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FOXBORO®

Instruction

MI 019-166
March 1998

E83L (Styles A and B), E83W (Styles E, F and H), and E83F (Styles B, C, and D) Vortex Flowmeter

Sensor/Amplifier Replacement



E83L STYLES A ND B
(FLANGED BODY SHOWN)



E83W WAFER BODY
STYLES E AND F



E83F FLANGED BODY
STYLES B AND C

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1. Introduction

The vortex flowmeter has a field-replaceable sensor. The sensor is a piezoelectric crystal encapsulated between two welded diaphragms. Sensors come in several versions; a silicone or Fluorolube filled capsule for standard temperature applications of 0 to 204°C (400°F) and an unfilled capsule for high temperature applications in the range of 204 to 427°C (400 to 800°F). Both versions also come in either 316 ss or Hastelloy C materials.

The vortex shedding principle creates an alternating differential pressure on the sensor diaphragms which is transmitted to the piezoelectric crystal. This pressure, acting on the crystal, causes it to develop voltage pulses with a frequency equal to the vortex shedding frequency and proportional to the flow rate of the fluid.

Damage can occur to the sensor because of improper installation or application, requiring replacement of the sensor.

NOTES:

1. If the flowmeter is equipped with an optional isolation manifold (-K), refer to instruction MI 019-171 for sensor replacement.

2. Before starting the disassembly procedure to remove a sensor, make sure the Test Procedures have been completed. See Instruction MI 019-161. Although the illustrations shown are of the E83L, they also apply to the E83W and E83F.

3. When not using the -K isolation manifold option, the process pressure must be removed and the process fluid drained from the meter before starting disassembly.

Foxboro has not produced instruments using the older style (with coax cable) sensors since early 1983. The newer (2-wire) sensors are not compatible with older type electronics. Therefore, you may be required to upgrade to the improved electronics module when changing to the 2-wire sensor.

2. Selecting the Parts Required

2-wire Sensor

If the existing sensor has two wires (NOT a coaxial cable), the existing electronics module is suitable for use with a grounded sensor. Order a sensor kit of the same type as the existing sensor. No other conversion parts are required. Order the appropriate kit from Table 1.

Then proceed to “Disassembly” on page 7 or page 13.

Table 1. Sensor Kits for Various Transmitter Types

Transmitter Model Code	Body Material	Fill Fluid	Sensor Kit Part No.
E83L-.....C	Hastelloy C	Fluorolube	K0147QD
E83L-.....H	Hastelloy C	Silicone Oil	K0147QC
E83L-.....F	AISI 316 SS	Fluorolube	K0147QB
E83L-.....S	AISI 316 SS	Silicone Oil	K0147QA
E83W-...C	Hastelloy C	Fluorolube	K0147QD
E83W-...H	Hastelloy C	Silicone Oil	K0147QC
E83W-...F	AISI 316 SS	Fluorolube	K0147QB
E83W-...S	AISI 316 SS	Silicone Oil	K0147QA
E83F-.....C	Hastelloy C	Fluorolube	K0147QD
E83F-.....H	Hastelloy C	Silicone Oil	K0147QC
E83F-.....F	AISI 316 SS	Fluorolube	K0147QB
E83F-.....S	AISI 316 SS	Silicone Oil	K0147QA
E83FA-....S	AISI 316 SS	Silicone Oil	K0147QA
E83FA-....R	Hastelloy C	Silicone Oil	K0147QC
E83FA-....F	AISI 316 SS	Fluorolube	K0147QB
E83FA-....D	Hastelloy C	Fluorolube	K0147QD
E83WA-....S	AISI 316 SS	Silicone Oil	K0147QA
E83WA-....R	Hastelloy C	Silicone Oil	K0147QC
E83WA-....F	AISI 316 SS	Fluorolube	K0147QB
E83WA-....D	Hastelloy C	Fluorolube	K0147QD

Each sensor kit includes:

- 1 Sensor Assembly
- 1 O-ring
- 1 Bonnet Gasket
- 1 Sensor Flow Dam
- 2 Tie Wraps
- 1 Instruction Manual

Old Style Coaxial Cable Sensor Replacement Parts

Integrally Mounted Transmitters

Integrally Mounted Meter with White-Faced Non-Encapsulated Electronics Module

If the existing sensor has a coaxial cable and the existing electronics are integrally mounted with the flowtube (not remote mounted), check the electronics module type. If the module has a white face with DIP switches, it is compatible with the new style 2-wire sensors. Order a new sensor kit of the same type as the existing sensor. No other conversion parts are required. Order the appropriate kit from Table 1.

Proceed to “Disassembly” on page 7.

Integrally Mounted Meter with Black-Faced Fully Encapsulated Electronics Module

If the existing sensor has a coaxial cable, a black-faced fully encapsulated electronics module (module does not have a white face and DIP switches), and the electronics are integrally mounted with the flowtube, you must upgrade the existing electronics module with the newer type module in addition to replacing the sensor. Order the appropriate kit from Table 1 and also select an electronics upgrade kit of your choice.

Table 2. Electronics Upgrade Kits

Description	Kit
Improved Analog Electronic Module	B0194RF
FoxCom Intelligent Electronic Module	K0147DZ
HART Intelligent Electronic Module	K0147HX

Proceed to “Disassembly” on page 7.

Remote Mounted Transmitters

Remote Mounted Meter with White-Faced Non-Encapsulated Electronics Module

If the existing sensor has a coaxial cable, the electronics is remote mounted (not integrally mounted with the flowtube), and the electronics module has a white face and DIP switches, the electronics module is compatible with the new style 2-wire sensor. However, an adapter kit is needed to facilitate connection of the 2-wire sensor in the sensor junction box. These additional parts are needed so that you will not have to string new 2-wire cable between the electronics and junction box housings. Order the appropriate sensor kit from Table 1 and also a K0147BJ Remote Adapter Kit.

Proceed to “Disassembly” on page 13.

Remote Mounted Meter with Black-Faced Fully Encapsulated Electronics Module

If the existing sensor has a coaxial cable, the electronics is remote mounted (not integrally mounted with the flowtube), and the electronics module is black faced and completely encapsulated, you must upgrade the electronics module when you replace the sensor. In addition, the adapter kit to facilitate connection of the 2-wire sensor in the sensor junction box AND another adapter to connect coax to 2-wire in the electronics housing are required. These additional parts are needed so that you will not have to string new 2-wire cable between the electronics and junction box housings. Order the appropriate sensor kit from Table 1 and also the following items:

1 K0147BJ Remote Adapter Kit
1 K0147BH Adapter Kit

Select the electronics upgrade kit of your choice from the following:

Table 3. Electronics Upgrade Kits

Description	Kit
Improved Analog Electronic Module	B0194RF
FoxCom Intelligent Electronic Module	K0147DZ
HART Intelligent Electronic Module	K0147HX

Then proceed to “Disassembly” on page 13.

Intelligent Upgrade Kits

If you have chosen an intelligent type electronics upgrade kit (K0147DZ or K0147HX), the module included with the kit must be configured before it can be used. Both versions (FoxCom and HART) can be configured by using the optional Local Display/Configurator, available as Kit K0147EK, as well as the configurators listed below. Before proceeding, be sure that the correct version of a configurator is available.

1. Kit K0147DZ — FoxCom Models 83F-D, 83W-D, and 83S-D, Style A

NOTE: Configurators for I/A Series FoxCom electronics:

- *The HHT requires data pack L0122EV.*
- *The PC10 requires Version 2.0 or later.*
- *The I/A Series System requires Version 4.0 or later to accept the vortex signal.*

---

2. Kit K0147HX — HART Models 83F-T. 83W-T. and 83S-T, Style A

NOTE: Configurators for I/A Series HART electronics:

- *The I/A Series system requires HART: Revision 5; Vortex, Field Device v. 1, DD v.1; or later.*
- *Hand-Held HART Model 275 Communicator (Foxboro HT991).*

---

3. Disassembly/Reassembly Instructions

Flowmeter with Integral Electronics Module

Disassembly

WARNING: To avoid personal injury, before loosening any bolts to remove topworks or flowmeter from line, check the line to ensure that process fluid is not under pressure, and that the line is empty.

1. Remove power from the electronics module.
2. Remove field terminal cover, O-ring, and output indicator (if this option is present). Remove electronics module compartment cover.
3. Disconnect input wiring and conduit connections.
4. Unscrew captive mounting screws on electronics module. (See Figure 2.)
5. If 2-wire, remove the wires from the terminal block, or remove coaxial sensor lead from the back of the electronics module. Use needlenose pliers on the connection.
6. Remove clamp from wires and verify that sensor lead is free to slide out. (If 2-wire, go to Step 8.)
7. If you are replacing the electronics module, remove the red, yellow, and blue leads from the terminal block. Clip off the spade type terminals, leaving as much wire as possible.
8. If you are replacing the electronics module, clip the tie wraps from the wires.
9. Remove mechanical connector bolts (see Figure 1).
10. Lift off electrical housing, mechanical connector, and sensor assembly as a unit. The sensor assembly, including O-ring, gasket, and flow dam, will not be reused. New ones will be used.
11. Remove gasket from body. (This gasket will not be reused.)
12. Remove the flow dam assembly. This flow dam will not be reused. It may be attached to the sensor assembly or it may be in the sensor opening in the body.
13. Grasp sensor assembly and remove from mechanical connector (see Figure 1).

