G = 2	6.5	17	20	28.5
H = 3	9.3	32	40	N/A
J = 4	8.8	41	60	N/A

2. Installation

Selecting the Location for the Sensor

— **! CAUTION** —

Prior to shipment, Invensys routinely tests all sensors at 1.5 times the maximum rated pressure for each model as shown in Table 3, “Standard Specifications,” on page 6. For sanitary sensors, this test ensures integrity of the insulator only. For industrial sensors, this test ensures integrity of the insulator and the two sets of O-rings captured within the assembly. Since the threaded rods that hold the industrial sensor together must be removed to allow installation in the process line, the sensor as installed no longer represents the pressure tested assembly. It is recommended that the user pressure test the assembly after installation, preferably with water, prior to placing the line back in service.

The sensor can be installed in plastic or nonmagnetic metal piping to avoid the remote possibility of magnetizing the sensor assembly (see “Flange Types and Materials” on page 19) and can usually be placed at any convenient location in the pipeline. To ensure good performance, however, the location should be analyzed relative to the factors listed below:

- ◆ Flow through the sensor can be in either direction, but upstream/downstream disturbances must be within the guidelines shown in Figure 10 and Figure 11.
- ◆ For accuracy, it is essential that the tube be completely full during operation. Horizontal, vertical, or sloping positions are acceptable, but some positions require special attention to ensure that the tube remains full. In addition to obvious problem locations such as down flowing vertical runs, consider areas where air pockets may form and where siphoning action or low pressure areas could create voids.
- ◆ Effects of upstream disturbances, such as valves, elbows, etc., are difficult to predict, but in nearly all cases, standard accuracy will be realized if there are at least five pipe diameters of straight pipe upstream of the sensor. Downstream disturbances that are three or more pipe diameters from the end of the sensor will not affect performance. The inside diameter of the piping should be the same as or larger than the nominal size of the sensor bore. Sensors can be placed in larger nominal size pipelines by using tapered conical reducers. The small end of the reducers can be directly coupled to the sensor and can have an included angle of 16° maximum.
- ◆ Buildup of sedimentary deposits within the sensor or on the metallic terminations may change the cell factor, proportionate to the thickness of the deposit, and may therefore affect accuracy and require in-line recalibration at intervals dependent on the magnitude of the fouling condition in the application.
- ◆ The presence of entrained air or bubbles within the insulator may lead to errors in measurement proportional to the volume of fluid they displace.
- ◆ The mounting orientation of the sensor must be horizontal to vertically “up” with the toroid cover on the top to prevent access of contamination. This is mandatory for sanitary sensors and strongly recommended for industrial sensors. See Figure 10.

- ◆ The 871FT Sanitary PEEK sensor is a 3-A compliant sanitary device, however it is not designed to be used in applications defined in 3-A Sanitary Standard Number 74, Section D10.1.2.

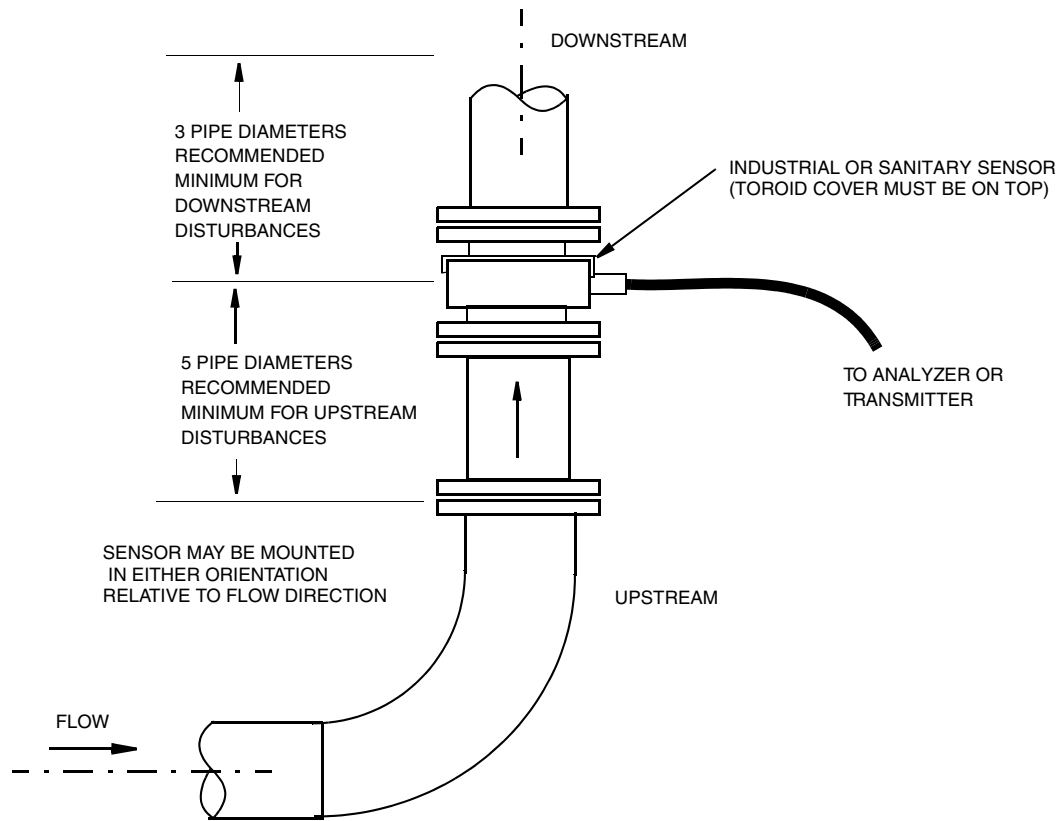


Figure 10. Vertical Mounting of Sensor

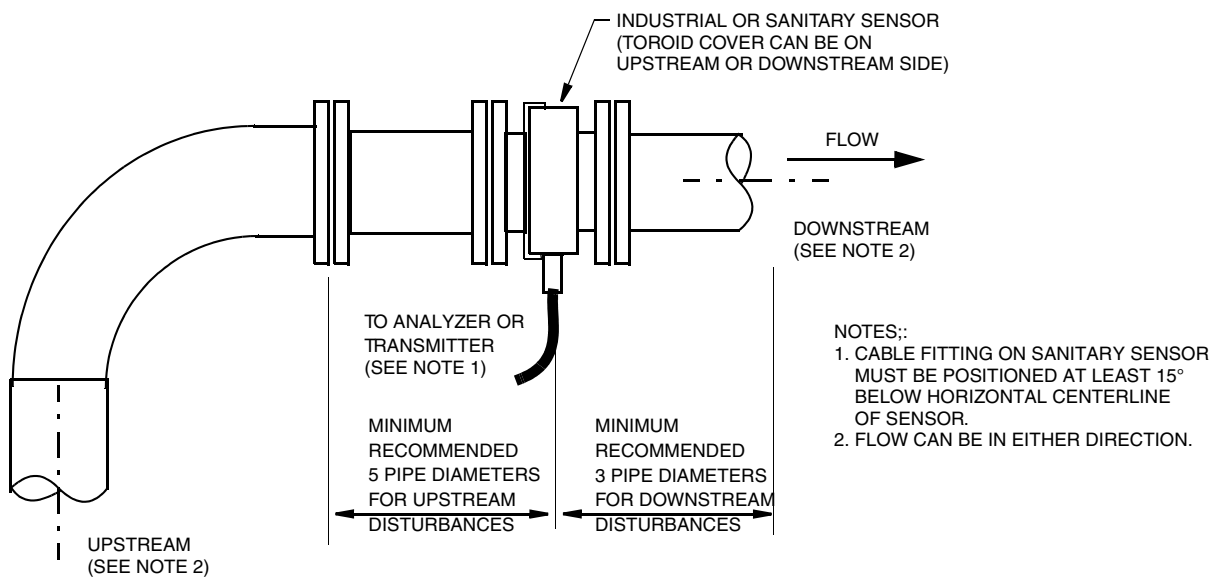


Figure 11. Horizontal Mounting of Sensor

Pipeline Preparation

Flow-Through Sensor Dimensions

Refer to the dimensional prints listed in “Reference Documents” on page 3 for complete information. Note that the dimensions noted for the Industrial sensors should be increased to accommodate the two required flange gaskets (supplied by user).

Flange Types and Materials

Process piping and flanges must not be magnetized. Sanitary sensors must be installed in nonmagnetic metal piping systems or, if placed in nonmetallic systems, a nonmagnetic metal spoolpiece (user supplied or contact Invensys) with a length of at least one tube diameter must be installed on each end of the sensor. Industrial models with integral metal flanges may be installed into nonmagnetic metal or nonmetallic pipe and flange systems.

Pipeline Support and Alignment

Adequately support the pipeline to carry its weight when full and to control pipeline motions such as may be caused by water hammer or other disturbances within the piping system.

In cases where temperature differences will occur, make provisions to allow for thermal expansions in a manner that will preserve the initial alignment of the piping at the sensor.

The pipeline must provide support for the sensor and the alignment must be accurate enough to allow sealing at the flanges or Tri-Clamp type joints with normal clamp tightening forces. Cantilever or bending loads on the sensor must be minimized. Use through-bolting wafer style mounting for all line sizes.

Pre-Startup Cleaning

It is recommended that a flanged “spool piece” (user-supplied) the same length as the sensor be installed. Insert it in the line before startup. On startup, any foreign objects in the line such as pieces of wood or metal, should be located and removed before the sensor is installed. This greatly lessens the possibility of accidental damage to the sensor.

Unpacking and Handling Procedures

Before removing the sensor from its shipping carton, move it as close as possible to its installation point. Flanged-body sensors are shipped with end covers to protect the sensor lining. If the covers must be removed for receiving inspection, *reinstall the end covers after inspection.*

To lift a flanged-body sensor out of its carton, use a rope fall, chain hoist, or similar tool as shown in Figure 12. In some instances, it may be more convenient to insert bolts into the flange bolt holes and use hooks around the bolts for lifting (rather than tying slings around the sensor).

 **CAUTION**

Never put anything through the sensor to lift it.

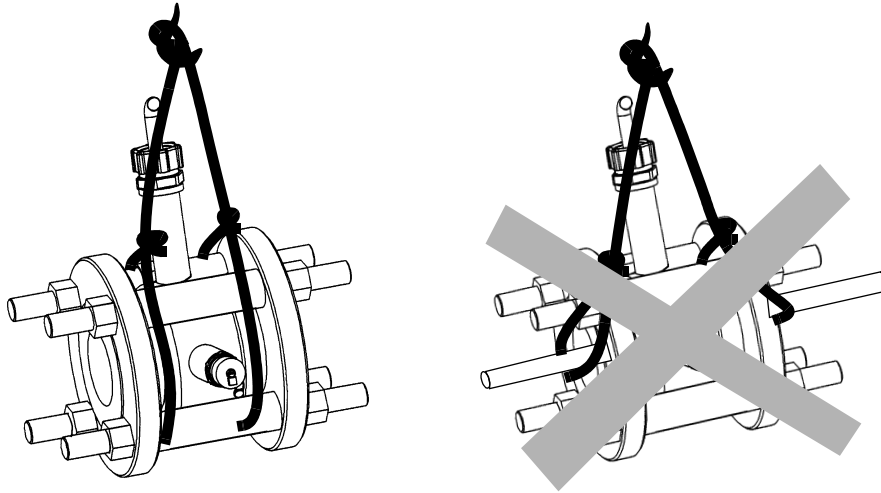


Figure 12. Handling Flanged-Body Sensor

After removing the sensor from its shipping cartons, inspect it for visible damage. If any damage is observed, notify the carrier immediately and request an inspection report. Obtain a signed copy of the report from the carrier.

Sensor Mounting

1. Position sensor in pipeline. Note that the sensor can be installed in either direction relative to direction of flow. Select the orientation that provides best access for routing of cables.
2. Verify that the desired gasket is in place (user supplied).
3. For sanitary sensors, install Tri-Clamp assembly provided with sensor and tighten to 25 lb·in torque (Tri-Clamp fitting) or 20 lb·ft torque (high pressure fitting)
4. For industrial sensors with flange fittings as shown in Figure 2, loosely install mounting bolts as required. Begin tightening the flanges to the sensor. Initially, this should be done by carefully tightening the nuts in an order that will bring the flanges flat against the sensor gaskets. Through-bolt mounting wafer-style is recommended for all line size industrial models.
5. Tightening of flange nuts requires special care – first, to create a uniform clamping load on the sensor, and second, to avoid overcompressing the gaskets. Begin by bringing the flanges into full face contact with the gaskets, using minimum possible torque. This should be done by tightening the nuts adjacent to the largest flange-to-gasket gaps until full circle contact is made. Then, with all nuts at least finger-tight, proceed to tighten the nuts following a diametrically opposite pattern. Turn the first nut 1/6 of a turn, then move to the next nut and tighten it 1/6 of a turn. Continue this sequence until the maximum torque spec for each nut, shown in the following table for the various flange sizes, has been reached.

Table 10. Maximum Mounting Nut Torques for Flanged Sensors

Flange		Bolt Size	Maximum Mounting Nut Torque	
Class	Size (in)		kg·m	lb·ft
150	1, 1-1/2	1/2-13	5.8	42
	2, 3, 4	5/8-11	13.8	100
300	1/2, 1, 2	5/8-11	13.8	100
	1-1/2, 3, 4	3/4-10	17.8	130

! CAUTION

The torque values in this table are for 316 SS bolts and flanges per ANSI B.16.5-1977. If plastic flanges are used, consult specifications supplied with the plastic flanges.

System Wiring

The two cable types available with the sensor are terminated in numbered, tinned, spadeless leads or leads with spade lugs. Spadeless terminations are used with 873EC or 873AEC Analyzers and spade lug types for wiring to junction boxes or to 875EC Analyzers or 870ITEC Transmitters. The standard cable is PVC-jacketed and has eight conductors (see Figure 13). The PVC cable is selected for use in conduit wiring applications where the conduit provides RFI/EMI shielding and electrically interconnects the metal shield on the sensor with power ground on the analyzer. The optional cable is Teflon-jacketed, has integral RFI/EMI shielding, and has nine conductors (see Figure 14). A low smoke cable is also available. It has eight conductors (see Figure 13).

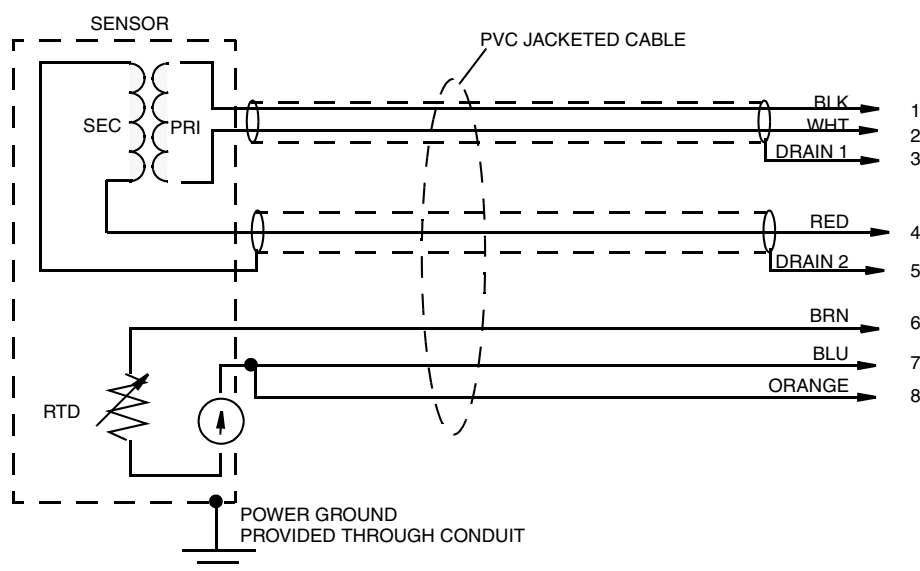


Figure 13. Flow-Through Sensor with PVC-Jacketed 8-Conductor Cable

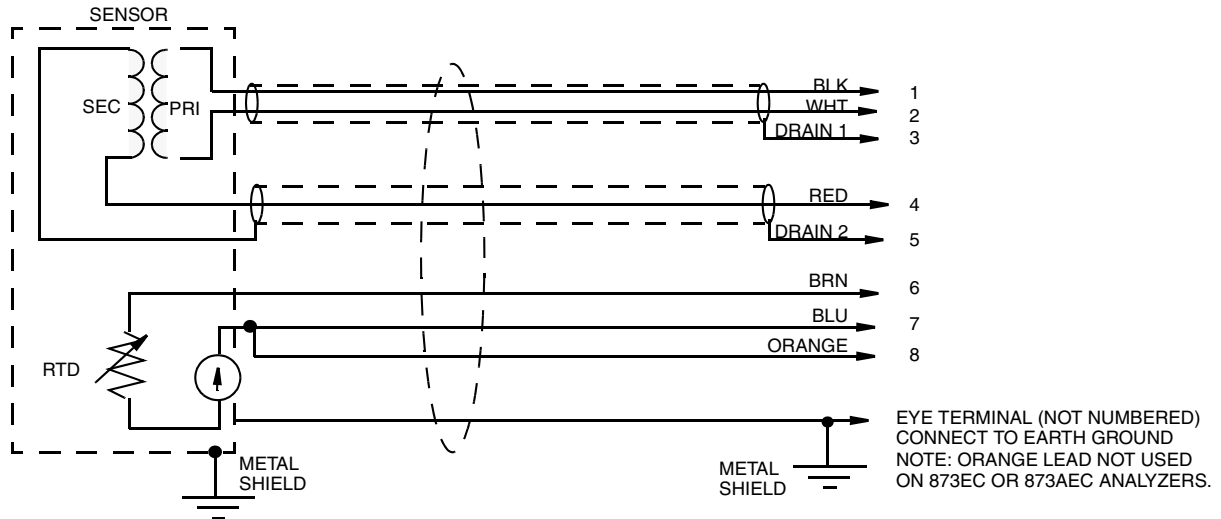


Figure 14. Flow-Through Sensor with Teflon-Jacketed 9-Conductor Cable

Wiring to 873EC and 873AEC Analyzers

Sensor wiring to the plastic NEMA 1 and metal NEMA 4X analyzer are shown in Figure 15 and Figure 16, respectively. In each case, Leads 1 through 7 are connected to the corresponding numbered terminals on the back of the analyzer.

For the metal NEMA 4X Analyzer and Teflon-jacketed cable, the orange lead No. 8 from the sensor is not used. The ground lead (with the eye terminal) is connected to the grounding stud on the inside of the analyzer case. When using the metal NEMA 4X Analyzer with PVC-jacketed cable, the wires are connected as numbered and should be installed in conduit to provide shielding between the analyzer and the metal case on the sensor.