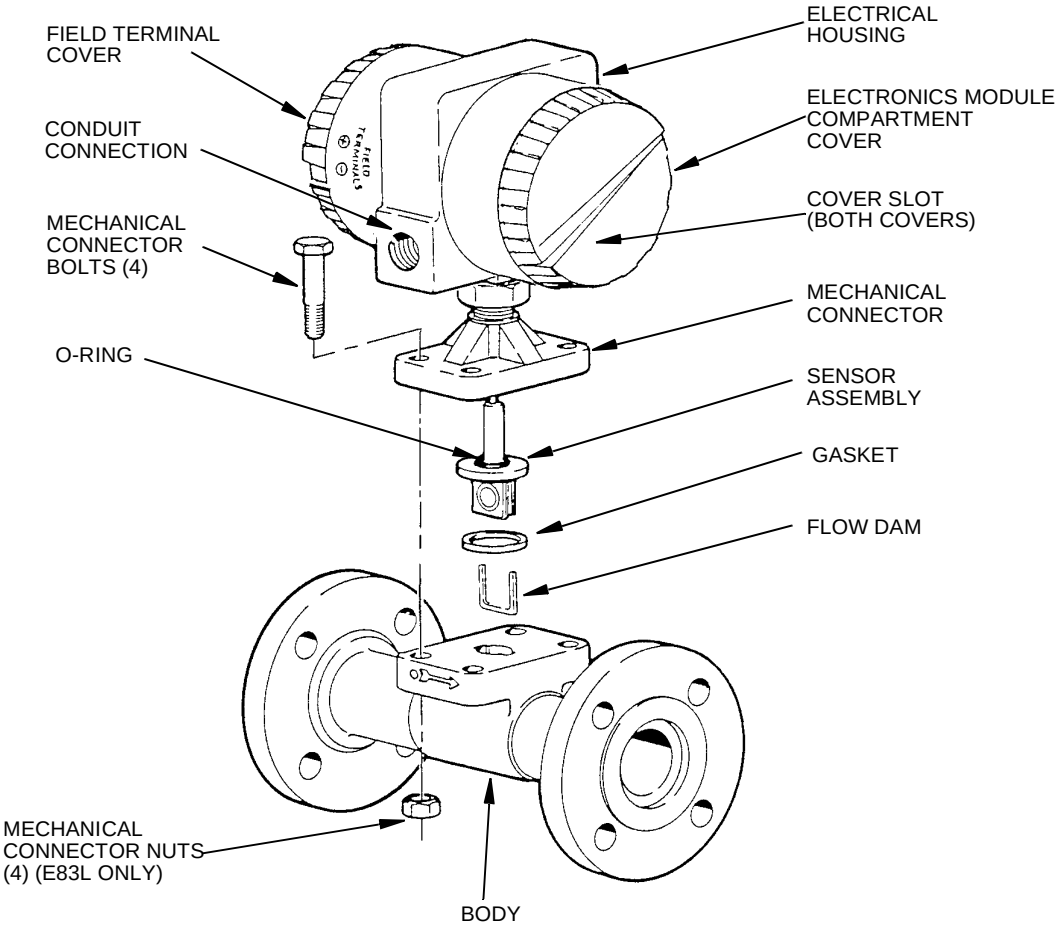


Figure 1. Flowmeter Assembly

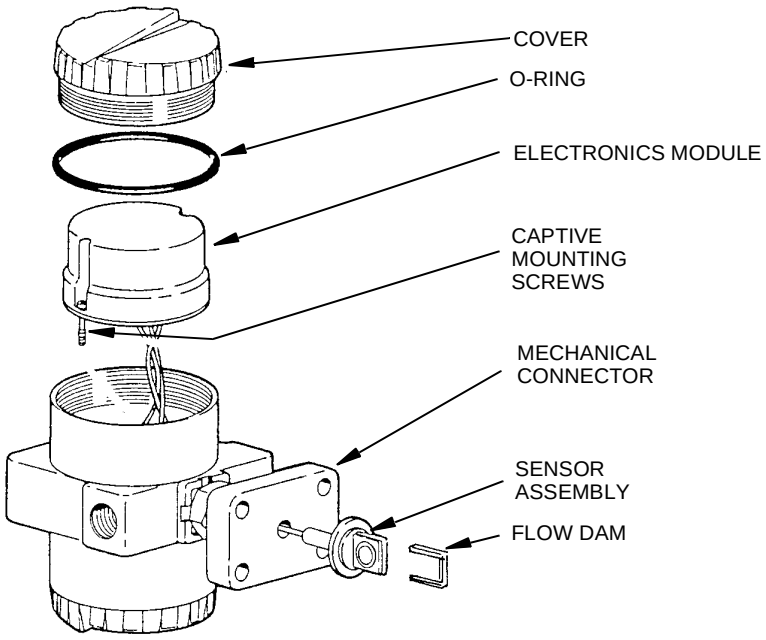


Figure 2. Electrical Housing/Mechanical Connector

Reassembly

NOTE: Verify that all parts are available before starting reassembly. See Table 1 on page 3.

To reassemble the meter, do the following:

1. Slide O-ring over the sensor leads and onto neck of sensor assembly (see Figure 3).
2. Feed sensor assembly leads through hole in mechanical connector. Gently pull sensor leads out of electrical housing until sensor assembly is touching mechanical connector. (See Figure 3.)

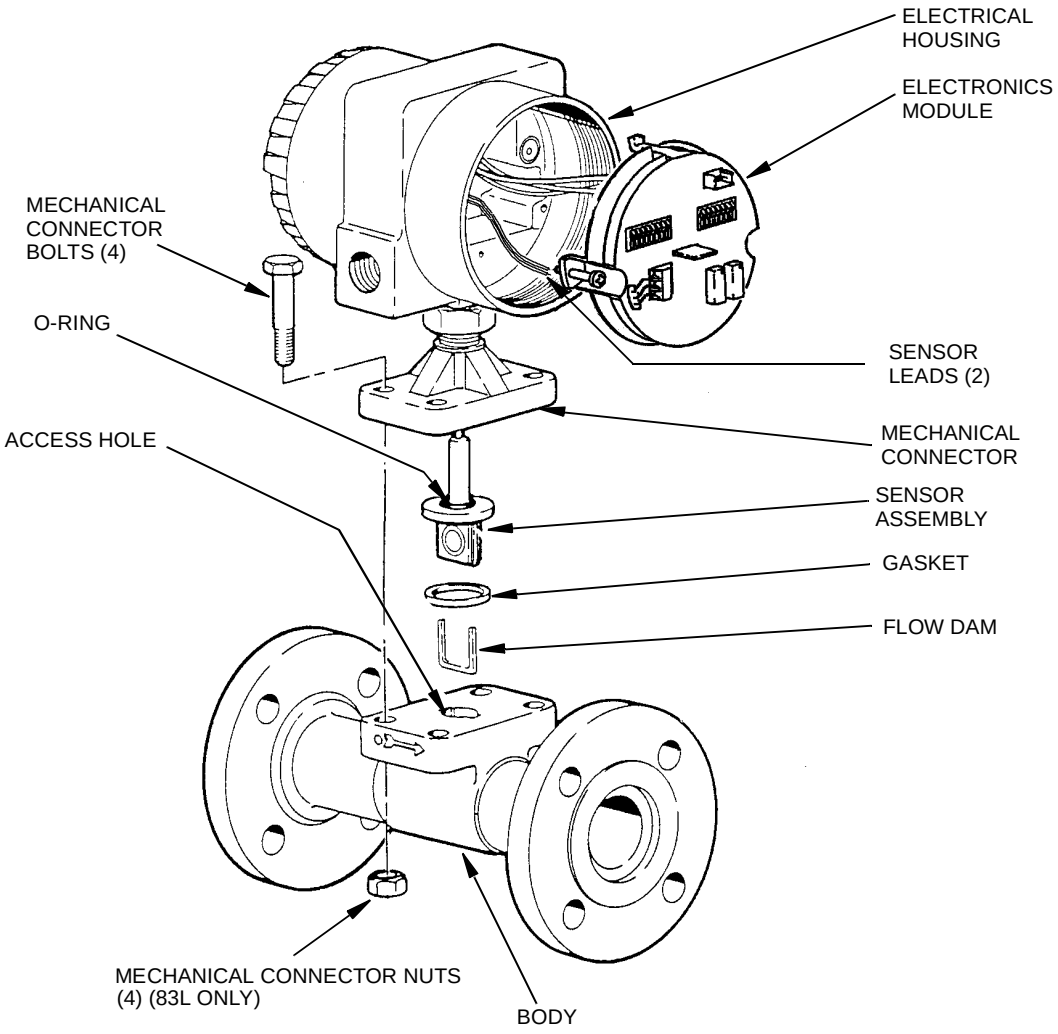


Figure 3. Flowmeter Assembly

WARNING: Take special care not to scratch, mar, ding, or dent the surface of the sensor stem or the sensor bore in the mechanical connector during assembly. This is especially critical to the integrity of the flameproof surface finish for CENELEC units.

3. Place the flat gasket over the sensor in contact with the serrated sealing surface. Center the gasket. Slide the flow dam into the groove of the sensor.
4. Carefully insert the sensor into the meter body and assemble the four bolts finger tight.

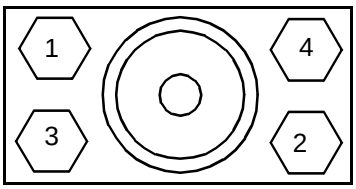
WARNING: It is important that the gasket be sealed uniformly to provide a good seal. The following steps will assure a uniform seal. Failure to follow these steps could result in personal injury due to gasket leakage.

5. Tighten all connector bolts in steps of 1.2 N•m (1 lb•ft) up to 2.8 N•m (2 lb•ft) per the sequence shown in Figure 4.

   For example,

   $$\frac{1.2}{1}$$

   means 1.2 N•m or 1 lb•ft.



MAXIMUM TORQUE 34 N•m (25 lb•ft)

Figure 4. Connector Bolt Torquing Sequence

6. Continue to tighten in steps of 7 N•m (5 lb•ft) using the same sequence. The maximum torque needed for safe operation is 34 N•m (25 lb•ft) per Figure 4.

NOTE: Replacing the sensor does not change the K-factor.

WARNING: The reassembled meter must be hydrostatically tested:
1. To prevent injury from escaping process fluids.
2. To maintain agency certification of this product.
3. To prove the integrity of the parts and workmanship in containing process pressure.

The meter must hold the appropriate pressure per Table 4, "Maximum Test Pressure," on page 12 for 1 minute without leaking.

7. If you are also replacing the electronics module with the analog version, feed the red, yellow, and blue leads through the slots in the electronic module PWAs. Do not strip the insulation before feeding the wires through. See Figure 5.

8. Strip the insulation back about 1/4 inch and connect the wires to the color coded terminals on the front of the electronics module. Remove the slack by pulling the excess wire back through the slots.
9. Connect the brown and yellow sensor wires to the color coded terminal block on the back of the electronics module. See Figure 5.
10. Apply new tie wraps. Bring all of the wires together and, while pushing slack away from the electronics module, tie the cable together.
11. Insert the electronics module into the housing, align the mounting holes, and tighten the captive mounting screws. Take care not to squeeze the signal cable or output wires between the electronics module and housing when tightening the screws.
12. Perform a post assembly dielectric test on the field terminal side. Short the terminals "+", "–", and "A" together. Apply 500 V dc or 707 V ac for 1 minute between the housing ground and the shorted terminals. Do not apply the voltage to the individual terminals. This test is required in order to ensure that there are no faults to ground of the internal wiring.
13. Set Switch J for correct output mode (pulse or 4 to 20 mA output).

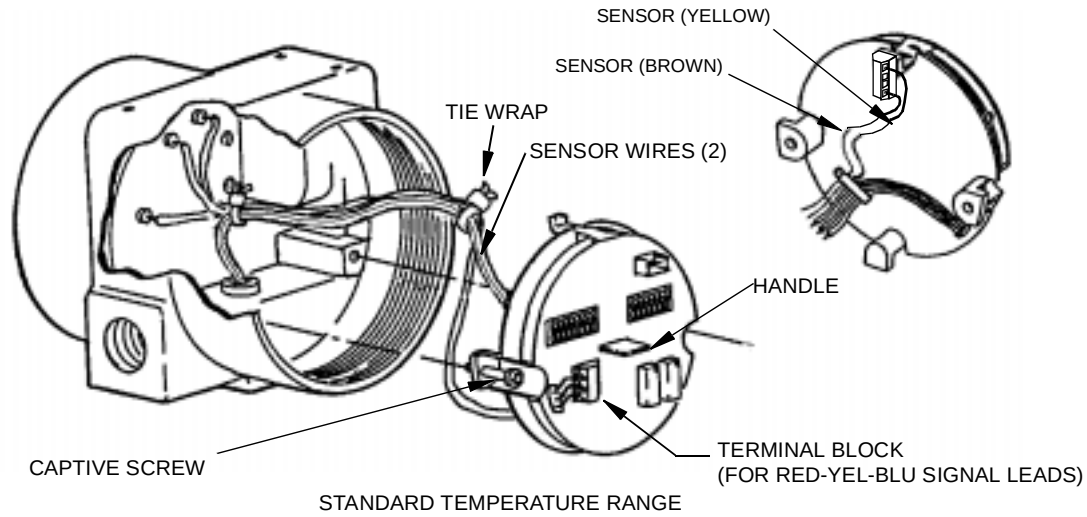


Figure 5. Electronics Module

Table 4. Maximum Test Pressure

Flowmeter Model	End Connection	Test Pressure	
		MPa	psi
E83L	PN 10/16	3.6	---
	PN 25/40	7.6	---
	Class 150	---	425
	Class 300	---	1100
	Class 600	---	2175
	Threaded	15.5	2250
	Butt-Weld	15.5	2250
E83W	PN 100	15	---
	Class 600	---	2175
E83F	PN 40	7.6	---
	Class 150	---	425
	Class 300	---	1100
	Class 600	---	2175

Flowmeter with Remote Electronics Module

Disassembly

1. Remove power from the electronics module.

NOTE: Perform Steps 2 through 8 only you are replacing the electronic module. Otherwise, skip to Step 9.

2. Remove the electronics module compartment cover and unscrew the captive mounting screws.
3. If 2-wire, remove two wires from the terminal block, or if coax, remove the coaxial sensor lead from the back of the electronics module. Use needle nose pliers on the connector and pull straight out. Do not unscrew the connector.
4. Remove clamp from wires and check to make sure sensor lead is free to slide out.
5. Remove the red, yellow, and blue leads from the terminal block. Clip off the spade type terminals, leaving as much wire as possible.
6. Connect adapter K0147BH to the brown and yellow terminals of the 4-terminal block. Plug the sensor cable into the adapter. See Figure 5 on page 11.
7. Feed the red, yellow, and blue signal wires through (see Figure 5 on page 11). Then strip the insulation back approximately 1/4 inch an connect them to the small terminal blocks on the module. Connect the red wire to the terminal marked R(+), the blue wire to the terminal marked B(-), and the yellow wire to the terminal marked Y.
8. Insert the module into the housing and rotate it one full turn clockwise. This prevents the wires from being pinched under the mounting screws. Locate the module over the mounting holes and tighten the captive screws.
9. Remove junction box cover (see Figure 7).
10. Disconnect sensor lead connection.
11. Remove wire clamp.

WARNING: To prevent personal injury, before loosening any bolts to remove the mechanical connector from the line, check the line to ensure that process fluid is not under pressure, and that the line is empty.

12. Remove mechanical connector bolts (4).
13. Grasp sensor assembly and remove sensor from mechanical assembly (see Figure 8).