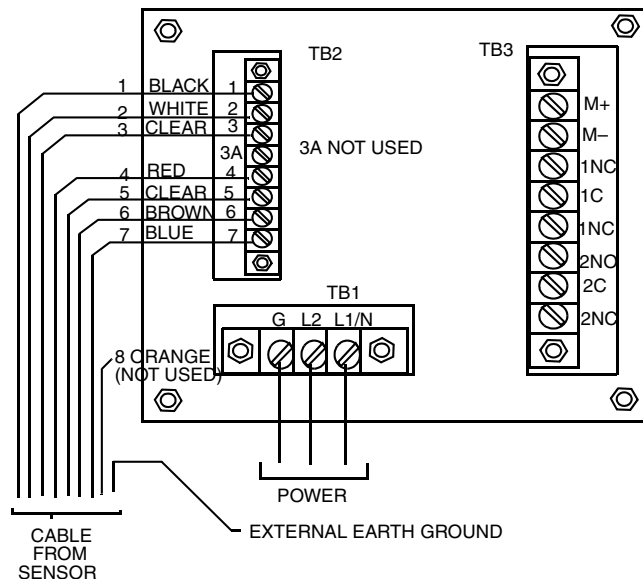


Figure 15. Sensor Wiring to Plastic 873EC or 873AEC NEMA 1 Analyzer

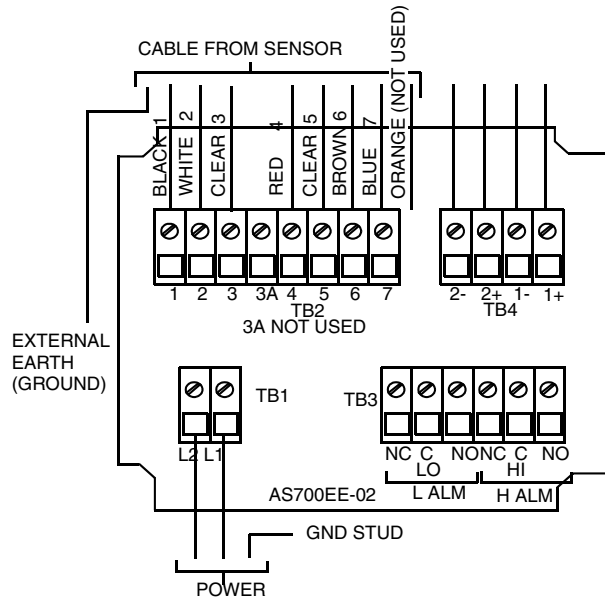


Figure 16. Sensor Wiring to Metal 873EC and 873AEC NEMA 4X Analyzer

The plastic NEMA 1 Analyzer should be used only with the Teflon-jacketed cable, since provision is not otherwise made for metal conduit connection to this instrument. The orange lead No. 8 from the sensor is not used and the ground lead with the eye terminal is connected to the green wire power ground terminal on the back of the analyzer.

Wiring to 870ITEC Analyzers

When wiring sensors to 870ITEC Transmitters using standard PVC jacketed cable, Leads 1 through 8 are connected to the corresponding numbered terminals on the back of the analyzer. This cable is normally run in conduit, which provides earth ground between sensor and transmitter. When wiring with Teflon jacketed cable, the lead with the eye terminal is provided for grounding and is connected to the case earth ground on the transmitter (see Figure 17).

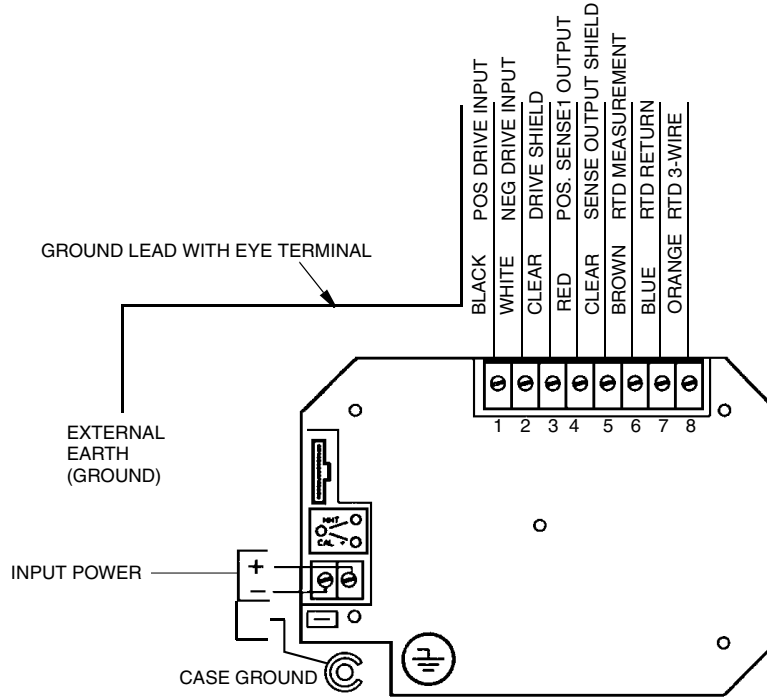


Figure 17. Sensor Wiring to 870ITEC Analyzer

Wiring to 875EC Analyzers

Wiring connections on 875EC panel-mounted analyzers are located on the rear of the housing. Those on pipe- or surface-mounted analyzers are located in the lower compartment of the housing. Connect sensor leads 1 through 8 per Figure 18. To meet CE requirements, the ac cable must be routed away from all other I/O wiring, especially the sensor cable.

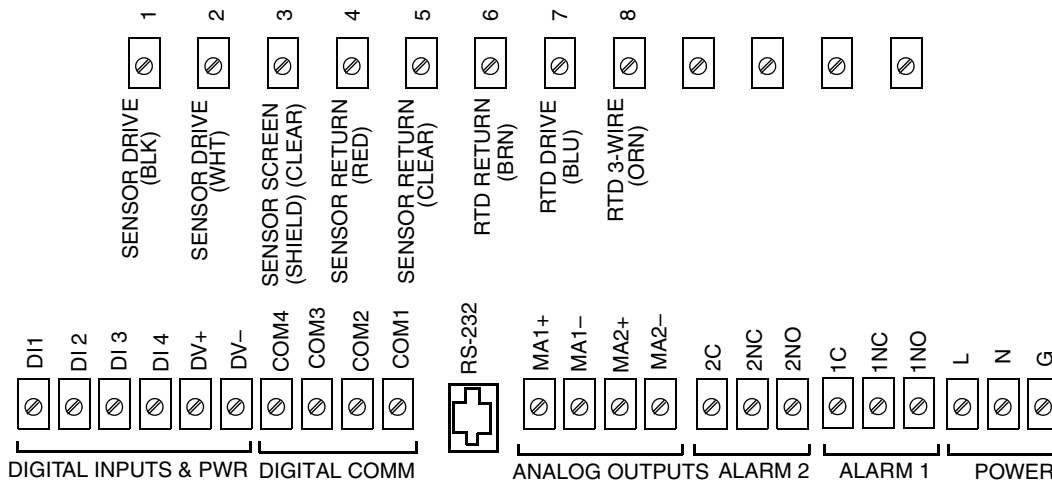


Figure 18. Sensor Wiring to 875EC Analyzer

Junction Box Installation

The maximum recommended cable length between the sensor and the analyzer or transmitter is 30 m (100 ft). Where possible, the sensor should be supplied with the appropriate length of cable for the intended installation. To minimize inaccuracies that may result from use of a junction box, the analyzer/sensor system should be calibrated as a system after installation, using the appropriate procedure as described in “Bench Calibration” on page 27.

Four extension cables are available for wiring between junction box Part No. BS807DY and the analyzer or transmitter. These cables are ordered with customer-specified lengths.

— NOTE —

Cables used with an 873EC or 873AEC Analyzer are terminated with stripped and tinned wires; cables used with an 870ITEC Transmitter or 875EC Analyzer are terminated with spade lugs, as listed in the following table.

The two PVC-jacketed shielded cables can also be used with junction box Part No. BS807NS and the analyzer or transmitter.

Part No.	Jacket	No. of Conductors	Use between junction box and ...
BS807PB	Teflon	8, plus ground	873EC or 873AEC Analyzer (lugs/lugless)
BS807PA	Teflon	8, plus ground	870ITEC Transmitter or 875EC Analyzer (lugs/lugs)
BS807PD	PVC	8, no ground	873EC or 873AEC Analyzer (lugs/lugless)
BS807PC	PVC	8, no ground	870ITEC Transmitter or 875EC Analyzer (lugs/lugs)

Junction Box Mounting

The junction box (Foxboro Part No. BS807DY (used with Teflon- or PVC-jacketed cable) or BS807NS (only used with PVC-jacketed cable) is used when the distance between sensor and monitor or transmitter is more than the cable length on the sensor. Note that the maximum recommended separation between sensor and analyzer or transmitter is 30 m (100 ft).

— CAUTION —

Cable length must be considered so that connections can be made without exposing cable to damage.

1. Select a rigid surface and a location protected from damage or exposure to excessive moisture and corrosive fumes.
2. Position the junction box against the mounting surface and mark the location of the mounting holes.
3. Drill the mounting holes on the marked centers.
4. Mount the junction box with appropriate hardware (user-supplied).

Junction Box Wiring

1. Remove the junction box cover, loosen nuts on cable sealing glands and slide sensor and extension cables through seals. (See Figure 19.)

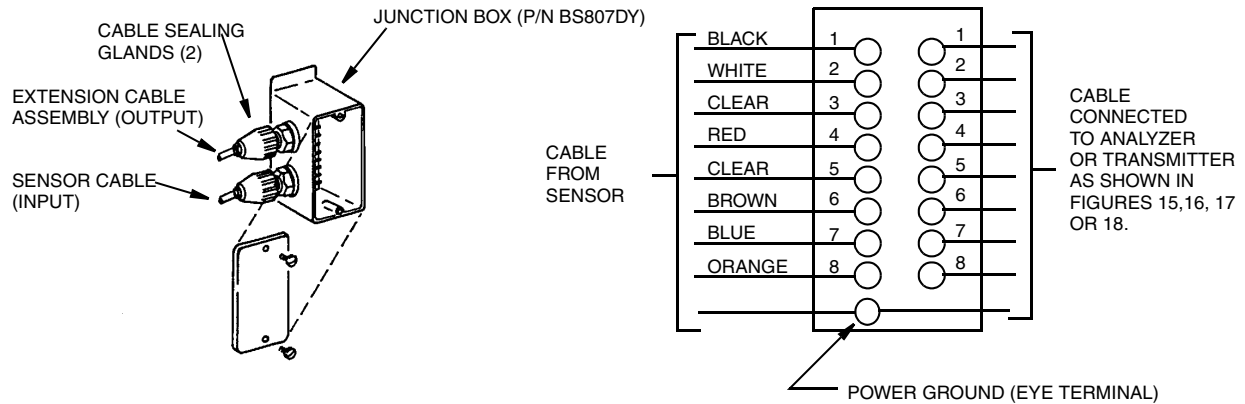


Figure 19. Junction Box Wiring With 9-Conductor Teflon-Jacketed Cable

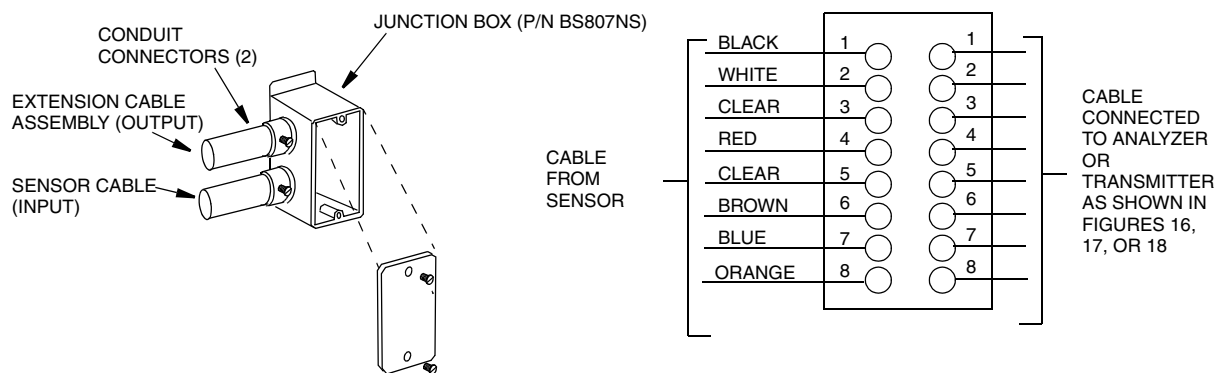


Figure 20. Junction Box Wiring with 8-Conductor PVC-Jacketed Cable

2. Fasten the numbered wires on the sensor cable to the corresponding numbered terminals on the terminal strip (wires 1-8). The ground wire on the Teflon-jacketed cable has an eyelet and is attached to one of the terminal strip mounting studs (see Figure 19). If PVC cable is used, since there is no ground wire, the user must supply conduit connectors to replace the sealing glands supplied with the junction box so as to insure required EMI/RFI electrical shielding between analyzer/transmitter and sensor. (See Figure 20.)
3. Fasten the numbered wires on the extension cable assembly to the corresponding numbered terminals on the terminal strip. For the Teflon-jacketed cable, the ground wire on the cable is attached to the terminal stud with the ground wire from the sensor. For the PVC-jacketed cable, this ground connection is made through the conduit connections (see Figure 20).

3. System Calibration

The 871FT Flow-Through Conductivity Sensor, when connected to an 875EC Analyzer, 870ITEC Transmitter, or 873EC Analyzer is calibrated as a system, using either of two procedures; a “Bench Calibration” using resistances or a “Solution Calibration” using solutions.

— **NOTE** —

Conductivity conversions are given at the end of this chapter for your convenience.

Bench Calibration

Since the analyzer or transmitter measures conductance (in S, mS, or μS) and the quantity desired is conductivity (in S/cm, mS/cm, or $\mu\text{S/cm}$), it is necessary to introduce the cell factor (l/cm) into the calibration procedure. These cell factors are indicated by the Model Code and are tabulated in Table 11. This procedure is found in “Bench Calibration” on page 27. The cell factors shown in Table 11 are accurate to $\pm 2\%$. If desired, the cell factors may be checked using the procedure “Determination of Geometric Cell Factors” on page 35.

Solution Calibration

When a system calibration using solutions is employed, specific knowledge of the cell factor is not required. A standard solution of known conductivity or a sample of process with independently measured conductivity is used for this procedure, as outlined in “Solution Calibration” on page 33.

— **! CAUTION** —

All electrodeless sensors can become magnetized if they come in close proximity to magnetic sources such as motors or electrical lines carrying high current. If this occurs, the measurement values obtained may be in error, particularly at low conductivity ranges (such as less than 500 $\mu\text{S/cm}$). For this reason, Invensys recommends that any sensor to be used in a low conductivity application first be degaussed to eliminate any possibility that the sensor has been magnetized either during shipping or on-site. For information on degaussing a magnetized sensor, see TI 612-005. Invensys routinely degausses all electrodeless sensors prior to shipment.

— **NOTE** —

For step-by-step examples of calibration procedures for 871FT Sensors with 875EC Analyzers, 870ITEC Transmitters, or 873EC Analyzers, refer to MI 611-220.

Bench Calibration

To perform a bench calibration, you must:

1. Enter data into your analyzer or transmitter
2. Perform a calibration at the low value

3. Calculate a resistance value
4. Perform a calibration at the full scale value.

Entering Data Into Analyzer or Transmitter

1. Check the model code for the sensor being calibrated. The 871FT-1 and -3 are high range conductivity sensors and the 871FT-2 and -4 are low range conductivity sensors.
2. Enter the appropriate cell factor information.

For the 873EC Analyzer, enter the appropriate C_T from Table 11 for the sensor being used in the configuration menu.

For the 870ITEC Transmitter, enter the appropriate $C_{f(\text{elec})}$ from Table 11 for the sensor being used in the configuration menu.

For the 875EC Analyzer, by entering the sensor type, the $C_{f(\text{elec})}$ is automatically set.

3. Refer to Table 12 to determine the minimum and maximum full scale conductivity range desired for the system being calibrated.

Enter the desired full scale conductivity range in the 873EC Analyzer, 870ITEC Transmitter, or 875EC Analyzer using the appropriate configuration menu.

Table 11. Geometric and Electrical Cell Factors of Flow-Through Sensors

Sanitary Sensors					
Line Size	$C_{f(\text{geom})}^{(1)}$	$C_{f(\text{elec})}^{(2)}$		$C_T^{(3)}$	
	cm^{-1}	High Range $\square=1$	Low Range $\square=2$	High Range $\square=1$	Low Range $\square=2$
871FT- \square C (1/2 in)	11.6	5.80	2.27	8	5
871FT- \square D (3/4 in)	4.14	2.07	0.81	7	13
871FT- \square E (1 in)	2.67	1.34	0.52	10	3
871FT- \square F (1-1/2 in)	1.11	0.56	0.22	3	1
871FT- \square G (2 in)	0.62	0.31	0.12	2	11
871FT- \square H (3 in)	0.38	0.19	0.07	9	11
871FT- \square J (4 in)	0.21	0.10	0.04	1	12

Industrial Sensors					
Line Size	$C_{f(\text{geom})}^{(1)}$	$C_{f(\text{elec})}^{(2)}$		$C_T^{(3)}$	
	cm^{-1}	High Range $\square=3$	Low Range $\square=4$	High Range $\square=3$	Low Range $\square=4$
871FT- \square C (1/2 in)	3.02	3.02	0.59	7	9
871FT- \square E (1 in)	1.06	1.06	0.21	15	1
871FT- \square F (1-1/2 in)	0.49	0.49	0.09	14	11
871FT- \square G (2 in)	0.49	0.49	0.09	14	11
871FT- \square H (3 in)	0.25	0.25	0.05	3	12

Industrial Sensors					
Line Size	$Cf_{(geom)}^{(1)}$	$Cf_{(elec)}^{(2)}$		$C_T^{(3)}$	
	cm^{-1}	High Range $\square=3$	Low Range $\square=4$	High Range $\square=3$	Low Range $\square=4$
871FT- \square J (4 in)	0.15	0.15	0.03	16	12

(1) $Cf_{(geom)}$ is used to calculate the loop resistance value for full scale calibration (or for nonzero low end calibration value).

(2) $Cf_{(elec)}$ is used in the configuration of the 870ITEC Transmitter.

(3) C_T is used in the configuration of the 873EC Analyzer.

Table 12. Minimum and Maximum Full Scale Conductivity Ranges

Sanitary Sensors				
Line Size	High Range $\square=1$		Low Range $\square=2$	
	Minimum $\mu S/cm$	Maximum mS/cm	Minimum $\mu S/cm$	Maximum mS/cm
871FT- \square C (1/2 in)	1000	2000	500	2000
871FT- \square D (3/4 in)	500	2000	500	1000
871FT- \square E (1 in)	500	2000	200	500
871FT- \square F (1-1/2 in)	100	1000	50	200
871FT- \square G (2 in)	100	1000	50	100
871FT- \square H (3 in)	100	1000	50	100
871FT- \square J (4 in)	50	500	50	50

Industrial Sensors				
Line Size	High Range $\square=3$		Low Range $\square=4$	
	Minimum $\mu S/cm$	Maximum mS/cm	Minimum $\mu S/cm$	Maximum mS/cm
871FT- \square C (1/2 in)	500	2000	100	500
871FT- \square E (1 in)	1000	2000	50	200
871FT- \square F (1-1/2 in)	1000	2000	50	100
871FT- \square G (2 in)	1000	2000	50	100
871FT- \square H (3 in)	200	1000	50	50
871FT- \square J (4 in)	200	500	50	50

Calibration at Low Value

1. Connect the sensor to the analyzer or transmitter.

— NOTE

For in-line calibration of industrial sensors, the sensor must be empty or filled with a solution having a conductivity at least 1000-fold less than the full scale range for which the system will be calibrated. If this is not possible, the sensor **must** be removed from the piping system, emptied, cleaned, and dried before proceeding.