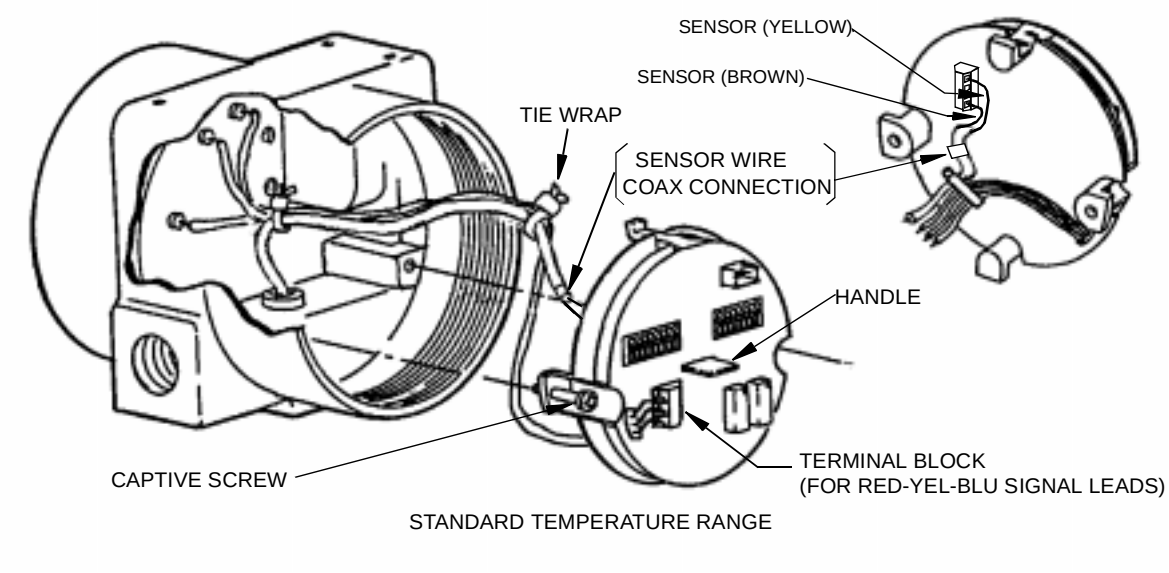


Figure 6. Electronics Module

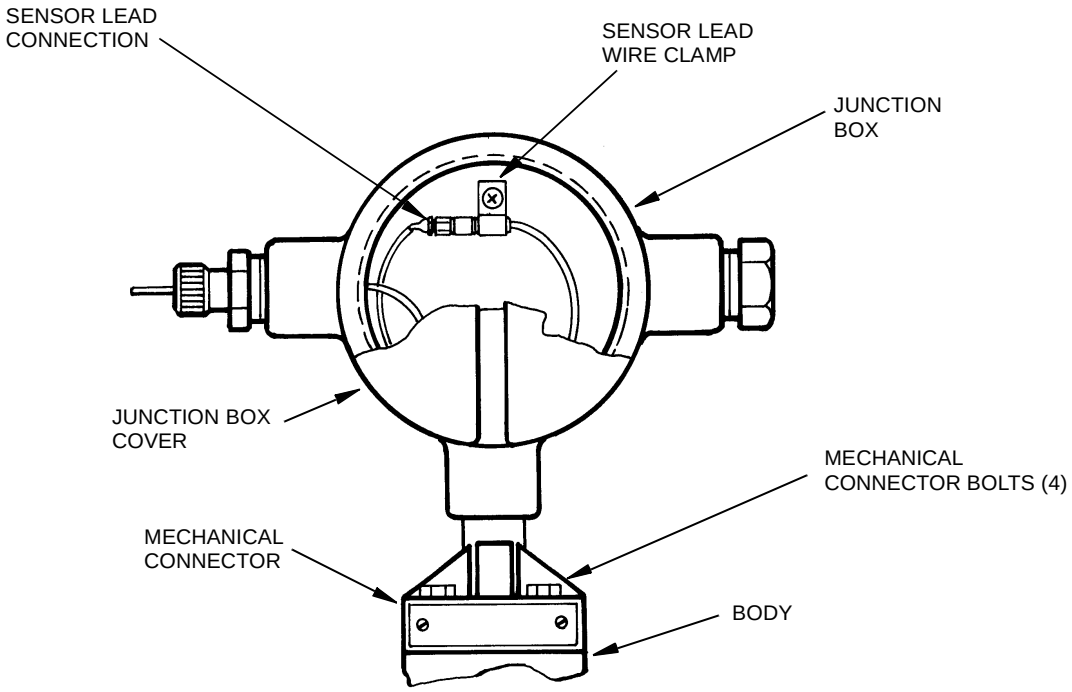


Figure 7. Flowtube/Junction Box

Reassembly

NOTE: Verify that all parts are available before starting reassembly. See Table 1.

1. Slide O-ring over sensor lead and onto neck of sensor assembly (see Figure 8).

2. Place the flat gasket over the sensor in contact with the serrated sealing surface. Center the gasket. Slide the flow dam into the groove of the sensor.
3. Feed sensor assembly leads through hole in mechanical connector, gently pull sensor lead out of junction box housing until sensor assembly is touching the mechanical connector. (See Figure 8.)
4. Refer to Figure 8 and follow "Reassembly" Steps 4 through 6 on page 10.

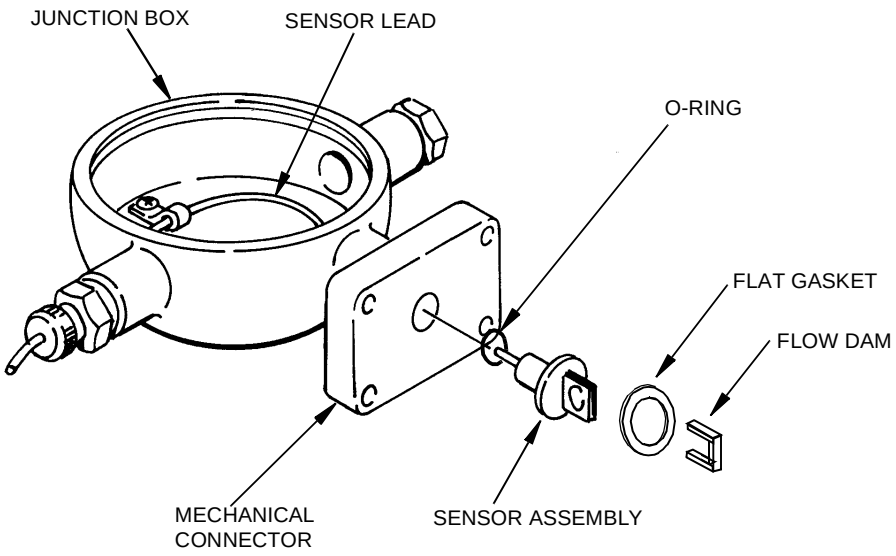


Figure 8. O-Ring/Sensor Assembly/Flow Dam

5. Install 2-position connector (part of remote adapter kit) in remote housing, using the 6-32 screw supplied.
6. Connect the yellow and brown sensor wires to the 2-position connector. (See Figure 9.)
7. Connect the yellow and brown female adapter wires (the longer adapter) to the 2-position connector, making sure that they connect yellow to yellow and brown to brown with the sensor wires.
8. Plug the coax connectors together and reinstall the wire clamp.

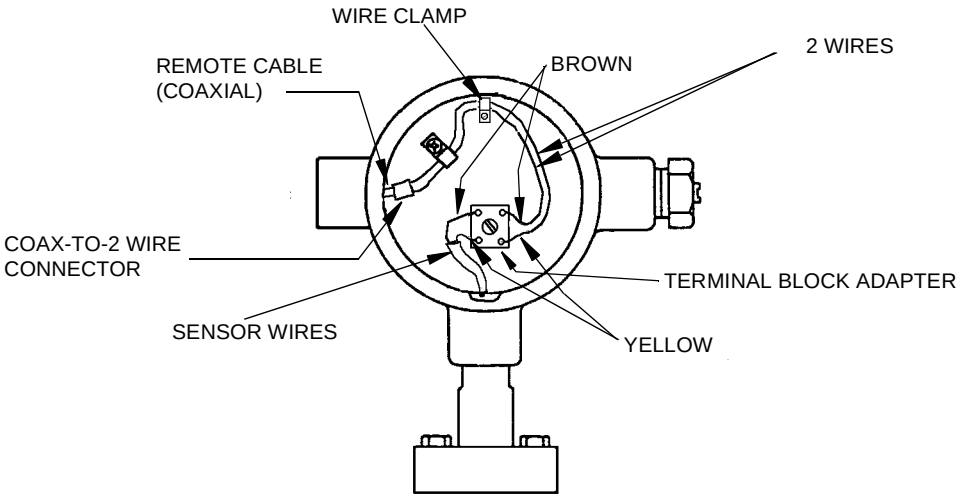


Figure 9. Junction Box with Coaxial Adapter

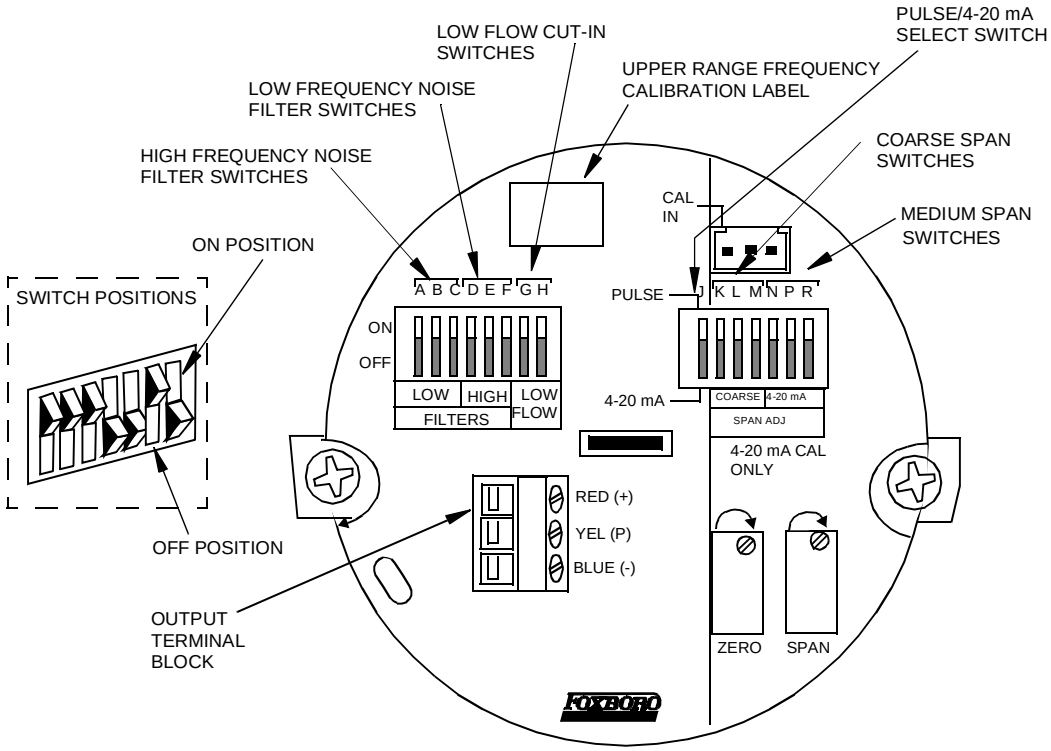


Figure 10. Electronic Module Switch Locations

4. Calibrating the 4 to 20 mA Signal

NOTE: The Electronic Module does not require calibration if the unit is being operated in the pulse mode; i.e., switch "J" is set to the "ON" position. Do not attempt to calibrate the 4 to 20mA output with the J switch in the "ON" position.

The equipment and procedure for calibrating the vortex flowmeter varies to a slight extent on whether or not a calibration cable (Foxboro Part No. K0146HP) is available. This cable allows you to connect the test signal generator at the front of the Electronic Module, rather than to the sensor input terminals at the rear. If this cable is not available, do not install the new Electronic Module in the housing until the calibration has been completed.

Required Equipment

1. Signal generator (10 to 3000 Hz), capable of being set to within 0.1% of upper range frequency. Chassis must be isolated from power ground; i.e., output must be floating. Do not ground or earth! A battery operated signal generator is recommended, if available.

   If the calibration cable (Foxboro Part No. K0146HP) is available, one of the following signal generators can be used:

   - Pulse generator, +7 Volts, 50% duty cycle.
   - Square wave generator, 7 Volts peak-to-peak centered on +3.5 V (i.e., +3.5V dc offset).
   - Square or sine wave generator, 14 Volts peak-to-peak centered on zero (i.e., zero dc offset).

   If the calibration cable is not available then the following signal generator must be used:

   - Sine wave generator, 1 Volt peak-to-peak centered on zero (i.e., zero dc offset).
2. 250 ohm precision resistor (±0.1%), 1/4 Watt minimum.
3. Voltmeter, range 1 to 5 Volts dc, capable of being set to within 0.1% (used to measure 4 to 20mA loop current via the voltage drop across the precision resistor).
4. Power Supply (10.5 to 50.0 Volts dc), 24 Volts recommended.

Calibration Procedure

Calibration of an Electronic Module is a four step process:

1. Determine the Corrected K-Factor
2. Determine the Upper Range Frequency

3. Set the Electronic Module Switches
4. Adjust the Span Potentiometer

NOTE: Since a replacement module is being installed, the upper range frequency should appear on the label on the front of the module being replaced (see Figure 10). If this is the case, skip to Step III below. Otherwise, begin with Step I.

I. Determining the Corrected K-Factor

The first step in calibrating an Analog Electronic Module is to determine the Corrected K-Factor. The Reference K-Factor stamped on the flowmeter data label is established under reference conditions. These reference conditions correspond to a flowing process temperature of 20°C (70°F) and 50 pipe diameters or greater of straight pipe upstream of the meter (Schedule 40 piping for flange and wafer meters; Schedule 5 for sanitary meters). For application conditions other than reference conditions, the Reference K-Factor should be corrected, as described in Appendix A, by multiplying it by the total bias correction factor (BCF) to obtain the Corrected K-Factor.

NOTE: If using FlowExpert in Step II to determine the upper range frequency, set the process temperature correction factor (TCF) equal to unity when computing the total bias correction factor in Appendix A.

II. Determining the Upper Range Frequency (Full Scale Frequency)

To calibrate an Analog Electronic Module, it is necessary to determine the vortex frequency corresponding to the desired upper range flow value. Since a replacement module is being installed, this frequency should appear on the label on the front of the module being replaced (see Figure 10). If this is the case, skip to Step III. Otherwise, calculate the upper range frequency by one of the following procedures:

1. *Using FlowExpert* — This meter selection/sizing software program, available from Foxboro, displays a *nominal* upper range frequency, based on a built-in *nominal* K-factor and corrected for process temperature (see 2nd page of Vortex Sizing Results).

NOTE: During the sizing process, select the desired flow units for the upper range value and be sure to enter the flowing process temperature.

To determine the *actual* upper range frequency, press <F3>, as instructed at the lower left hand side of the results screen, and then enter the Corrected K-factor (computed in Step I) and the desired upper range value. In computing the total bias correction factor in Step I, set the process temperature correction factor (TCF) equal to unity. *FlowExpert* incorporates this correction internally, based on the flowing process temperature that was input during the sizing process.

2. *Manual Procedure* — Compute the upper range frequency by following the procedures outlined in Appendix B.

III. Setting the Electronic Module Switches (A-F, G-H, J-N, P, and R)

1. *High Frequency Noise Filter (Switches A, B, and C)* — Use the upper range frequency determined in Step II to select the appropriate level setting for the high frequency noise filter (see Table 5). Set switches A, B, and C accordingly. This is the proper setting for doing the calibration, and also the correct setting for the application.

   Example:

   Upper range frequency = 523 Hz
   Since this is between 350 and 700, A is set to "OFF", B to "ON", and C to "ON".

2. *Low Frequency Noise Filter (Switches D, E, and F)* — Since a replacement module is being installed, record the current positions of switches D, E, and F. These positions need to be reset after calibration is completed. During this calibration, set all three switches to "OFF".

3. *Low Flow Cut-In (Switches G and H)* — Since a replacement module is being installed, record the current positions of switches G and H. These positions need to be reset after calibration is completed. During calibration set switch G to "OFF" and H to "ON".

4. *Output Mode (Switch J)* — Set switch J to "OFF". This sets the Output Mode to 4-20mA.

5. *Span Switches (K-M, N, P, R)* — The span switches must be set to encompass the upper range frequency determined in Step II. This insures that the span potentiometer can be used in the final step to calibrate the module. Since a replacement module is being installed set the span switches to duplicate the settings of the module being replaced, otherwise follow the procedure below.

   a. Set the coarse span switches (K, L, and M) per the intervals defined in Table 5.

   Example:

   Upper range frequency = 312.
   Since this is between 200 and 400, K is set to "ON", L to "OFF", and M to "OFF".

   b. The medium span switches (N, P, and R) are then set per Table 7.

   Example:

   The frequency, 312 Hz, represents a value that is 56% of the value between 200 and 400.

$$\frac{312 - 200}{400 - 200} \times 100 = 56\%$$

   Since 56% lies between 50% and 75%, N is set to "ON", P to "OFF", and R to "ON".

IV. Adjusting the Span Potentiometer

The procedure for adjusting the span potentiometer is as follows:

1. Hook up the power supply, precision load resistor, and voltmeter as shown in Figure 11. Then connect the power to the Red(+) and Blue(-) terminals on the 3-connector terminal block on the front of the Electronic Module.
2. If the calibration cable (K0146HP) is available, connect the signal generator (see Required Equipment) to the 3-pin input receptacle marked CAL IN on the front of the Electronic Module (see Figure 11).

NOTE: Plugging the cable into the 3-pin receptacle separates the sensor input electrically from the module.

   If the calibration cable is <u>not</u> available, connect the wires from the sine wave generator (1 Volt peak-to-peak, centered on zero) to the B(+) and Y(-) terminals on the 4-connector terminal block on the <u>rear</u> of the module.

3. Set the signal generator to the upper range frequency established in Step II. Adjust the span potentiometer until the voltage measured across the 250-ohm precision resistor is 5.00 Volts (± 0.1%). This is equivalent to 20 mA flowing in the loop.
4. Set the signal generator frequency to zero. The voltage across the load resistor should read 1.00 Volts (±0.1%). If it does not, adjust the zero potentiometer until the voltage reading is as specified. This is equivalent to 4 mA flowing in the loop.
5. Disconnect the test equipment. If the Electronic Module has not yet been installed, reconnect the sensor leads and replace the module as described in“Reassembly” on page 14.
6. Write the calibrated upper range frequency on the supplied adhesive label, and stick it to the front face of the module.
7. Calibration of the module is now complete. However, prior to putting the meter into service the Low Frequency Noise Filter switches (D, E, and F) and the Low Flow Cut-In switches (G and H) must be reset to their original positions, as recorded earlier. If any uncertainty exists, establish and set the appropriate switch settings (D through H) according to the instructions in the Installation section of MI 019-189 (see “Electronic Module Switches”).