2. For sanitary sensors mounted in nonconductive piping systems (See “Flange Types and Materials” on page 19), disconnect one end of the grounding strap between the Tri-Clamp fittings by disconnecting its wing nut. This allows in-line calibration irrespective of the solution conductivity within the sensor. Do **not** remove the Tri-Clamp fitting.
3. If using a Foxboro calibration plug (EP485A) or Foxboro calibration cable, remove the RTD connector.
4. With infinite resistance (no calibration plug or calibration cable connected to the sensor), and using the procedure in the applicable instruction for the analyzer or transmitter being used (MI 611-224 for 875EC, MI 611-212 for 870ITEC, or MI 611-167 for 873EC), calibrate the low value at 0.0 $\mu\text{S}/\text{cm}$, 0.0 mS/cm or 0.0 S/cm , depending on the desired range (or at a nonzero low value, if desired). Also see MI 611-220, System Calibration Examples.

Calculating the Resistance Value

The resistance required to calibrate your system at full scale value is dependent upon when your sensor was manufactured and if you are using a Foxboro calibration cable. The date of manufacture is determined from the last four digits of the Origin Date Code found on the sensor data plate. A code of 2B0149 means the sensor was manufactured in week 49 of 2001,

Use formula “a” to calculate full scale loop resistance:

- ◆ If using a user-supplied calibration wire looped through the sensor **or**
- ◆ If using a Foxboro calibration cable **and** your sensor has an Origin Date code earlier than 2B9710.

Formula “a”: $(Cf_{(\text{geom})} \cdot 1000 \cdot 1) / (\text{FS in mS/cm}) = \text{Loop R in ohms}$

where

$Cf_{(\text{geom})}$ = geometric cell factor for the sensor being calibrated, found in Tables 11.

FS = Full Scale conductivity value expressed in mS/cm

R = Resistance value, in ohms, to set on the decade resistance box.

Use formula “b” to calculate full scale loop resistance:

- ◆ If using a Foxboro calibration cable **and** your sensor has an Origin Date code of 2B9710 or later.

Formula “b”: $(Cf_{(\text{geom})} \cdot 1000 \cdot 25) / (\text{FS in mS/cm}) = \text{Loop R in ohms}$

where

$Cf_{(geom)}$ = geometric cell factor for the sensor being calibrated, found in Tables 11.

FS = Full Scale conductivity value expressed in mS/cm

R = Resistance value, in ohms, to set on the decade resistance box.

Example:

Calibrate an 871FT-1F Sanitary Flow-Thru Sensor with Full Scale Conductivity = 500 μ S/cm using a Foxboro calibration cable.

From Table 11, $Cf_{(geom)} = 1.11 \text{ cm}^{-1}$.

From Formula “a”,

$R = (1.11 \cdot 1000 \cdot 1) / (0.5) = 2220$ ohms for a sensor with a pre-2B9710 Origin Code.

From Formula “b”,

$R = (1.11 \cdot 1000 \cdot 25) / (0.5) = 55,500$ ohms for a sensor with an Origin Code of 2B9710 or later.

The resistance value calculated in these formulas assume a Foxboro calibration cable assembly is used or a user supplied calibration wire is used with a single loop or turn through the sensor as shown in the third setup of Figure 21. When the value of the resistance calculated is very small (less than 10 ohms), the resistance of the wire could affect the accuracy of the calibration. To avoid this, use multiple loops of user-supplied calibration wire through the sensor as shown in the fourth setup of Figure 21. The resistance calculated is then multiplied by the square of the number of turns.

Example:

Calibrate an 871FT-3G Industrial Flow-Thru Sensor with a full scale conductivity = 500 mS/cm.

From Table 11, $Cf_{(geom)} = 0.49 \text{ cm}^{-1}$.

From Formula “a”,

$R = (0.49 \cdot 1000 \cdot 1) / (500) = 0.98$ ohms for a sensor with a pre-2B9710 Origin Code.

From Formula “b”,

$R = (0.49 \cdot 1000 \cdot 25) / (500) = 24.5$ ohms for a sensor with an Origin Code of 2B9710 or later.

The resistance calculated in Formula “a” is less than 10 ohms. Therefore, you may decide to use 10 turns of wire. With 10 turns of wire, multiply the resistance value by 10^2 or 100 and use a resistance of 98 ohms to calibrate the full scale value to 500 mS/cm.

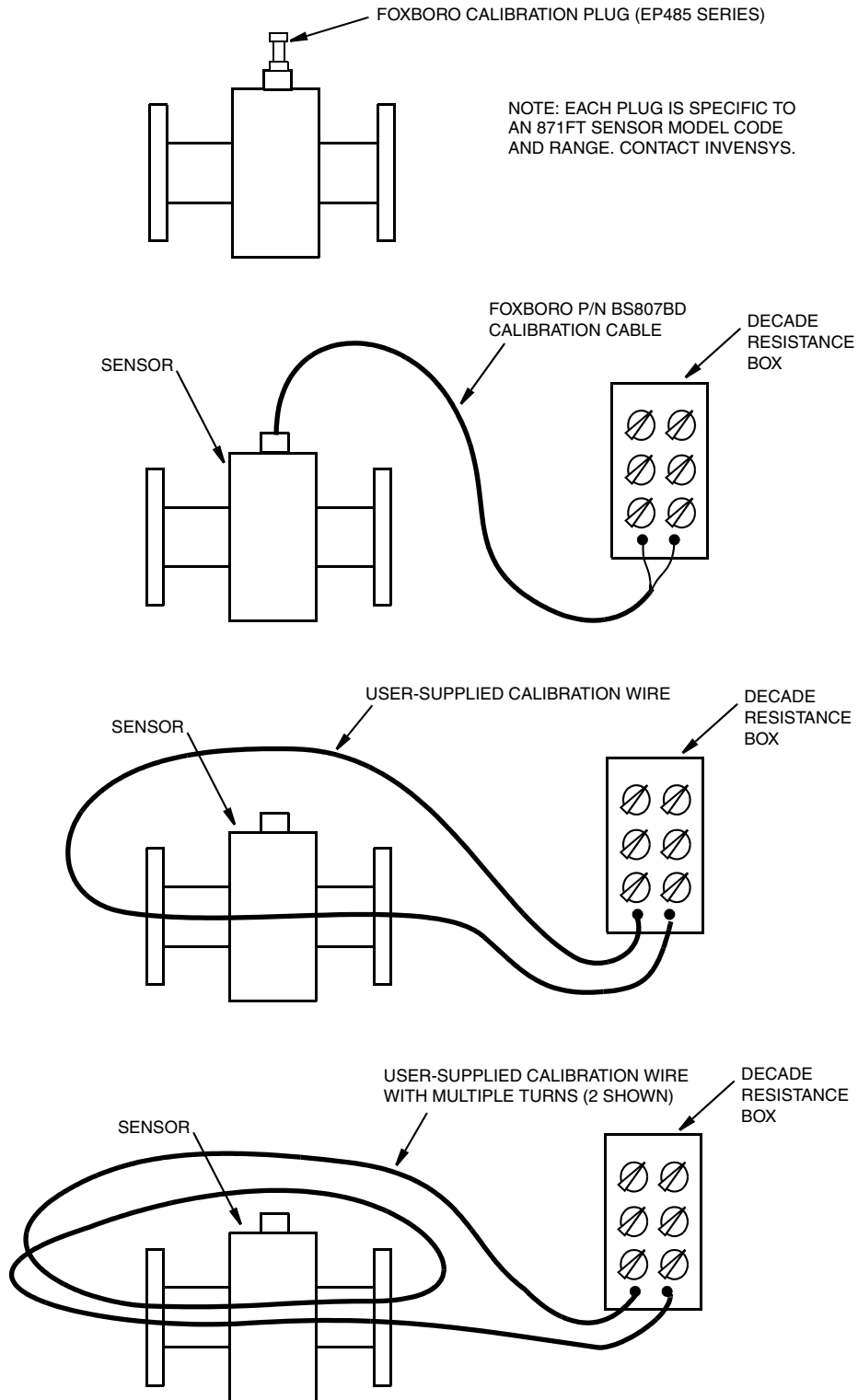


Figure 21. Flow-Through Sensor Cell Factor Calibration

Calibration at Full Scale Value

1. If using a Foxboro calibration plug, connect the plug to the RTD connection.
If using a Foxboro calibration cable assembly or user-supplied calibration wire, connect it to a decade resistance box as shown in Figure 21 and set to the resistance calculated above.
On sanitary sensors, if you disconnected the grounding strap in the “Calibration at Low Value” procedure on page 29, reinstall the strap.
2. Using the procedure in the appropriate instruction manual for the analyzer being used (MI 611-224 for 875EC, MI 611-212 for 870ITEC, or MI 611-167 for 873EC), calibrate at the full scale value. Also see MI 611-220, System Calibration Examples.
3. Disconnect the calibration plug or calibration cable/wire and reinstall RTD Cable (if used).
4. Reinstall the sensor into the process if previously removed.

Solution Calibration

This calibration may be performed using:

- ◆ NIST Standard KCl Solutions available from NIST or commercial suppliers (contact Invensys for additional information),
- ◆ Equivalent solutions that may be prepared by the user, or
- ◆ A grab sample obtained by analyzing the process solution by means of an independent conductivity measurement.