Table 5. High Frequency Noise Filter Switches

Step	Upper Range Frequency in Hz	Switch Positions		
		A	B	C
1	1500 to 3000	off	off	on
2	700 to 1500	off	on	off
3	350 to 700	off	on	on
4	160 to 350	on	off	off
5	80 to 160	on	off	on
6	<80	on	on	off

Table 6. Coarse Span Switches

Coarse Span Frequency Step	Frequency (Hz) at the Upper Range Value	Switch Positions		
		K	L	M
1	12.5 to 25	off	off	off
2	25 to 50	off	off	on
3	50 to 100	off	on	off
4	100 to 200	off	on	on
5	200 to 400	on	off	off
6	400 to 800	on	off	on
7	800 to 1600	on	on	off
8	1600 to 3200	on	on	on

Table 7. Medium Span Switches

Percent of Coarse Span Frequency Step	Medium Span Switch Positions		
	N	P	R
0 to 25	on	on	off
25 to 50	off	on	off
50 to 75	on	off	on
75 to 100	off	off	on

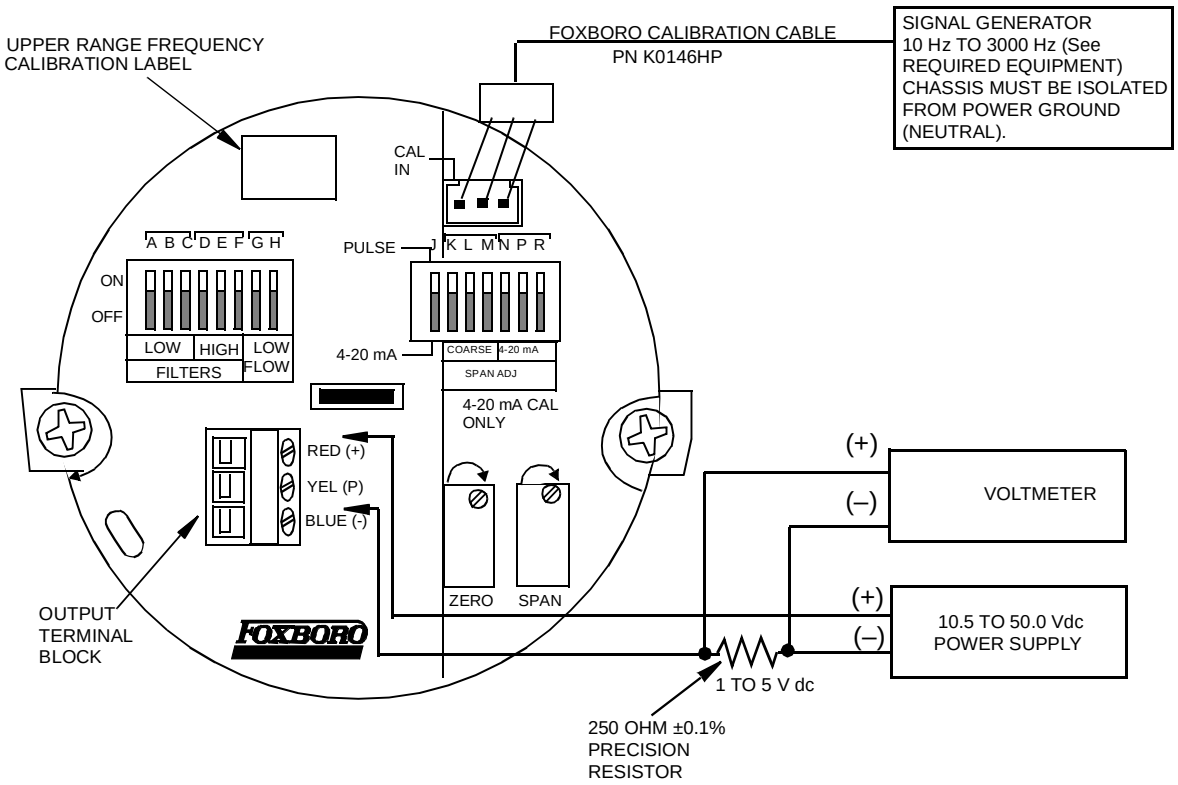


Figure 11. Analog Electronic Module Calibration Hookup

5. Configuration

Refer to Configuration section in the Intelligent Electronics MI that is included with the Intelligent Transmitter Electronics Kit.

Appendix A. Determining the Corrected K-Factor

The correct K-factor to be used in a given application differs, in general, from the K-factor determined under calibration (reference) conditions. This is a result of process temperature and piping influences. The procedure for determining the Corrected K-Factor is described in this appendix

Before proceeding, it is important to understand the difference in the three K-factors referred to in this MI. They are defined as follows:

- *Nominal K-Factor* — This is the median Reference K-Factor for all meters of a given line size. It should not be used in calibrating the 4 to 20mA output. The value of the Nominal K-Factor may differ from the Reference K-Factor for a given meter by ±5%.
- *Reference K-Factor* — This is the K-factor determined by flow calibration for a specific vortex flowmeter, and the one to be used in this appendix for determining the Corrected K-Factor. The Reference K-Factor can be found on the flowmeter data plate.
- *Corrected K-Factor* — This is the K-factor used in Appendix B to determine the upper range frequency needed to calibrate the 4 to 20mA output. It includes process temperature and piping influences.

NOTE: The Corrected K-Factor computed in this appendix is used in Appendix B for determining the calibration frequency at the upper range flow rate. The total bias correction factor used to compute the Corrected K-Factor may also be applied directly to the flow rate or flow total to correct for process temperature and piping effects, if this correction has not been included in determining the calibration frequency at the upper range flow rate.

Process Temperature Correction Factor (TFC)

The K-factor of a vortex flowmeter is affected by dimension changes from thermal expansion. The correction factor for this effect (TFC) is:

$$TFC = 1 - 3 \times \alpha \times (T - T_0)$$

where, for

US Customary Units		SI Units
$\alpha = 9.59 \times 10^{-6}\ °F^{-1}$	(316/304 SS)	$\alpha = 17.3 \times 10^{-5}\ °C^{-1}$
$\alpha = 7.02 \times 10^{-6}\ °F^{-1}$	(Hastelloy C)	$\alpha = 1.26 \times 10^{-5}\ °C^{-1}$
T = Process Temp. (°F)		T = Process Temp. (°C)
$T_0 = 70\ °F$		$T_0 = 20°C$

Example:

For a 316 stainless steel flowtube at a process temperature of 300°F

$$TFC = 1 - 3 \times 9.59 \times 10^{-6} \times (300 - 70) = 0.993$$

Mating Pipe Correction Factor (MCF)

Flange and Wafer Meters (83F-A, 83W-A, E83FA, E83WA)

Table 8 shows the K-factor offset caused by the use of pipe other than the Schedule 40 pipe used at the factory to determine the Reference K-Factor. For example, the K-factor of a 4-inch flowmeter installed in Schedule 10 pipe has an offset of +0.5%. Therefore, the K-factor value specified on the flowmeter data plate should be increased by 0.5%. The mating pipe correction factor (MFC) equals one plus the percent offset divided by 100.

$$MFC = 1 + (+0.5)/100 = 1.005$$

Table 8. Flange and Wafer K-Factor Mating Pipe Offset

Size		Schedule 10		Schedule 80		DIN Ser. 1 PN 40		DIN Ser. 1 PN 100	
mm	Inch	Wafer	Flange	Wafer	Flange	Wafer	Flange	Wafer	Flange
15	0.75	1.2%	1.0%	-0.8%	-1.0%	1.2%	1.0%	1.0%	0.5%
25	1	1.0%	0.8%	-0.5%	-0.8%	1.0%	0.8%	1.0%	0.5%
40	1.5	0.7%	0.5%	-0.3%	-0.5%	0.7%	0.5%	0.5%	0.5%
50	2	0.6%	0.4%	-0.4%	-0.5%	0.6%	0.4%	0.5%	0.4%
80	3	0.5%	0.5%	-0.4%	-0.5%	0.5%	0.5%	0.4%	0.5
100	4	0.5%	0.5%	-0.7%	-0.5%	0.5%	0.5%	0.5%	0
150	6	0.4%	0.3%	-0.4%	-0.5%	0.3%	0.2%	0.3%	0.3%
200	8	0.4%	0.3%	-0.4%	-0.5%	0.3%	0.2%	-0.30%	-0.3%
250	10	-	0.3%	-	-0.5%	-	0	-	-0.5%
300	12	-	0.3%	-	-0.5%	-	0	-	-0.5%

Upstream Piping Disturbance Correction Factor (UCF)

The flowmeter should be installed in straight unobstructed pipe to ensure that it will perform to its full capabilities. The information in Figures 12 through 16 shows the offset that can be expected by introducing various upstream disturbances.