— NOTE —

For highest accuracy, this calibration may be performed using NIST Standard KCl Solutions or equivalent solutions that may be prepared by the user.

Preparation of Solutions

For preparation of solutions, use deionized or distilled water with a conductivity less than 2 $\mu\text{S}/\text{cm}$

Table 13. Conductivity of Calibrating Solutions

Measuring Range	Solution	Conductivity*		
		at 0 °C	at 18 °C	at 25 °C
100-1300 $\mu\text{S}/\text{cm}$	A			147 $\mu\text{S}/\text{cm}$
	B	540 $\mu\text{S}/\text{cm}$	873 $\mu\text{S}/\text{cm}$	1.01 mS/cm
	C	774 $\mu\text{S}/\text{cm}$	1.22 mS/cm	1.41 mS/cm
1.00-13.0 mS/cm	D	7.14 mS/cm	11.2 mS/cm	12.9 mS/cm
10.0-130.0 mS/cm	E	65.2 mS/cm	97.8 mS/cm	111.3 mS/cm
100-1300 mS/cm	F			251 mS/cm
	G			826 mS/cm

Table 13. Conductivity of Calibrating Solutions (Continued)

Measuring Range	Solution	Conductivity*		
		at 0 °C	at 18 °C	at 25 °C

*For solutions A, B and C, the conductivity of the water used for preparation of solutions should be added to the values specified.

— **NOTE** —

Solution conductivity is a strong function of temperature. For intermediate temperatures or temperatures outside the range shown in Table 13, sufficient accuracy may be obtained by linear interpolation or extrapolation using the values shown.

Solution A: Dilute 100 ml of Solution C to 1000 ml at 20°C (68°F).

Solution B: Weigh 500 mg dry NaCl and add water to give 1 kg solution (0.05 wt percent NaCl).

Solution C: Weigh 0.7440 g dry KCl and dilute to 1000 ml at 20 °C (68°F).

Solution D: Weigh 7.4365 g dry KCl and dilute to 1000 ml at 20 °C (68°F).

Solution E: Weigh 74.2640 g dry KCl and dilute to 1000 ml at 20 °C (68°F).

Solution F: Saturate water with NaCl at 20 °C (68°F).

Solution G: This conductivity level requires use of an acid solution. For information, contact Invensys.

Enter Data Into Analyzer or Transmitter

1. Check the model code for the sensor being calibrated. The 871FT-1 and -3 are high range conductivity sensors and the 871FT-2 and -4 are low range conductivity sensors.

For the 873EC Analyzer, enter the appropriate C_T from Table 11 for the sensor being used in the configuration menu.

For the 870ITEC Transmitter, enter the appropriate $C_{f(\text{elec})}$ from Table 11 for the sensor being used in the configuration menu.

For the 875EC Analyzer, by entering the sensor type, the $C_{f(\text{elec})}$ is automatically set.

2. Refer to Table 12 to determine the minimum and maximum full scale conductivity range for the system being calibrated.

Enter the desired full scale conductivity range in the 873EC Analyzer, 870ITEC Transmitter, or 875EC Analyzer using the appropriate configuration menu.

— **! CAUTION** —

When calibrating analyzer/sensor systems using solutions or when calibrating cell factors using solutions, it is important to account for the effect of temperature in the procedure.

Calibration Procedure

1. Prepare a calibration solution having a known conductivity in the required measuring range (see Table 13 and “Preparation of Solutions” on page 33).
2. Connect the sensor to the analyzer or transmitter.

— **NOTE** —

For in-line calibration of industrial sensors, the sensor **must** be empty or filled with a solution having a conductivity at least 1000-fold less than the full scale range for which the system will be calibrated. If this is not possible, the sensor **must** be removed from the piping system, emptied, cleaned, and dried before proceeding.

3. For sanitary versions mounted in nonconductive piping systems (See “Flange Types and Materials” on page 19), disconnect one end of the grounding strap between the Tri-Clamp fittings by disconnecting its wing nut. This allows in-line calibration irrespective of the solution conductivity within the sensor. Do **not** remove the Tri-Clamp fitting.
4. Using the procedure in the applicable instruction for the analyzer or transmitter being used (MI 611-224 for 875EC, MI 611-212 for 870ITEC, or MI 611-167 for 873EC), calibrate the low value at 0.0 $\mu\text{S}/\text{cm}$, 0.0 mS/cm or 0.0 S/cm , depending on the desired range (or at a nonzero low value, if desired). Also see MI 611-220, System Calibration Examples.
5. On sanitary sensors, reinstall the grounding strap removed in Step 3.
6. Fill the sensor with the appropriate calibrating solution selected from Table 13 or measure the conductivity of the solution in the sensor using an independent conductivity system. (Note effects of temperature on conductivity. Typically conductivity increases with temperature.)

— **NOTE** —

Assure that bore of sensor is completely full.

7. Using the procedure in the applicable instruction for the analyzer or transmitter being used (MI 611-224 for 875EC, MI 611-212 for 870ITEC, or MI 611-167 for 873EC), calibrate for the conductivity of the known solution. Also see MI 611-220, System Calibration Examples.

— **NOTE** —

Solution conductivity is a strong function of temperature. For intermediate temperatures or temperatures outside the range shown in Table 13, sufficient accuracy can possibly be obtained by linear interpolation or extrapolation using the values shown.

Determination of Geometric Cell Factors

Cell Factors are determined by the geometries of the sensors and will remain constant as long as the length and diameter of the insulating bore pieces within the sensor do not change. Nominal Cell Factors for the available sensor geometries are shown in Table 11. This procedure can be used to more accurately determine these cell factors.

In performing this procedure, you must:

1. Perform a solution calibration of the sensor and record the resulting conductivity
2. Determine the resistance necessary to reproduce this conductivity value
3. Calculate the geometric cell factor.

Performing a Solution Calibration

1. Follow the procedure “Solution Calibration” on page 33.

— **NOTE** —

This calibration cannot be an in-line calibration.

2. Record the conductivity value.

Determining the Resistance Value

1. Remove the solution from the sensor. Rinse and dry the sensor.
2. Remove the RTD connector from the sensor and connect a Foxboro calibration cable or loop a user-supplied calibration wire through the sensor (see Figure 21).
3. Connect the calibration cable/wire to a decade resistance box. Dial in the value of resistance necessary to reproduce the conductivity value recorded in Step 2 of the previous section.

— **NOTE** —

If the value of resistance necessary to reproduce the desired conductivity reading is smaller than 10 ohms, the resistance of the wire could affect accuracy. In such a situation, pass several turns of your user-supplied calibration wire through the sensor (see the fourth setup of Figure 21) and then connect to the decade resistance box. The resistance required to reproduce the conductivity noted in Step 3 is now larger by a factor of the square of the number of turns of wire through the sensor. Thus, if 10 turns of wire are used and the resistance on the decade box is 500 ohms, the resistance used in the cell factor equation in the next section is $500/10^2$ or 5 ohms.

Calculation of Cell Factor

1. Calculate the cell factor using the appropriate formula, which depends on your conductivity range:

$$Cf_{(\text{geom})} = (\text{Conductivity, } \mu\text{S/cm})(\text{Resistance, } \Omega/10^6) = \text{cm}^{-1}$$

$$Cf_{(\text{geom})} = (\text{Conductivity, mS/cm})(\text{Resistance, } \Omega/10^3) = \text{cm}^{-1}$$

$$Cf_{(\text{geom})} = (\text{Conductivity, S/cm})(\text{Resistance, } \Omega) = \text{cm}^{-1}$$

where:

Conductivity is that recorded in Step 2 of “Performing a Solution Calibration” above.

Resistance is that determined in Step 3 of “Determining the Resistance Value” above.

Example 1

Calibrate the cell factor of an 871FT-1F Sanitary Flow-Through Sensor using Solution D from Table 13. Conductivity = 11.2 mS/cm at 18 °C.

Using an 873EC Analyzer

1. Configure Ct = 3. This value comes from Table 11.
2. Configure the Full Scale Range = 20 mS/cm. 0 to 20 mS/cm is the range above the 11.2 mS/cm value given in the example.
3. Configure **TEMP** to 18.0. °C.
4. Perform a solution calibration per “Calibration Procedure” on page 35. Record the conductivity.
5. Determine the resistance value by performing the procedure in “Determining the Resistance Value” above. If the value of resistance necessary to display the conductivity (which should be 11.2 mS/cm) is 99.1 ohms, then calculate the cell factor.

$$Cf_{(\text{geom})} = (11.2)(99.1/10^3) = 1.11 \text{ cm}^{-1}$$

Using an 870ITEC Transmitter

1. Configure $Cf_{(\text{elec})} = 0.56 \text{ cm}^{-1}$ This value comes from Table 11.
2. Configure the Full Scale Range = 20 mS/cm. 0 to 20 mS/cm is the range above the 11.2 mS/cm value given in the example.
3. Configure **TEMP** to 18.0.°C.
4. Perform a solution calibration per “Calibration Procedure” on page 35. Record the conductivity.
5. Determine the resistance value by performing the procedure in “Determining the Resistance Value” above. If the value of resistance necessary to display the conductivity (which should be 11.2 mS/cm) is 99.1 ohms, then calculate the cell factor.

$$Cf_{(\text{geom})} = (11.2)(99.1/10^3) = 1.11 \text{ cm}^{-1}$$

Using an 875EC Analyzer

1. Configure the Full Scale Range = 20 mS/cm. 0 to 20 mS/cm is the range above the 11.2 mS/cm value given in the example.
2. Configure **TEMP** to 18.0.°C.
3. Perform a solution calibration per “Calibration Procedure” on page 35. Record the conductivity.
4. Determine the resistance value by performing the procedure in “Determining the Resistance Value” above. If the value of resistance necessary to display the conductivity (which should be 11.2 mS/cm) is 99.1 ohms, then calculate the cell factor.

$$Cf_{(\text{geom})} = (11.2)(99.1/10^3) = 1.11 \text{ cm}^{-1}$$

Example 2

Calibrate cell factor of 871FT-2G sensor using Solution E from Table 13.