Referring to Figure 12, for example, if a liquid installation requires one 90º elbow upstream of the flowmeter and the vortex shedder is parallel to the elbow plane, it is recommended that the elbow be placed at least 30 pipe diameters from the flowmeter, thus negating the effect of the elbow, and providing 0% change in the K-factor. If it is possible to allow only 20 pipe diameters of straight pipe, the K-factor offset can be derived from Figure 12 as follows:

Draw a vertical line at 20 pipe diameters in Figure 12. The point at which it crosses the curve indicates a K-factor offset of approximately +0.7% from the Reference K-Factor on the flowmeter data plate. Therefore, the Reference K-Factor should be increased by +0.7% to account for the elbow disturbance. The upstream piping disturbance correction factor (UCF) equals one plus the percent offset divided by 100.

$$UCF = 1 + (+0.7)/100 = 1.007$$

NOTES:

1. The graphs shown in Figures 12 through 16 are a result of laboratory tests conducted using water as the process fluid, and using elbows and reducers at varying distances upstream of the flowmeter. The results are also applicable to gas and steam flow.

2. The distance axis of the graphs shown in Figures 12 through 16 apply specifically to wafer type vortex flowmeters. For flange meters, add 1-1/2 Pipe Diameters to the measured distance between flanges; for sanitary meters, add 1/2 Pipe Diameter.

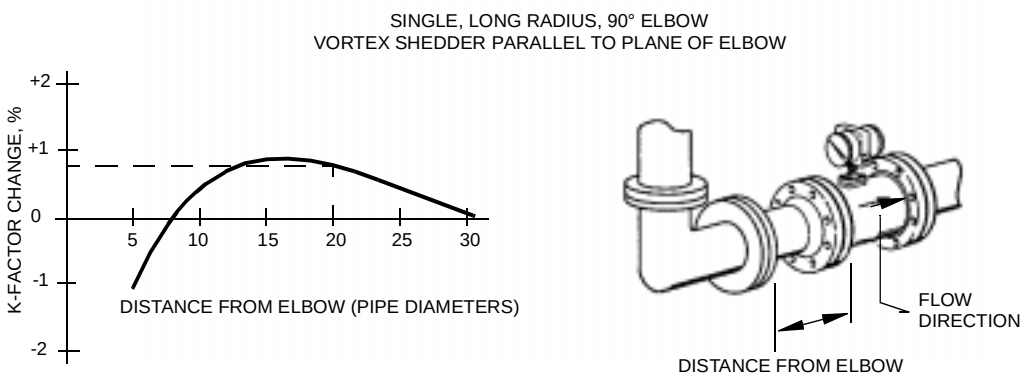


Figure 12. K-Factor Change vs. Distance from Elbow - Single Elbow with Shedder Parallel to Elbow Plane

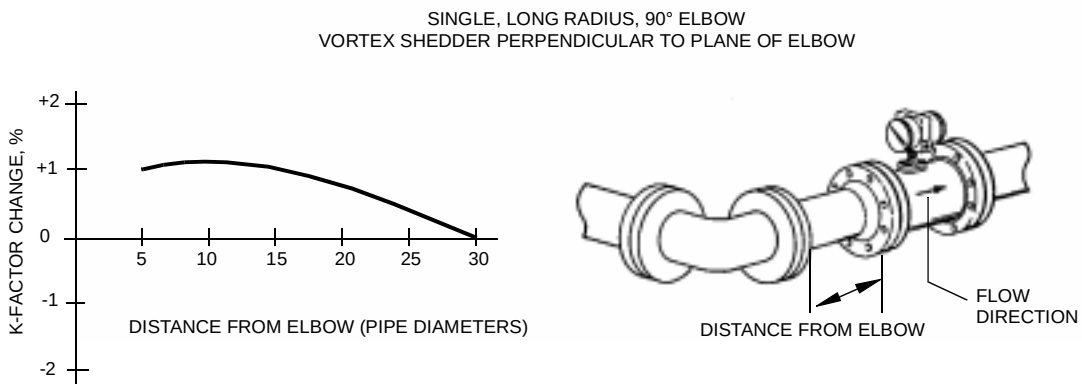


Figure 13. K-Factor Change vs. Distance from Elbow - Single Elbow with Shedder Perpendicular to Elbow Plane

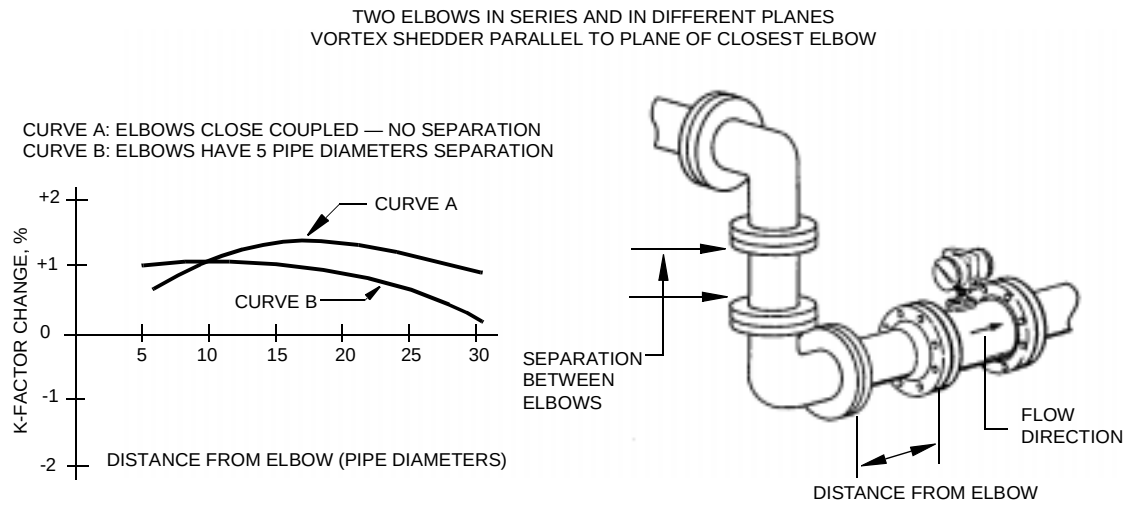


Figure 14. K-Factor Change vs. Distance from Elbow - Two Elbows with Shedder Parallel to Plane of Closest Elbow

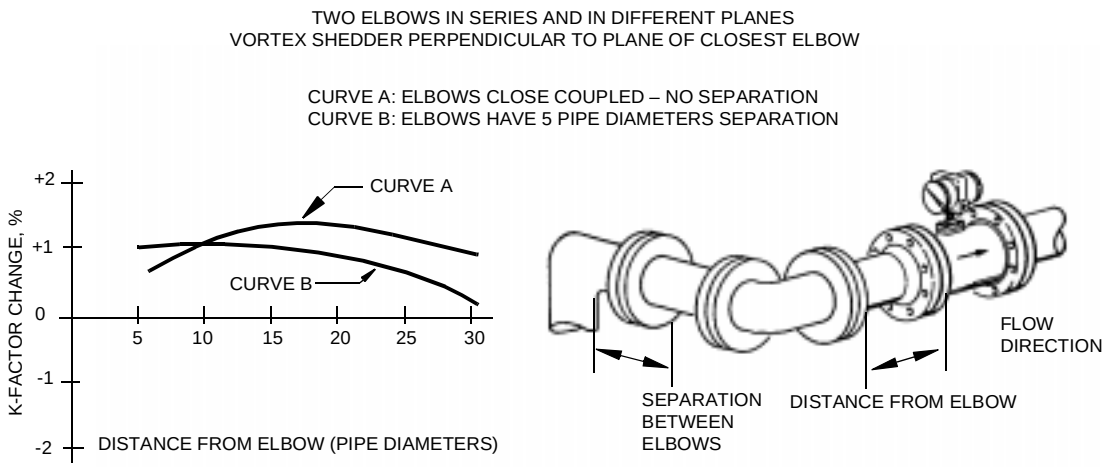


Figure 15. K-Factor Change vs. Distance from Elbow - Two Elbows with Shedder Perpendicular to Plane of Closest Elbow

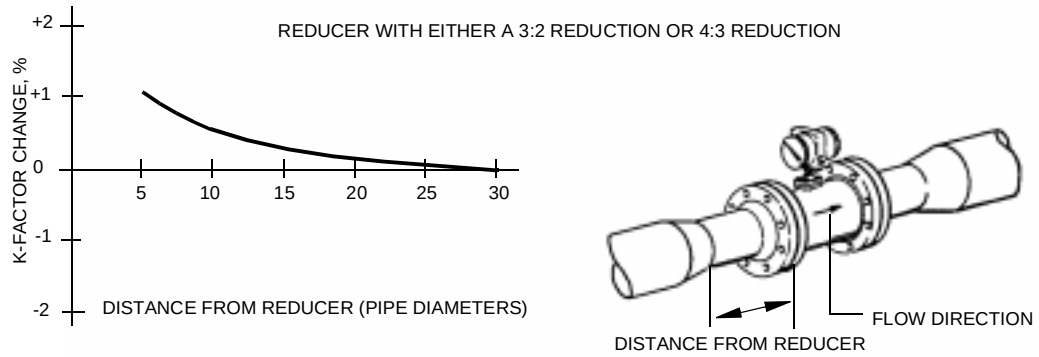


Figure 16. K-Factor Change vs. Distance from Reducer

Total Bias Correction Factor (BCF)