Conductivity = 111.3 mS/cm at 25 °C. However the temperature in the lab is 21.5°C.

Using an 873EC Analyzer

1. Configure Ct = 11 (Table 11). This value comes from Table 11.
2. Configure the Full Scale Range = 200 mS/cm. 0 to 200 mS/cm is the range above the 111.3 mS/cm value given in the example.
3. Configure **TEMP** to 21.5 °C.
4. Perform a solution calibration per “Calibration Procedure” on page 35. Record the conductivity.

— **NOTE** —

Because the calibration was done at 21.5°C, the conductivity should have been close to the value calculated as follows:

$$97.8 \text{ mS/cm} + (0.02/\text{°C})(3.5\text{°C})(97.8 \text{ mS/cm}) = 104.6 \text{ mS/cm}$$

where:

97.8 mS/cm is the conductivity at 18°C per Table 13

2%/°C is the approximate temperature coefficient in the range of 18 to 25°C

3.5°C is the difference of 21.5 - 18°C

5. Determine the resistance value by performing the procedure in “Determining the Resistance Value” on page 36.

— **NOTE** —

Because the resistance value is less than 10 ohms, use multiple loops of user-supplied calibration cable as explained in the note in that section.

If the value of resistance necessary to display the conductivity (which should be 104.6 mS/cm) is 5.88 ohms, then calculate the cell factor.

$$Cf_{(\text{geom})} = (104.6)(5.88/10^3) = 0.615 \text{ cm}^{-1}$$

The value of resistance necessary to display 104.6 mS/cm should be 5.88 ohms within the accuracies of the solution and the analyzer/sensor system. If the actual resistance necessary to display 104.6 mS/cm is 5.74 ohms, then the calculation is:

$$Cf_{(\text{geom})} = (104.6)(5.74/10^3) = 0.60 \text{ cm}^{-1}$$

Using an 870ITEC Transmitter

1. Configure Cf_(elec) = 0.12). This value comes from Table 11.
2. Configure the Full Scale Range = 200 mS/cm. 0 to 200 mS/cm is the range above the 111.3 mS/cm value given in the example.
3. Configure **TEMP** to 21.5.0. °C.
4. Perform a solution calibration per “Calibration Procedure” on page 35. Record the conductivity.

— NOTE

Because the calibration was done at 21.5°C, the conductivity should have been close to the value calculated as follows:

$$97.8 \text{ mS/cm} + (0.02/\text{°C})(3.5\text{°C})(97.8 \text{ mS/cm}) = 104.6 \text{ mS/cm}$$

where:

97.8 mS/cm is the conductivity at 18°C per Table 13

2%/°C is the approximate temperature coefficient in the range of 18 to 25°C

3.5°C is the difference of 21.5 - 18°C

- Determine the resistance value by performing the procedure in “Determining the Resistance Value” on page 36.

— NOTE

Because the resistance value was less than 10 ohms, use multiple loops of user-supplied calibration cable as explained in the note in that section.

If the value of resistance necessary to display the conductivity (which should be 104.6 mS/cm) is 5.88 ohms, then calculate the cell factor.

$$Cf_{(\text{geom})} = (104.6)(5.88/10^3) = 0.615 \text{ cm}^{-1}$$

The value of resistance necessary to display 104.6 mS/cm should be 5.88 ohms within the accuracies of the solution and the analyzer/sensor system. If the actual resistance necessary to display 104.6 mS/cm is 5.74 ohms, then the calculation is:

$$Cf_{(\text{geom})} = (104.6)(5.74/10^3) = 0.60 \text{ cm}^{-1}$$

Using an 875EC Analyzer

- Configure the Full Scale Range = 200 mS/cm. 0 to 200 mS/cm is the range above the 111.3 mS/cm value given in the example.
- Configure **TEMP** to 18.0°C.
- Perform a solution calibration per “Calibration Procedure” on page 35. Record the conductivity.

— NOTE

Because the calibration was done at 21.5°C, the conductivity should have been close to the value calculated as follows:

$$97.8 \text{ mS/cm} + (0.02/\text{°C})(3.5\text{°C})(97.8 \text{ mS/cm}) = 104.6 \text{ mS/cm}$$

where:

97.8 mS/cm is the conductivity at 18°C per Table 13

2%/°C is the approximate temperature coefficient in the range of 18 to 25°C

3.5°C is the difference of 21.5 - 18°C

- Determine the resistance value by performing the procedure in “Determining the Resistance Value” on page 36.

— NOTE

Because the resistance value was less than 10 ohms, use multiple loops of user-supplied calibration cable as explained in the note in that section.

If the value of resistance necessary to display the conductivity (which should be 104.6 mS/cm) is 5.88 ohms, then calculate the cell factor.

$$Cf_{(\text{geom})} = (104.6)(5.88/10^3) = 0.615 \text{ cm}^{-1}$$

The value of resistance necessary to display 104.6 mS/cm should be 5.88 ohms within the accuracies of the solution and the analyzer/sensor system. If the actual resistance necessary to display 104.6 mS/cm is 5.74 ohms, then the calculation is:

$$Cf_{(\text{geom})} = (104.6)(5.74/10^3) = 0.60 \text{ cm}^{-1}$$

Conversion Factors

$$1 \text{ S} = 1000 \text{ mS}$$

$$1 \text{ S} = 1,000,000 \text{ } \mu\text{S}$$

$$1 \text{ mS} = 1000 \text{ } \mu\text{S}$$

$$1 \text{ S/m} = 0.01 \text{ S/cm}$$

$$1 \text{ mS/m} = 0.01 \text{ mS/cm}$$

$$1 \text{ } \mu\text{S/m} = 0.01 \text{ } \mu\text{S/cm}$$

$$1 \text{ S/m} = 1 \text{ mho/m}$$

$$1 \text{ S/m} = 0.01 \text{ mho/cm}$$

$$1 \text{ S/cm} = 1 \text{ mho/cm}$$

$$1 \text{ mS/cm} = 0.001 \text{ mho/cm}$$

4. Troubleshooting

Table 14. Symptoms, Possible Causes, and Remedies

Symptom	Possible Cause	Remedy
Noisy signal	1. Improper grounding. 2. Cavitation or bubbles trapped in sensor.	See “System Wiring” on page 21.
No signal	1. Open toroid. 2. Loose connection in wiring to sensor.	See Table 15. Replace.
Reduced sensitivity	1. One of drive toroids electrically open.	Replace toroid assembly. Remove sensor and clean. See Warning.
Temperature reads incorrectly	1. Short/open RTD. 2. Temperature setup incorrect.	Replace RTD Assembly. Check configuration of analyzer or transmitter.
Accuracy/change of cell factor	1. Deposits within sensor. 2. Magnetization.	Clean sensor. See Warning. Demagnetize.

— ! WARNING —

Use protective clothing and extra care when removing any industrial sensor for cleaning. Process fluid may be trapped in O-ring grooves.

Sensor Resistance Check

Cable resistances to facilitate problem isolation are shown in the following table.

Table 15. Cable Resistance

Connection	Resistance
1 to 2	0 (short)
1 or 2 to 3	infinite
1 or 2 to 4 or 5	infinite
4 to 5	0 (short)
4 or 5 to 6, 7 or 8	infinite
6 to 7	see Table 7 on page 13
7 to 8	0 (short)

Model Code

<u>Flow-Through Conductivity Sensor</u>	871FT
<u>Sensor Type</u>	
Sanitary, High Range Conductivity	-1
Sanitary, Low Range Conductivity	-2
Industrial, High Range Conductivity	-3
Industrial, Low Range Conductivity	-4
<u>Nominal Line Size</u>	
1/2 in(a)(c)	C
3/4 in(a)(l)	D
1 in(e)(c)	E
1-1/2 in(e)	F
2 in(e)	G
3 in(f)	H
4 in(f)	J
<u>End Connection Material</u>	
None (One-piece Insulator - Sanitary) (a)	1
Hastelloy C-276 (b)	2
316 Stainless Steel (b)	3
Carpenter 20-CB3 (b)(h)	4
<u>Insulator Material</u>	
Virgin PEEK (Sanitary)(3A/FDA compliant)(a)(l)	A
PVDF (b)(i)(p)	B
PCTFE (i)(j)(p)	C
Glass-filled PEEK (b)	D
<u>End Connection Form</u>	
Tri-Clamp (a)	1
Pipe, NPT (b)(e)(f)	2
Flange, ANSI Class 150 (b)(d)	3
Flange, ANSI Class 300 (b)(k)	4
<u>RTD</u>	
None	C
1000 ohm Platinum(m)	R
100 ohm Platinum	T
<u>Cable Options</u>	
Cable Length Per Sales Order (n)	-3
Cable With Lugless Terminations (o)	-4
Shielded Teflon Cable (q)	-9
<u>O-ring Options (b)(d)</u>	
Viton (i)	-V
Perfluoroelastomer (Chemraz)	-P
<u>Calibration Cable</u>	
Calibration Cable Assembly	-C

NOTES:

- a. Sanitary only.
- b. Industrial only.
- c. Sanitary:
 - ◆ 1/2-inch line size uses 3/4 inch Tri-clover mounting flange and clamp.
 - ◆ 1 inch and 1-1/2-inch line sizes use 1-1/2 inch Tri-clover mounting flange and clamp.
- d. Standard O-Ring material is EPDM.
- e. 1-inch, 1-1/2-inch, and 2-inch industrial versions use flange/NPT pipe adapter (available from Invensys).
- f. NPT pipe mounting not available in End Connection Form 3 (ANSI Class 150), sizes 3 and 4 inch; and End Connection Form 4 (ANSI Class 300).
- g. Not used.
- h. Industrial sleeves are Alloy 20, ASTM A-351, Grade CN-7M.
- i. Must be specified for high concentration sulphuric acid or oleum applications. Choose Carpenter 20 End Connection Material and PCTFE or PVDF Insulator Material.
- j. Available only with End Connection Form 1, 2, 3, or 4.
- k. Only available in 316 S.S. (all sizes) and Hastelloy C276 (1/2 in only)
- l. English Sanitary 3/4 inch available only in Virgin PEEK.
- m. Choose for use with 870ITEC Transmitter or 875EC Analyzer.
- n. Maximum recommended cable length 30 m (100 feet) total.
- o. Choose for use with 873EC or 873AEC Analyzer.
- p. The Sanitary Type (-1 and -2) sensors with Tri-Clamp end Connections and Virgin PEEK Insulator material comply with 3A standards.
- q. 873EC or 873AEC NEMA 1 (Plastic) Analyzer requires the selection of the teflon cable.