The total bias correction factor (BCF) equals the product of the individual correction factors.

$$BCF = TCF \times MCF \times UCF$$

Example:

Using the individual examples above,

$$BCF = 0.993 \times 1.005 \times 1.007 = 1.005$$

Determination of Corrected K-Factor

The Corrected K-Factor is calculated by multiplying the Reference K-Factor by the Total Bias Correction Factor:

$$\text{Corrected K-Factor} = BCF \times \text{Reference K-factor}$$

Appendix B. Determining the Upper Range Frequency (URF)

The upper range frequency (URF) is the frequency of vortex shedding at the upper range value (URV). The URF is the frequency that must be input to the transmitter to calibrate the 4 to 20mA output, so that 20mA corresponds to the URV. The URF may be calculated with the aid of *FlowExpert*, a meter sizing/selection software program available from Foxboro (see "Calibrating the 4 to 20 mA Signal" on page 17), or by following the procedure outlined below.

Calculation of Upper Range Frequency

The equation used to calculate the URF depends on the type of measurement units desired:

Volume Flow at Flowing Conditions

(1) $$URF = CRF \times CF \times \frac{URV}{Time}$$

Volume Flow at Base Conditions

(2) $$URF = CRF \times CF \times \frac{URV}{Time} \times \frac{\rho_b}{\rho_f}$$

Mass Flow

(3) $$URV = CRF \times CF \times \frac{URV}{Time} \times \frac{1}{\rho_f}$$

where,

URF = Vortex frequency corresponding to upper range flowrate (URV)

CKF = Corrected K-factor in pulses/ft^3 or pulses/l, from Appendix A

Time = If flow rate is per second, Time = 1
If flow rate is per minute, Time = 60
If flow rate is per hour, Time = 3600
If flow rate is per day, Time = 86400

CF = Conversion factor that converts CKF to actual volume or mass flowrate units (see Table 9).

URV = Upper range value in desired flowrate units

ρ_b = Base density in lbs/ft^3 or kg/m^3

ρ_f = Flowing density in lbs/ft^3 or kg/m^3

Table 9. Conversion Factors (CF)

To Convert (RF)	Multiply By (CF)	To Obtain (pulses per)
p/L	1.0	L
	3.7854	U.S.gal
	4.546	IMP gal
	28.32	ft^3
	1000	m^3
	119.2	bbl (31.5 gal)
	159.0	bbl (42.0 gal)
p/U.S. ft^3	0.13368	U.S.gal
	0.16054	IMP gal
	1.0	ft^3
	35.32	m^3
	0.03532	L
	4.211	bbl (31.5 gal)
	5.615	bbl (42.0 gal)

Calculation of Gas Density

To find the gas density at base or flowing conditions, use one of the following equations:

When using SI units,

(4) $$\rho = \frac{3.48 \times G \times P_{abs}}{Z \times T_{abs}}$$

When using U.S. Customary units,

(5) $$\rho = \frac{2.70 \times G \times P_{abs}}{Z \times T_{abs}}$$

where

ρ = Gas density at base or flowing conditions in lbs/ft^3 or kg/m^3, as applicable.

G = Specific gravity of gas.

P_{abs} = Absolute pressure at base or flowing conditions in psi or kPa, as applicable.

T_{abs} = Absolute temperature at base or flowing conditions in R or K units, as applicable.

Z = Gas compressibility factor at base or flowing conditions, as applicable.

Examples of Upper Range Frequency Determination

The examples that follow show how to calculate the upper range frequency (URF) for liquid, gas, and steam applications.

NOTE: The minimum possible URF is 12.5 Hz for a 20 mA output. The maximum possible URF is 3000 Hz.

Liquid Example

Given:

- 80 mm (3 in) wafer Hastelloy C flowmeter
- Reference K-Factor = 80.8 pulses/ft^3 (from the data plate)
- Upper Range Value = 300 Usgpm
- Flowing Temperature = 90°F
- 40 pipe diameters of straight pipe upstream of meter
- Schedule 80 piping

The Corrected K-Factor is, from Appendix A,

$$CKF = TCF \times MCF \times UCF \times RKF$$

$TCF = 1 - 3 \times 7.02 \times 10^{-6} \times (90-70) = 1.000$
$MCF = 1 + (-0.4)/100 = 0.996$
$UCF = 1.0$

$CKF = 1.000 \times 0.996 \times 1.0 \times 80.8 = 80.5$ pulses/ft^3

Since the desired flowrate is volume at flowing conditions (USgpm), the URF is calculated using equation (1):

$$URF = CRF \times CF \times \frac{URV}{Time}$$

Also, since the flowrate is in USgpm, CF = 0.13368 (from Table 9) and Time = 60 (# of seconds per minute).

Hence,

$$URF = 80.5 \times 0.13368 \times \frac{300}{60} = 53.8 \text{ Hz}$$

Gas Example (Air)

Given:·

- 100 mm (4 in) flanged 316SS flowmeter
- Reference K-Factor = 34.6 pulses/ft^3 (from the data plate)
- Upper Range Value = 300,000 SCFH
- Flowing Temperature = 100°F (560°R); Base Temperature = 59°F (519°R)
- Flowing Pressure = 65 pisa
- S.G. = 1.0 for air
- Z = 1.0
- Single elbow in a plane perpendicular to the shedder, 20 pipe diameters upstream of meter
- Schedule 40 piping

The Corrected K-Factor is, from Appendix A,

$$CKF = TCF \times MCF \times UCF \times RKF$$

$TCF = 1 - 3 \times 9.59 \times 10^{-6} \times (100 - 70) = 0.999$
$MCF = 1.0$
$UCF = 1 + (+0.7)/100 = 1.007$

$CKF = 0.999 \times 1.0 \times 1.007 \times 34.6 = 34.8$ pulses/ft^3

Since the desired flowrate is volume at base conditions (SCFH), the URF is calculated using equation (2),

$$URF = CRF \times CF \times \frac{URV}{Time} \times \frac{\rho_b}{\rho_f}$$

Also, since the flowrate is in SCFH, CF = 1.0 (from Table 9) and Time = 3600 (# of seconds per hour).

The Flowing and Base Densities are calculated using Equation (5),

$$\rho_f = \frac{2.70 \times G \times P_{abs,f}}{Z \times T_{abs,f}} = \frac{2.70 \times 1.0 \times 65}{1.0 \times 560} = 0.313 \text{ lbs/ft}^3$$

$$\rho_b = \frac{2.70 \times G \times P_{abs,d}}{Z \times T_{abs,d}} = \frac{2.70 \times 1.0 \times 14.7}{1.0 \times 519} = 0.0765 \text{ lbs/ft}^3$$

Hence,

$$URF = 34.8 \times 1.0 \times \frac{300000}{3600} \times \frac{0.0765}{0.3134} = 707.9 \text{ Hz}$$

Steam Example (Saturated)

Given:

- 50 mm (2 in) wafer 316 SS flowmeter
- Reference K-Factor = 262.2 pulses/ft^3 (from the data plate)
- Upper Range Value = 5000 lb/hr
- Flowing Temperature = 445°F
- Flowing Pressure = 400 pisa
- Close coupled double elbow with shedder parallel to plane of closest elbow, 10 pipe diameters upstream of meter
- Schedule 80 piping

The Corrected K-Factor is, from Appendix A,

$$CKF = TCF \times MCF \times UCF \times RKF$$

$TCF = 1 - 3 \times 9.59 \times 10^{-6} \times (445-70) = 0.989$
$MCF = 1 + (-0.4)/100 = 0.996$
$UCF = 1+ (+1.0)/100 = 1.010$

$CKF = 0.989 \times 0.996 \times 1.010 \times 262.2 = 260.9$ pulses/ft^3

Since the desired flowrate is mass flow (lbs/hr), the URF is calculated using equation (3),

$$URF = CRF \times CF \times \frac{URV}{Time} \times \frac{1}{\rho_f}$$

Also, since the URV/ρ_f is in ft^3/hr, CF = 1.0 (from Table 9) and Time = 3600 (# of seconds per hour).

From Steam Tables, $\rho_f = 0.8614$ lbs/ft^3.

Hence,

$$URF = 260.9 \times 1.0 \times \frac{5000}{3600} \times \frac{1}{0.8614} = 420.7$$

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