5. Maintenance

There are six O-rings in the 871FT Sensor. Their life is dependent on the chemical, concentration, and temperature of the solution being monitored. Therefore, eventually, they need to be replaced. You may also want to change the O-rings if you decide to use the sensor in a different application that requires a different O-ring material. O-ring kits are available in EPDM (standard), Viton, and Chemraz. The O-rings should always be replaced as a set. Refer to PL 611-017 to ascertain the part numbers for 1/2 to 4 inch line size sensors.

The replacement of the O-rings requires that the sensor be removed from the line and disassembled. The following procedure is illustrated with views of an industrial sensor.

1. Remove the hex nuts from the threaded rods. For sensors installed in a process line, two wrenches may be required to remove the nuts. Then remove the rods. The sensor can now be removed from the process line for further disassembly.

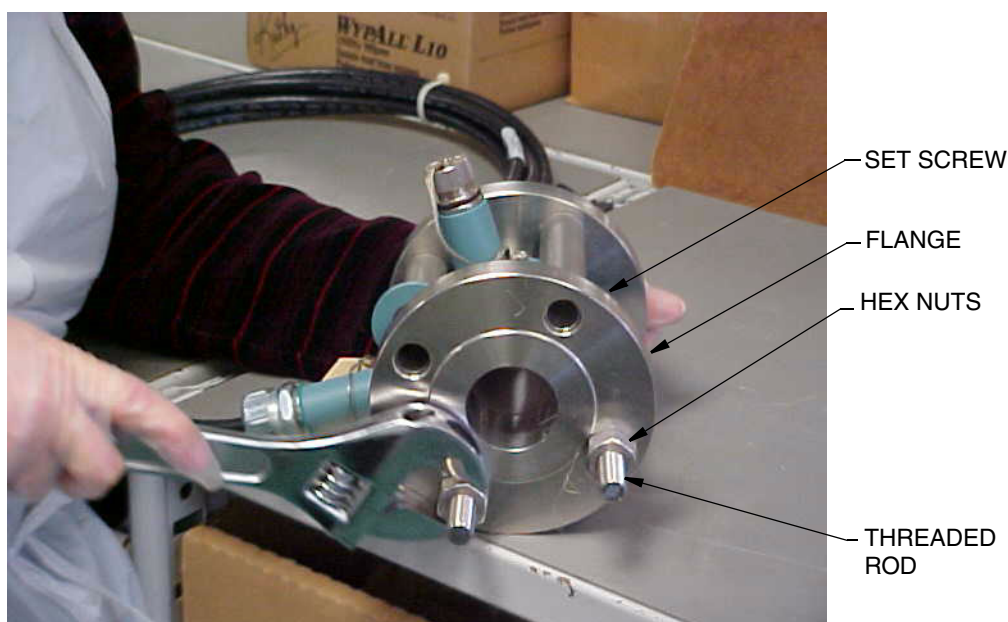


Figure 22. Removing the Hex Nuts

2. Loosen the set screws on the edge of one flange so the flange can be removed from the spacers.
3. Remove the flanges and spacers leaving the toroid assembly with the toroid sleeves.

— NOTE —

The O-rings may become dislodged from the O-ring grooves in the end of the toroid sleeve during removal of the flanges. In Figure 23 note that one O-ring remained in the O-ring groove and the other is on the flange.



Figure 23. Separation of Flanges from the Toroid Assembly

4. Carefully remove one toroid sleeve from the toroid assembly.



Figure 24. Removal of First Toroid Sleeve from the Toroid Assembly

5. After removal of one toroid sleeve, the other sleeve and the insulator (bore piece) can easily be removed from the toroid assembly. You can now see the inner and outer toroid sleeve O-rings.



Figure 25. Removal of Second Toroid Sleeve and Insulator from Toroid Assembly

6. Grab the toroid sleeve, either by hand or by some mechanical means (as shown) and carefully remove the insulator using a twisting motion. Even though the toroid sleeve is well lubricated with silicone grease, sometimes it is necessary to use a strap wrench on the spine of the insulator to start the rotation of the insulator in the sleeve.

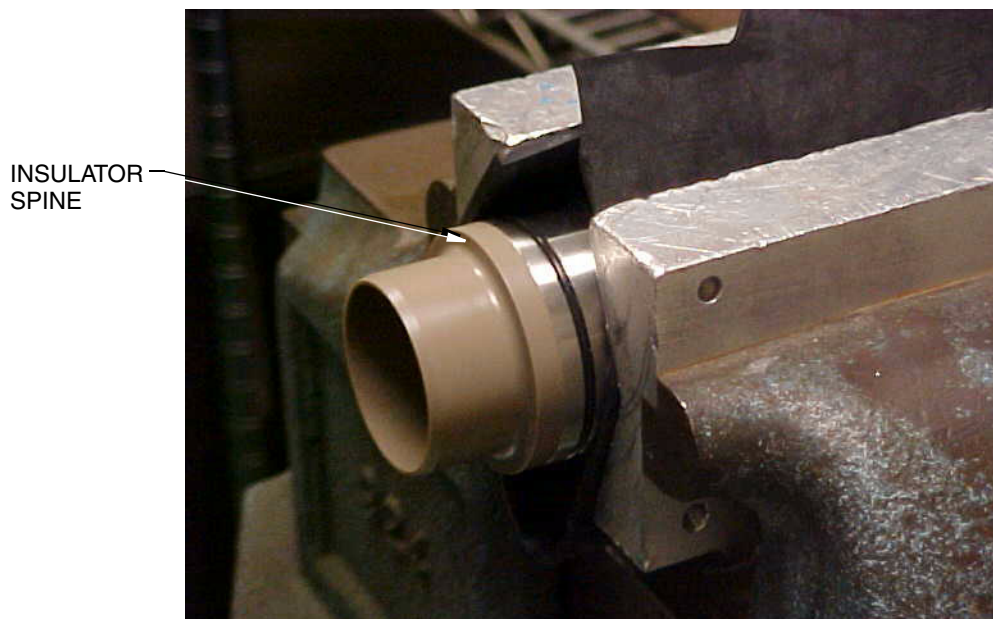


Figure 26. Removal of Insulator from Second Toroid Sleeve

7. Lubricate the new O-rings with the silicone grease supplied in the O-ring kit.
8. Replace the flange to toroid O-rings in the end of the toroid sleeve. Assure that the O-rings are not twisted or nicked.
9. Replace the inner and outer toroid sleeve O-rings. Assure that the O-rings are not twisted or nicked.
10. Using care not to damage the new O-rings, reassemble the sensor by reversing Steps 1 through 6.

Appendix A. Pressure/Temperature Derating Tables

Table 16. Sanitary Type, PCTFE

If Maximum Pressure (psi)	Then, Maximum Temp (°F)
60	140
55	150
50.5	160
46	170
41.5	180
37	190
32.5	200
28	210
23.5	220
19	230
14.5	240
10	250

— NOTE

Pressure of 15.3 psi at 250°F can be used for a short period of time (2 hours) for hot water or steam sterilization. For longer periods, contact Invensys.

Table 17. Industrial Type, ANSI Class 150, PVDF

If Maximum Pressure (psi)	Then, Maximum Temp (°F)
100	140
96	150
93	160
89	170
85	180
82	190
78	200
74	210
71	220
67	230
63	240

Table 17. Industrial Type, ANSI Class 150, PVDF

If Maximum Pressure (psi)	Then, Maximum Temp (°F)
60	250

Table 18. Industrial Type, ANSI Class 150, Glass Filled PEEK

If Maximum Pressure (psi)	Then, Maximum Temp (°F)
275	140
271	150
268	160
265	170
262	180
259	190
256	200
253	210
249	220
246	230
243	240
240	250
237	260
234	270
231	280
227	290
224	300
221	310
218	320
215	330
212	340
209	350
205	360
202	370
199	380
196	390
193	400
190	410

Table 19. Industrial Type, ANSI Class 150, PCTFE

If Maximum Pressure (psi)	Then, Maximum Temp (°F)
100	140
90	150
82	160
74	170
66	180
58	190
50	200
42	210
34	220
26	230
18	240
10	250

Table 20. Industrial Type, ANSI Class 300, PVDF

If Maximum Pressure (psi)	Then, Maximum Temp (°F)
365	150
334.5	160
304	170
273.5	180
243	190
212.5	200
182	210
151.5	220
121	230
90.5	240
60	250

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